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Contemporary Advances in Sports Science

Edited by Redha Taiar

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Meet the editor

Prof. Redha Taiar, Ph.D., is a professor at the University of Reims Champagne-Ardenne. His research focuses on engineering for medicine and high-level sports. He was previously an engineer for companies such as Arena, Sidas, and Medicapteurs Corporation. He has helped engineer anti-fatigue mats for industry workers, and triathlon swimsuits and ski suit fabrics for the Olympic Games in Brazil and Sotchi, respectively. He obtained a Ph.D. in Biomechanics and is a specialist in biomechanics of health disease and rehabilitation.

Contents

Preface

This book quantifies the state of technological progress in measuring the impact of sports in humans, ranging from those who are sedentary to those who participate in high-level sporting activities. The idea for this book came after many years of work in biomechanics, health disease, and rehabilitation. Chapters show the scope of sports analysis and technologies in human performance and behavior. Sports are very important and help people increase mobility, optimize performance, and reduce their risk of disease. They can have beneficial social, cultural, economic, and psychological effects on health, wellbeing, and the environment. The combination of the principles of mathematics, functional anatomy, physiology, psychology, and mechanics allow for the exploration and understanding of biological sport problems. This book offers a range of principles, methods, techniques, and tools to provide the reader with a clear knowledge of variables improving sports' performance processes. The text considers physical, mechanical, physiological, psychological, and biomechanical aspects of sports performance, sports science, human posture, and musculoskeletal disorders. The book includes three sections: "Sports Injury," "Sports Performance," and "Sports Education."

This volume is a useful resource for engineers, researchers, and students in biomedical engineering and health sciences, as well as industry professionals.

We express our thanks to all the contributing authors for their successful collaboration in the interest of this book.

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Section 1

Sports Injury

Chapter 1

Use of an Evolution in Tecartherapy for Muscle Improvement and Treatment of Sports Injuries

Jesús Clemente Rodríguez Lastra and Ester Piñero Mendez

Abstract

Radiofrequency assisted medical devices have evolved dramatically in the last two decades, such that a simple set of fairly basic tools has now become an extremely sophisticated option. Most importantly, a physician's understanding of these devices can maximize treatment results. Diathermy, meaning "through heat," consists in the application of short-wave electromagnetic energy. The factor that determines whether a diathermy machine will increase body temperature is the amount of energy absorbed by the tissue. The development of this device allows selecting the frequency to apply between 0.8 1 and 1.2 MHz; the application of high energy power, through several channels and increasing the treatment area, allows taking the radiofrequency to another level in rehabilitation sports medicine. RF is applied to the target area by a handpiece that delivers energy, while a grounding pad is placed elsewhere on the body for the energy to pass through. The entry of RF into the body at the site of contact with the active electrode leads to heating a volume of tissue. This ability to heat a volume of tissue in a non-invasive way produces the immediate contraction of collagen, and the delayed synthesis of collagen, by thermal induction fibroblasts, and the production of epithelial, vascular growth factors. RF has a firm, safe and increasingly popular place in the therapeutic arsenal of sports medicine.

Keywords: sport Injury, radiofrequency Capenergy, Tecartherapy, cellular effects, pain, rehabilitation

1. Introduction

Diathermy treatment has long been used in the recovery of sports injuries, the term itself refers to heat, as the most important effect of the treatment. The movements of water molecules by the effect of electromagnetic waves, produce heat. But today it is known that molecular effects, especially in the cell membrane, produce the movement of ions, which function as signals for the immune response. The increased production of both epithelial and vascular growth factors, which improve healing and produce angiogenesis, increasing blood circulation, have given a new perspective to this treatment. Where, selecting the appropriate frequency, the highest energy power, expanding the treatment area and the possibility of recognizing the penetration of the energy in the tissue, gives a new perspective to the treatment of Tecartherapy, for the athlete's injuries. The effects of RF are detailed below. The objective of this Chapter is then to put in the hands of Physicians, Rehabilitators and Physiotherapists the current knowledge of the effects of the new RF equipment for the treatment of sports injuries.

Diathermy, a Greek word that means "through heat", consists of the application of short or long-wave electromagnetic energy. This wave radiation is in the radiofrequency (RF) range (3 kHz to 300 MHz frequency and 1 m to 100 km of wavelength). The use of diathermy dates back to 1892, when d'Arsonval used radio frequency electromagnetic fields with a 10 kHz frequency to produce a warm sensation without muscle contractions, that take place at a lower frequency [1] (Culotta 1970).

The most important factor that determines whether a diathermy device will increase body temperature is the amount of energy absorbed by the tissue. This is determined by the intensity of the electromagnetic field produced by the device and by the type of tissue in which it is applied. However, there are more factors that contribute to the penetration of energy in the body that we will evaluate below.

We will first describe the electromagnetic field. An electromagnetic field is the force field created around an electric current that is made up of an electric field and a magnetic field. Both electric and magnetic fields are produced when a charged particle moves at a constant speed. EMFs (Electro Magnetic Fields) are generated when the charged particle accelerates and increases in speed. Very often, this acceleration takes place in the form of an oscillation, therefore the electric and magnetic fields are oscillating.

The objective of this Chapter is to put in the hands of Physicians, Rehabilitators and Physiotherapists the current knowledge, of the effects of the new RF equipment for the treatment of sports injuries. This chapter will develop the basic concepts of innovative RF technology with the intention of minimizing the inflammatory and pain effects, that many musculoskeletal injuries cause, as well as, ensuring that tissue regeneration is done through total recovery from injury and that the recovery time is minimized. These concepts will be developed in detail in the next few lines.

2. Frequency

Frequency is the wavelength of the oscillation. Different frequencies are used in diathermy. As tissue absorption increases with frequency, it is often assumed that lower frequencies, on the order of MHz, result in better transfer efficiency. But it has been pointed out that the frequency of 1 MHz is the one that manages to overcome the resistance of the cell membrane and produce the intracellular effects that we will see later [2] (Ivorra 2002).

3. Power

One of the fundamental components of electromagnetic fields is power or energy. Electromagnetic waves provide energy to a system by virtue of their electric and magnetic fields. These fields can exert forces and move charges in the system and, therefore, work on them. However, there is energy in an electromagnetic wave itself, whether it is absorbed or not. Once created, the fields carry energy from a source. If some energy is then absorbed, the intensity of the field decreases. Clearly, the greater the strength of the electric and magnetic fields, the more work they can do and the greater the energy carried by the electromagnetic wave. In electromagnetic waves, the amplitude is the maximum field strength of the electric and magnetic fields. The energy of the waves is determined by the amplitude of the waves. The energy carried by a wave depends on its amplitude [3] (Ling et Al 2019).

4. Energy coupling

The water in the tissues is the fundamental cause of energy absorption in the human body: the more liquid accumulates in an area, the more energy is absorbed [4] (Romanenko et Al 2017). Being able to recognize the amount of energy that penetrates allows you to locate the area of inflammation. When the radio frequency wave penetrates the tissue, it moves water molecules. Remember that water molecules are a dipole, hence they vibrate with the waves as shown in **Figure 1**.

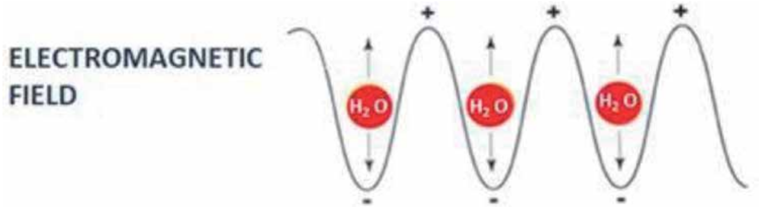

Figure 1.
Movement of water molecules due to radiofrequency oscillations.

5. Capacitive and resistive electrodes

The capacitive electrode is covered by an insulator. Imagine a capacitor formed on one side by the capacitive electrode, and on the other, a resistive conductor formed by the biological tissue and another metallic conductor (return plate) that closes the circuit. The capacitive conductor is made up of metal compounds and alloys. The application of a capacitive conductor is characterized by displacement currents instead of conduction, and the charged particles tend to have a higher charge density in the vicinity of the dielectric, act on the most superficial tissues (first 3 cm) rich in water and its energy tends to progressively increase from the return plate to the capacitive electrode with the consequent increase in temperature of the tissues.

In resistive mode, the electrode is conductive, metallic and is applied directly to the body. The current passes through the sector of the body where it is applied, dispersing towards the return electrode. During this process, heat is generated due to the energy delivery in the tissue and the resistance that the tissues oppose to its passage. The concentration of charges, and therefore the biological effect, occurs at the points of greatest resistance of the current, such as the bone tissue, which is located between the active electrode and the return electrode. But other highly resistant tissues due to their low water content such as tendons, ligaments and bands of muscles and tendons will have also biological effect. In this way, a charge displacement current is created within the biological tissue that determines the involvement of the deep layers and the consequent homogeneity of the endothermic response with greater depth. The plate electrodes are 200 m^2 capacitive electrodes (**Figure 2**).

The more area of application, the more energy is delivered. A larger area allows the penetration of the energy to be more extensive and the effects more extensive in the area of the injury and the surrounding tissues.

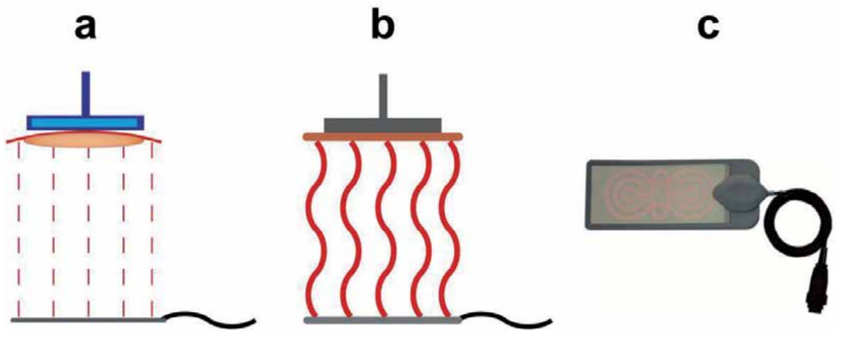

Figure 2.
Electrodes, resistive (a) capacitive (b) and capacitive plate of 200 cm^2.

6. Energy channels

Being able to increase the amount of energy by incorporating more channels to the treatment, first of all allows incorporating a larger area of application, covering more space around the lesion, and can be used simultaneously with physical activity, on the one hand. Moreover, the.

capacitive and resistive electrode can also be used simultaneously. An energy summation occurs where in the most superficial area the energy load is greater.

7. Thermal and athermal effects

Heat is generated in the tissue both by the electrical process and by the magnetic field. The static magnetic field cannot heat the human body as it does not transfer any net energy, so it does not produce heat. Therefore, the tissue heating mechanism is by electric current and is based on the generation of joules of heat. The heat generated is described by Joule's Law:

$$E = \frac{j^2}{\sigma} \quad (1)$$

Where E is the energy, j is the density of the electric current and σ is the electrical conductivity. The conductivity is 1 / R (R = resistance).

The absorption of electromagnetic energy by the tissues of the human body is complicated because there are different types of tissues, with different coefficients of conductivity. As the depth of penetration into the tissues increases, the frequencies change, such that most of the incident energy can be transmitted at one frequency, but absorbed at another. The depth of penetration per frequency depends on several factors: dry skin, infiltrated fat, and muscle, calculated according to the characteristics of the Gabriel model.

All mechanisms that cannot induce a temperature increase greater than 0.010 ° C (when we consider a system as a living organism), less than 0.001 ° C (when a system is considered as a cell), or again less than 0.0005 °C are considered nonthermal, when studying a sub-cellular system.

At present, there is a controversy between the thermal sensation of the patient and the application of energy. Hence the term athermic, as the temperature in the tissue does not increase. The real connotation of athermic is that the patient does not perceive the increase in temperature. The patient has little thermal sensation, since it is an application with little energy. Due to the fact that energy is introduced into the tissue, it causes the water molecules to vibrate and this produces heat.

8. Temperature or biological effects

The term diathermy already suggests that temperature is the main effect of electromagnetic waves in the body. But the cellular signaling effects that are produced are very important for the resolution of the lesions. We will now see the effects of temperature on tissues and electromagnetic energy on the cell. A general summary of biological effects is presented in **Figure 3**.

8.1 Heat and hyperthermia

Heat treatment in mammalian cells at temperatures above 40 °C produces multiple effects on cell metabolism. Hyperthermia inhibits protein synthesis. It induces the production of heat shock proteins and inhibits energy metabolism. At temperatures in the range of 50–60 °C it damages DNA and denatures it and at temperatures below 40–46 °C it produces chromosomal aberrations if the cell is in the S phase of mitosis.

An important role in this response is played by the Thermal Shock proteins (HSP), a superfamily of proteins highly conserved in evolution, which play an essential role in the conformational and functional protection of proteins within the cell. With molecular weights of 72 kDa, 73 kDa and 90 kDa they correspond to the largest classes of stress proteins expressed by the body.

Another effect of warming is the local effect. In general, the therapeutic range for sports medicine is assumed to be 41–45 °C, because this range causes the maximum increase in local blood flow [5] (Perez y Al 1993). Therefore, hyperthermia treatment is considered to provide effective therapeutic conditions. On the contrary, from a safety perspective, the possibility that treatment above 45 °C causes muscle damage cannot be ignored. The duration of heat treatment is also a concern in hyperthermia therapy. For example, in oncology, patients receive hyperthermia therapy at 45 ° C for 15 minutes if they do not feel pain. In short exposures 1–2 minutes of duration, temperatures of >45 °C can be reached, without the treatment causing damage to muscle tissue.

Concluding hyperthermia acts by producing an increase in heat shock proteins and increasing local blood flow.

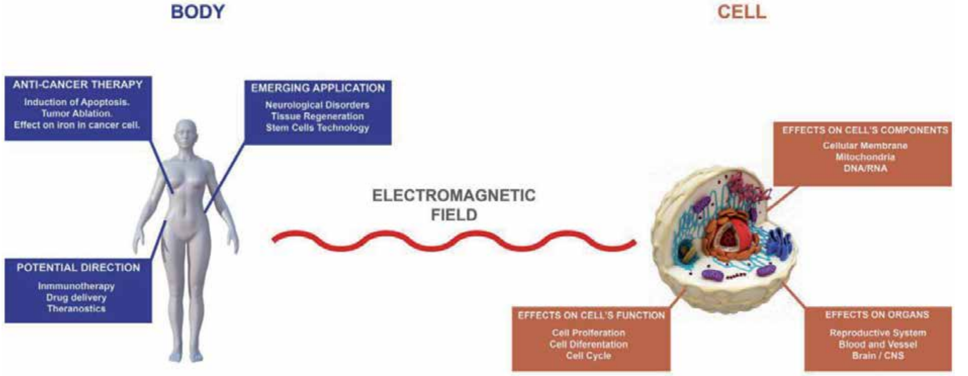

Figure 3.
Effect of the electromagnetic field on the cell and the body.

8.2 Effect on cells

Cells interact with their environment through the cell membrane. Among other functions, the cell membrane is responsible for the detection and subsequent transduction of external biochemical or other signals in the cytoplasmic space. The cell membrane is also considered the main site of interaction of EMF signals with cell systems.

A large body of literature has shown that various biological RF (Radio Frequency) effects can be produced without tissue heating, which are known as non-thermal biological effects of electromagnetic radiation.

The cell membrane is a 5–10 nm thick structure that surrounds and encloses the cell. It is made up of lipid and protein molecules. The most abundant membrane lipids are called phospholipids. The cell membrane is a lipid bilayer that allows the flow of ions through proteins that function as channels and ionic pumps. Ion flow can be stimulated with an external stimulus, to activate specific signaling pathways intracellularly. Although studies have applied electrical and magnetic stimuli to modify cell function, the parameters for stimulating the cell membrane are unknown.

The effects of exposure to an electromagnetic field can be understood as a chain of responses at different interrelated scales in the biological system. This chain of events begins with the interaction between the incoming wave and the charged atomic structure of biomolecules, mainly ions, especially outside the cell. This interaction leads to changes in the chemical composition and charge distribution of proteins and other macromolecules that are transduced into changes in biochemical signaling pathways.

8.3 Effects on calcium

Exposure to EMFs may act to cause excessive Voltage Dependent Calcium Channels (VGCC) activity in many cell types, suggesting that these may be direct targets of EMF exposure. Many of these studies specifically implicate L-type VGCCs, such that various L-type calcium channel blockers may block responses to EMF exposure. Stimulation of VGCC by the electromagnetic wave leads to an increase in intracellular Ca^{2+}, which can act in turn to stimulate the two calcium / calmodulin-dependent nitric oxide synthases and increase nitric oxide [6] (Wooda and Karipidisb 2021). This nitric oxide acts in therapeutic or potentially therapeutic responses of EMF, through its main physiological pathway, stimulating Guanosine Monophosphate cyclic (cGMP) and protein kinase G. Nitric oxide can act in pathophysiological responses to exposure to EMF, acting as a precursor of peroxynitrite, with its dual role, producing both oxidative stress and free radical decomposition products (**Figure 4**).

For lymphocytes, Ca^{2+} mobilization is among the first detectable events to be triggered by binding of a ligand (e.g., Antigen, receptor antibody, mitogenic lectin) to an appropriate receptor structure exposed on the outer cell surface. The cascade of cellular reactions in lymphoid cells subsequent to ligand-receptor interaction is best understood for T cells and has been extensively reviewed. In summary, ligand-induced Ca^{2+} mobilization is reflected in an initial increase in Ca^{2+} that is caused by inositol 1,4,5-triphosphate-induced Ca^{2+} release from intracellular stores and followed by a sustained influx of Ca^{2+} mediated by receptors from the extracellular environment, including cell proliferation, secretion, motility, etc. or cytotoxicity. With regard to the effects of electromagnetic fields on the immune system, it is proposed that Ca^{2+} regulation in lymphoid cells could be similarly affected by appropriate signals from electromagnetic fields, leading to informed responses of electromagnetic fields. In cells, for example, on proliferation or cell-mediated cytotoxic agents [7] (Pall 2013).

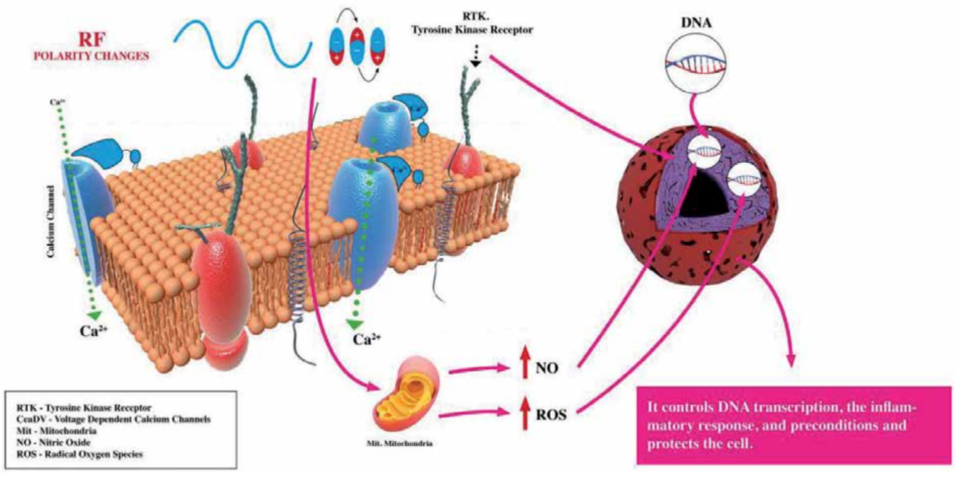

Figure 4.
Mobilization of intracellular calcium after opening the voltage-dependent calcium channels by electromagnetic energy.

Cellular Ca^{2+} mobilization in response to external EMF signals or interference of an EMF with Ca^{2+} regulatory processes is considered an important target of EMF action in tissues.

8.4 Effect on fibroblasts

Fibroblast is a type of cell that synthesizes the extracellular matrix and collagen, the structural framework of animal and human tissues, and plays a critical role in wound healing. Fibroblasts are the most common connective tissue cells in animals. The main function of fibroblasts is to maintain the structural integrity of connective tissues through the continuous secretion of precursors from the extracellular matrix, and as a result, this type of cell is critically involved in the wound healing process [8] (Aaron et Al 2013).

EMFs are known to play an important role in the cascade of processes that determine cell migration, adhesion, and differentiation. Electric currents and related

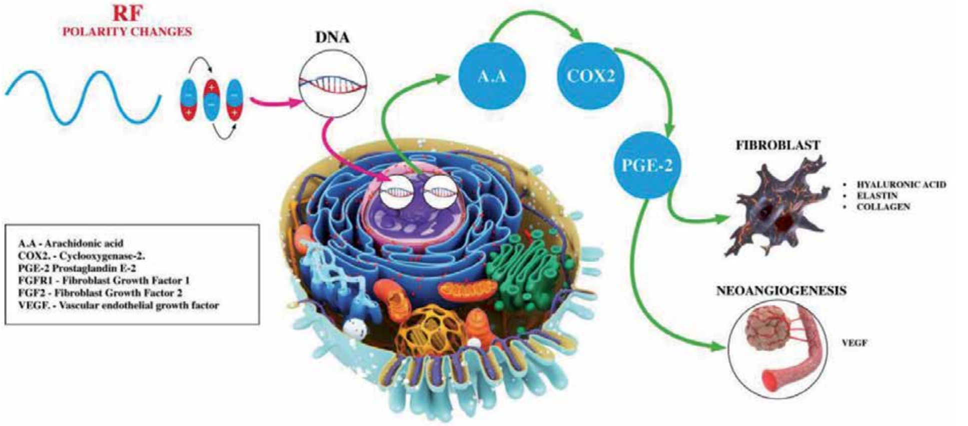

Figure 5.
Intracellular signaling and stimulation of fibroblasts increasing the levels of both epithelial and angiogenic growth factors.

fields are generated by passive absorption of Na^+ from the environment, leading to an internally positive transepithelial potential difference.

EMF can activate fibroblast migration. EMF has been shown to activate fibroblast proliferation. Activation of the expression of human fibroblast growth factor 1 (HFGF1), after exposure to EMF, showed that molecular wound healing pathways are activated in response to this resonant EMF in water (**Figure 5**).

For this reason, the application of EMF may have therapeutic relevance for wound healing and other pathologies.

9. Repair of collagen, hyaluronic acid and bone production

Collagen is considered to be one of the most important biomaterials in cartilage repair. We have shown that exposure to pulsed radiofrequency, that is, with more energy and little heat, improves chondrogenic differentiation and protein synthesis of the extracellular matrix of cartilage. Collagens are proteins composed of three polypeptide subunits known as α chains that exist in a single triple helix. There are more than 20 types of collagen in animal tissue. Scientific research has confirmed the activity of EMFs (electromagnetic fields) in this tissue [9] (De Mattei et al. 2007). In vitro and in vivo studies have shown that EMF can change some physiological parameters of bone cells, such as proliferation [10] (De Mattei et al. 1999), differentiation [11] (Lohmann et Al 2000), synthesis of extracellular matrix components [11–13] (Lohmann et Al 2000, Heermeier et Al 1998, Harting et Al 2000) and production of growth factors. In addition, EMFs can stimulate osteogenesis in bone. This has been shown in many studies [14] (Thamsborg et Al 2005).

Clinical studies demonstrated that EMF exposure could be useful for the treatment of degenerative cartilage disorders such as osteoarthritis. Several studies have investigated the effects of electromagnetic fields on cartilage cells and tissue, showing that electromagnetic fields can stimulate chondrocyte proliferation and increase the amount of ECM (extracellular matrix) components of cartilage. EMFs stimulate proteoglycan (PG) synthesis in vivo and in vitro. TrPs are critical components of the cartilage, and loss of TrP from tissue is seen in OA. EMF can stimulate the synthesis of PG [15] (Goldring 2000).

Electromagnetic fields have positive effects on bone and cartilage tissue. Electromagnetic fields affect the mobility of K, Ca^{2+}, Mg ions in bone and cartilage. They increase collagen synthesis [12] (Heermeier at Al 1998).

9.1 Angiogenesis

There is evidence to support the concept that radiofrequency acts by promoting angiogenesis through the coordinated release of fibroblast growth factor β-2 FGF-2 and, to a lesser extent, various other vascular growth factors angiopoietin-2 (Ang-2), thrombopoietin (TPO) and epidermal growth factor (EGF). This suggests that RF may facilitate healing by increasing blood vessel growth. This finding not only clarifies a novel mechanism for the action of RF, but also suggests widespread applications in the treatment of ischemic disease and a potential link between electromagnetic fields and increased tissue circulation.

9.2 Lymphatic drainage

When a sports injury occurs, the injury site reaction is inflammation, which is accompanied by edema. The phases of inflammation are, in order: organization of the hematoma, necrosis and finally, degeneration of the muscle fibers with

Figure 6.
Lymphatic drainage in the lower limb: The active plate, which delivers the energy, is placed on the sole and the passive plate, that takes it to the ground, is placed in the lumbar area. Lymph moves from one plate to the other.

diapedesis of macrophages and phagocytosis towards the necrotic material. After increased blood flow by the action of temperature and EMF, waste substances accumulate in the area of injury and surrounding areas (**Figure 6**).

Magnetic field interactions with blood flow have been demonstrated. In addition to this, electrically charged proteins also move between the electric poles. An approximately linear growth of the flow rate of water with an electric field intensity has been studied.

The magnetohydrodynamic law explains that the force experienced by an enclosed charge moves fluids. Erythrocytes and proteins have charge and these elements are inside the blood vessels. The RF energy acts on these elements according to this law, and moves the fluids in the body with a speed under an applied electric field. The blood, as the most abundant fluid in the body, will act as a fluid conductor necessary to conduct the energy, as it increases its flow. It has been suggested that the magnetic characteristics of the blood can be used to improve the hemodynamic disturbances associated with atherosclerosis.

The elimination of the substances, which accumulate during inflammation, is achieved by performing a lymphatic drainage: the active plate is placed on the feet or hands and the passive plate in the lumbar area. The movement of blood and the lymph drags the waste substances towards the chest area to join the thoracic duct and circulation [16] (Cau et Al 2019).

10. Effect on sports pathology

10.1 Effect on the muscles

In sports medicine, diathermy devices for musculoskeletal use have been identified by the term "Tecartherapy". Tecartherapy stands for Transference of Capacitive and Resistive Energy. The Tecartherapy intervention improves the spatio-temporal biomechanical parameters in runners. A study by Duñabeitia in 2018 [17], indicates that the application of capacitive and resistive RF after an exhaustive training session, rather than passive rest, generates a more efficient running pattern, even though selected physiological parameter markers are not affected. These findings highlight the potential role of Tecartherapy in accelerating recovery from muscle fatigue in runners, which could lead to better performance. Differences were detected in the length of the step and the angle of the stride, the height and the frequency between the group of treatment with Tecartherapy and the control group, with an increase of these (**Figure 7**).

10.2 Pain

RF procedures in chronic pain utilize alternating current in the AM RF band to produce effects on pain pathways [18] (Rea et Al 2011). In 2020 Bretelle y Col [19]

Figure 7.
The active plates can be used during physical exercise, which improves muscle performance.

publish a Clinical Trial, where they report that RF treatment, showed a significant reduction in perineal discomfort while walking and could halve the use of analgesics, which could improve well-being during this sensitive period. RF treatment showed a significant reduction in perineal discomfort while walking and could halve the use of analgesics, which could improve well-being during this sensitive period. Musculoskeletal diseases comprise several conditions that are characterized by pain and limitations in mobility, dexterity, and functional capacity, reducing people's ability to work and participate in social roles with associated impacts on mental well-being. Some of the most common and disabling musculoskeletal diseases are osteoarthritis, back and neck pain, tendinopathy, fibromyalgia, and myofascial pain. Also, muscle injuries are the most common category of injuries in athletes and comprise approximately 10% to 55% of all injuries. Most muscle injuries (> 90%) are contusions or strains, while lacerations are much less common. The most serious types of musculoskeletal diseases can cause chronic pain, dysfunction, recurrence, and even compartment syndrome. Studies are in development with partial results. They have shown that these latest generation radiofrequency devices reduce the recovery time from injuries, by increasing blood flow, signaling, and especially by lymphatic drainage [20] (Tramuntana 2020).

Calcium/calmodulin-dependent kinase II (CaMKII) signaling is essential to maintain aberrant hyperexcitability of the dorsal horn neuron in the pain condition. RF signals have been shown to modulate CaM-dependent signaling pathways that orchestrate the release of cytokines and growth factors in cellular responses to injury. RF signals have been shown to modulate CaM-dependent NO signaling cascades in articular chondrocytes [21] (Pilla et Al 2011) and other cells using CaM antagonists, and NO downstream inhibitory.

10.3 Trigger points

Trigger points are specific sensitive areas in a muscle. They are part of a condition called myofascial pain syndrome, which involves muscle stiffness, tenderness, and pain that radiates to other areas, also known as referred pain [22] (Melzack et al., 1997). The term "myofascial" has evolved from the perspective that it is likely that both muscle and fascia may be contributors to symptoms [23] (Akamatsu et al.). Trigger points arise from the clustering of sodium-sensitive sites. In fact, the excitation processes of cells involve the entry of sodium through the membrane of the muscle fibers. Therefore, it is thought that most, if not all, pain points will be associated with sodium-sensitive sites.

The effects of magnetic, electric and electromagnetic fields on sodium / potassium ATP-handle have been studied extensively over the last quarter of a century by various researchers, but the most important for trigger points are the studies conducted by https://www.mendeley.com/download-desktop-new/, in addition to the Na ion transport mechanism, by K-ATPase, EMF interactions with transient electrons and protons that are released from the oscillating motion that affects the bonds of hydrogen (H) in hydrated proteins which could be involved in the mechanism of action. It is highly probable that the hydrogen bonding of water molecules with ions / ligands could be a hypothesis, for understanding the effects of magnetic fields on pain relief. Therefore, it would be logical to transfer these interactions to the discussion of trigger points as an acceptable mechanism for pain relief in myofascial pain [24] (Blank 2005) (**Figure 8**).

There is a study with patients with trigger points that prevented them from carrying out their daily activities and where capacitive radiofrequency (C-RF) was applied. The results found proved that C-RF is an effective solution to treat painful conditions with a limiting factor for daily activities.

10.4 Muscle injuries

After a muscle injury secondary to trauma, there is a rupture of blood vessels, bleeding at the injury site, and subsequent edema. Direct trauma to muscle fibers also causes rupture of the basal lamina and sarcolemma and subsequent degeneration of the sarcomeres in the affected area [25] (Hazlewood and Markov 2007). Diathermy produces a much faster increase in soft tissue temperature. Associated with the increase in tissue temperature there is an increase in blood flow. Elevated tissue temperatures improve blood flow and can relieve muscle spasms and pain [26] Karpati et Al 1982), and improve recovery from injury.

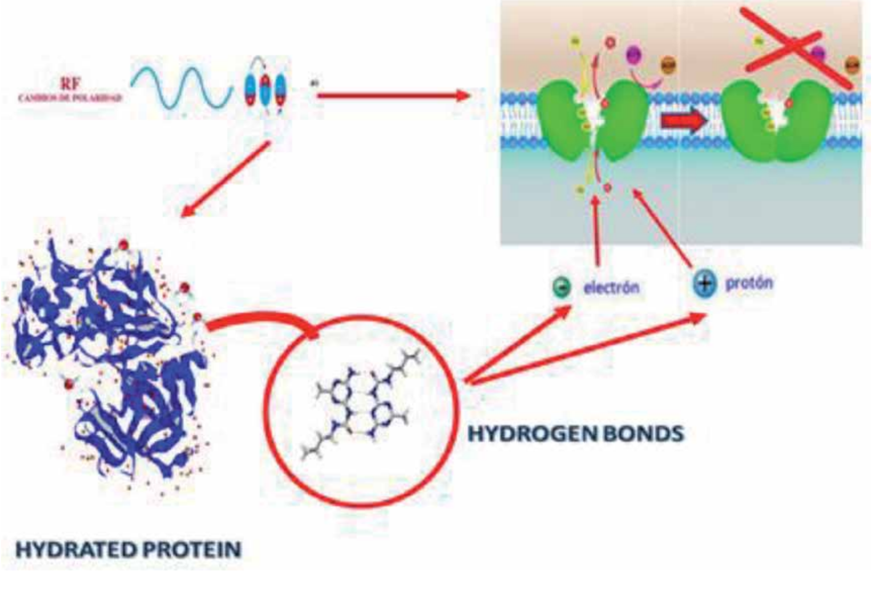

Figure 8.
Effect of electromagnetic energy on Na / K ATP ASA. Hydrogen bonds in protein release electrons and protons, which block the pump proteins.

10.5 Cartilage injuries

The use of RF for the treatment of injured cartilage has increased enormously in recent years. The safety and effectiveness of this technique depend on an understanding of the physics behind RF. First, it is not electrocautery. During application, a high frequency alternating current flows from the uninsulated probe tip into the tissue. Ionic agitation occurs in tissue when the ions try to follow the directional changes of the alternating current. This agitation produces frictional heating so that the tissue around the electrode tip, rather than the electrode plate itself, is the main source of heat. The heat produced during the application of RF is the difference between the heat generated by the flow of RF current through the tissue surrounding the probe tip and the heat that is dissipated in this region [27] (Ryland et Al 2001).

10.6 Urinary incontinence in female athletes

Urinary incontinence (UI) is defined as the involuntary loss of urine. When pressure inside the abdomen increases due to exertion, it is transmitted to the bladder causing the pressure within the bladder to be higher than in the urethra. For proper function of urination and urinary continence, intraurethral pressure must be higher than intravesical pressure both at rest and in activities that require effort. There is pelvic floor dysfunction in high-performance athletes associated with athletic activity and urinary incontinence. Eating disorders, constipation, family history of urinary incontinence, history of urinary tract infections and decreased flexibility of the plantar arch are associated with an increased risk of UI in elite female athletes. Pelvic floor physiotherapy as a treatment for urinary incontinence in elite female athletes, former elite female athletes and pregnant athletes who engage in regular aerobic activity leads to a higher continence gain than that obtained by nonathlete women [28] (Thyssen et al., 2002).

The use of radiofrequency with high power, which is a diathermic process generated by the radiation of an electromagnetic spectrum, resulting in an immediate retraction of existing collagen and the subsequent activation of fibroblasts causing non-ablative neocollagenesis. The female urethra is known for having a maximum length of five centimeters, and its anatomical structure and length justifies the use of radiofrequency on the external urethral meatus. Radiofrequency waves can reach a sufficient depth to induce collagen production in the whole urethra. RF has shown to be a treatment with low adverse effect. Patients reported no symptoms during or after treatment [29, 30] (Lordelo et Al 2017, Sodré et Al 2019). In **Figure 9**, the intracavitary electrodes are shown. E electrode (a) is the general one, to work vaginal and anal. The (b) is specific for pediatrics and vaginismus, because it is thinner for applications in which the (a) and it will be more difficult to apply. The (c) is rectal for anal application only. And the d is for specific rectal application, in specific and focused points. With this, the entire pelvic floor can be addressed intracavitary. These devices apply energy to the vagina in 360°.

The capacitive intracavitary device, shaped like a finger, allows not only the penetration of the energy that passes through the (**Figure 10**) pelvic floor structure

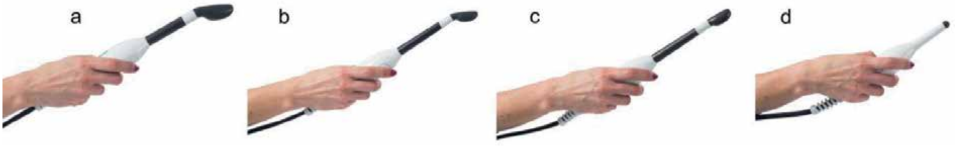

Figure 9.
Different capacitive intracacavitary vaginal devices.

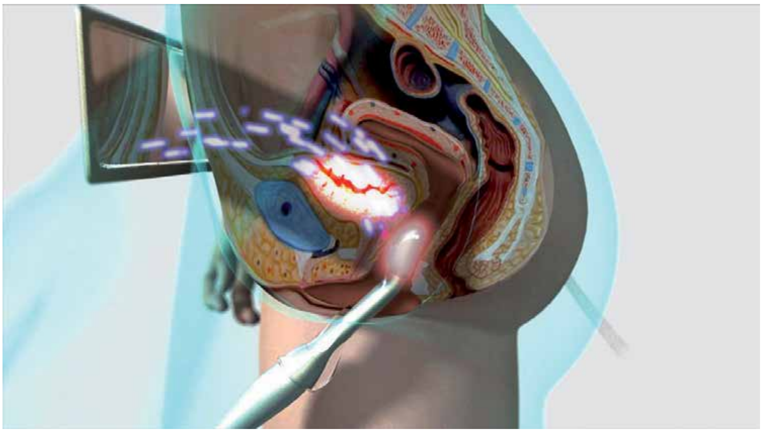

Figure 10.
Diagram of the use of the intracavitary device. The movement of energy towards the passive plate can be observed.

but also massages the vaginal region, allowing the vaginal introitus to reach the entire length of the vagina, which makes the urethra receive the necessary energy, to produce structural changes, to improve urinary incontinence.

11. The state of the technology

The state of the art determines the technological evolution of the equipment. Within the market, there are models with different characteristics and benefits, which present significant differences in energy delivery and, consequently, in obtaining results. It is important to become familiar with the available device options to gauge expectations for therapeutic efficacy.

The first generation of equipment was developed in the 80s. Today, they are still in the market with an exclusively manual use feature. They have a single channel, with a capacitive electrode holder, a resistive electrode holder and a return plate. The power of this equipment varies between 50 and 250 W.

The second generation of equipment was developed in the 2010s. This new technological family was characterized by increasing performance, as well as power, since the supply of electronic components allowed more complicated designs. The equipment of this second generation has an automatic working option, in addition to the classic capacitive and resistive electrode holders; they allow working in multi-channel (that is, several channels within the same container), they have a temperature sensor and even allow an intracavitary approach with controlled temperature. The input powers of these devices start at 300 W.

Although it is true that all devices start from the same type of energy, the dosage provided by both technologies makes a difference at the therapeutic level. This factor determines, not only a physiological improvement in obtaining results of 75%, but even that some equipment with temperature sensors avoid the absolute contraindication of its application in sensitivity disorders, when the temperature of the device can be controlled.

12. Cautions and contraindications with the use of radiofrequency

Over the years, a large number of contraindications to radiofrequency therapy have been identified. Some are clearly documented, others are based on assumptions. Others still depend on the dose or the location. For these reasons, the contraindications are divided into:

12.1 Absolute contraindications

Pregnancy - In view of the rapid division of embryonic tissue and the blood supply to the placenta, it is not advisable to treat pregnant women with radiofrequency.

Active bacterial infectious diseases (e.g. Tuberculosis) - In certain forms of tuberculosis or in active infections, heating in deep tissue can cause a large decrease in the number of leukocytes. Viral infections, on the contrary, have shown a positive reaction to the therapy.

Implanted electronic device - it is recommended that a patient with an implanted electronic device (e.g. cardiac pacemaker) not be subjected to radiofrequency, unless a specialized medical opinion has been previously obtained.

Hearing aids - Hearing aids must be removed. If they are subjected to radio frequency, hearing aids may experience irregularities in their operation. People with pacemakers and hearing aids should therefore not remain in the vicinity of radio frequency equipment when they are switched on.

Fever - Using radio frequency with fever can further increase metabolism. This could cause an even higher rise in temperature, leading to hyperthermia.

Neoformations - Active cancer is a contraindication when blood flow may imply the dissemination of the metastasis. Treatment of some muscular skeleton diseases may be accepted even when the patient has cancer, when this specification is detailed in the diathermy device User's Manual.

Sensitivity alterations - The application of radiofrequency should be used with caution on areas with sensory alterations. Special care is needed also for debilitated patients, since dosimetry depends largely on the sensation of heat felt by the patient. Pain is an indication that excessive heat is occurring. Sensitivity alteration is an absolute contraindication in devices with no temperature sensor control. This contraindication is avoided when the device has temperature sensor control and can be adjusted to a tolerable temperature without risk of burns.

12.2 Relative contraindications

Rheumatoid arthritis - Researchers report that deep heating in the treated joints can increase enzyme activity and induce breakdown of articular cartilage. Nevertheless, diathermy treatment in athermal or moderately thermal mode has shown a positive reaction. Dose management is important, and should be precise.

Large metal implants - Metals concentrate electromagnetic energy. To prevent possible concentrations of energy, around the implant and the resulting dangers (burns), radio frequency application should only be used if the indications are more important than the possible adverse effects while using specific guidelines and applied in mobile modalities with dose management.

Chronic systemic diseases - In decompensated chronic diseases such as diabetes, hypertension, coronary artery disease, kidney failure, etc. the use of radiofrequency concomitant to decompensated systemic diseases can induce adverse effects.

13. Conclusions

This chapter discusses the main effects of high-power, multi-channel radio frequency in sports lessons, the most important factor determining whether a diathermy device increases intracellular signaling, vascularity, and body temperature is the amount of energy absorbed by the tissue. This energy is provided in Tecartherapy devices through the generation of an electromagnetic field, and through the use of capacitive and resistive electrodes. The key results that contribute to improving sports injuries are presented, being able to improve, including muscular capacities. This electromagnetic field will have various metabolic effects on the vascular, musculoskeletal and immune systems, which are beneficial for work in different areas of health such as sports, pain, the vascular area, urogynecology, important in urinary incontinence in athletes, feminine among others, being increasingly extensible to other fields of health. This procedure is safe, with no known side effects, and the patient can be returned to normal activity immediately.

Manufactured Device.

Pictures courtesy of Capenergy Medical, S.L. Barcelona, Spain.

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Chapter 2

Blood Flow Restriction Training in Cardiovascular Disease Patients

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Abstract

Over the past two decades, blood flow restriction training (BFRT) has gained popularity not only in athletic performance training, but also with many researchers and physical therapists as an innovative rehabilitation tool. Blood flow restriction (BFR) exercise is a novel exercise modality in clinical settings, which induces muscle hypertrophy and increases strength with low to moderate training intensity through increased anabolic processes mediated by BFR (usually with cuff inflation). BFR limits arterial and venous blood flow and leads to blood pooling, which could increase the effects of exercise-induced training. Strength training at lower intensities (20–40% of maximum strength) in combination with BFR showed similar effects on muscle hypertrophy as training at 70% strength level without BFR. In this context, considering that periods of immobilization (or reduced functionality) due to pathology, injury, or surgery cause harmful effects on muscle mass and strength in both young and old people, muscular adaptations of occlusion exercise could be beneficial to the elderly and post-operative patients in rehabilitation regarding muscle regeneration. Furthermore, as this type of exercise does not require high loads, it might be a feasible method in cardiac rehabilitation. Therefore, this chapter aims to review all recent literature regarding the impact of low-load BFR resistance training in patients with cardiovascular pathologies on muscle strength and hypertrophy, vascular function, safety, cardiovascular responses, and inflammatory markers.

Keywords: blood flow restriction training, exercise, cardiovascular patients

1. Introduction

Even as we approach the third decade of the 21st century, cardiovascular disease continues to be the leading cause of death worldwide, accounting for one-third of deaths and being the leading cause of death in Europe [1–4]. More specifically, 4 million Europeans die of cardiovascular disease (CVD) each year (45% of all deaths) [5, 6].

CVDs are a group of disorders that include the heart, blood vessels (arteries, capillaries, and veins), or both [7]. The most common CVDs that are also important for public health are ischemic heart disease, coronary heart disease, and vascular strokes. This category also includes peripheral arterial disease, congenital heart disease, rheumatic heart disease, cardiomyopathy, and cardiac arrhythmias. Gender, age, race, and family history are among the non-modifiable factors of

CVDs, while clinical and behavioral factors are among the modifiable ones. Clinical factors include obesity, hypertension, dyslipidaemia, diabetes mellitus, and cholesterol. Behavioral factors include reduced physical activity, smoking, substance use, unhealthy eating habits and stressful lifestyle as well as the socio-economic level of individuals.

The treatment of these diseases is based mainly on medication of specialized drugs, specific medical invasive techniques, and specialized therapeutic exercises. Therapeutic exercise is one of the most documented approaches for functional rehabilitation of patients with CVD. There is ample research evidence that the recommended levels of exercise are sufficient to prevent ischemic heart disease, stroke, hypertension, and therapeutic exercise adjustments have been investigated to improve their effectiveness, quality of life, and function indicators as well as to reduce morbidity and mortality in patients with CVD [8–13].

Based on the findings of the above research, patients with CVD could benefit significantly if they joined rehabilitation programs using therapeutic exercise. These patients often have low levels of cardiovascular function, muscle mass, and strength [14]. Aerobic exercise as well as low-resistance exercise have been suggested in cardiovascular rehabilitation therapies with positive results in improving the above parameters [15, 16]. Given that high-intensity exercise can cause unwanted cardiovascular adjustments, such as high blood pressure or arrhythmias, it should be avoided in specific patient groups [17, 18]; and low-intensity exercise is identified at levels not exceeding the anaerobic threshold [19].

Low-intensity aerobic exercise has been reported to enhance peripheral circulation, reduce heart attacks and the need for hospitalization, and improve cardiovascular function and quality of life in people with CVD by enhancing their ability to perform daily activities without symptoms or limitations [20]. However, low-intensity aerobic exercise cannot provide adjustments to increase muscle strength and mass [21]; which is why low-resistance exercise is essential and can improve muscle strength, endurance and mass, as well as bone density [22–24].

In recent years, research has demonstrated a novel exercise model, low-load BFRT, which is a therapeutic approach that could lead to significant myodynamic adjustments without the need to apply high tensions and high loads, allowing the implementation of exercise programs even in high-risk groups of patients, such as CVD patients.

BFRT is becoming very popular, and for some scientists it is considered 'the state of art'. Restricting blood flow (not occluding) by itself, or in combination with exercise, results in beneficial adaptations to skeletal muscle and bones in various populations (old, young, trained, untrained). When BFRT is conducted, the blood flow to the exercising muscle is restricted by thin, computer-controlled, pressurized external constricting devices, such as pneumatic cuffs or inflated tourniquets, which are placed at the most proximal part of the arms or legs to reduce the amount of blood flowing back from the muscles in the extremities during a workout.

Historically, BFRT originated in Japan and involves the restriction of blood flow to exercising muscle. It was first described by Dr. Yoshiaki Sato, and the technique is based on blood flow moderation exercise (or vascular occlusion moderation training) involving compression of the vasculature proximal to the exercising muscles by specifically designed equipment. Dr. Sato evolved this technique called KAATSU, which is derived from the combination of the Japanese words for 'additional' (ka) and 'pressure' (atsu) [25]. KAATSU training is also known as vascular occlusion (VO) training. Dr. Sato evolved this technique during the period between 1973 and 1982 and developed various protocols that worked for people in different demographics (elderly, young, athletes, amateurs, etc.). The method was generalized for public use in the 1980s. Soon, the method was used by physicians, manipulative therapists, acupuncture therapists, moxa therapists, athletic trainers, and physio therapists all over the world.

According to the American College of Sports Medicine (ACSM), a standard conventional training conducted at an intensity of at least 65% + of one-repetition maximum (1RM) is needed to achieve adaptations for muscle hypertrophy.[2] Nevertheless there are numerous studies that support low intensity exercise (20%–40% 1RM) combined with blood flow restriction could be beneficial for stimulating an increase of muscle strength, hypertrophy, and endurance [26–28]. At the same time, the suggested permissible levels of exercise intensity for cardiovascular patients is <30% 1RM, which makes it insufficient to make positive adjustments to increase muscle mass and strength [22, 29].

Approaching exercise with blood flow restriction could be a promising type of exercise for high-risk groups of patients, as research supports that with loads of 20–30% of 1RM, combined with blood flow restriction, it is feasible to yield hypertrophy responses comparable to that observed with heavy-load resistance training [30–32].

Especially in the case of cardiovascular patients where the American Heart Association recommendations currently suggest lower loads and intensity training, 'occlusion exercising' could be a valuable tool in the hands of therapists as it can accelerate patient rehabilitation by minimizing functional deficits in muscle mass and strength that arise during periods of reduced mobility and activity. Therefore, this chapter aims to review all recent literature regarding the impact of low-load BFR resistance training in patients with cardiovascular pathologies on muscle strength and hypertrophy, vascular function, safety, cardiovascular responses, and inflammatory markers.

1.1 Blood flow restriction mechanism of action

The definitive mechanism by which this kind of exercise provides stimulation for increased muscle strength and mass has not yet been elucidated; however, mechanisms of action of BFR have been reported. The potential physiological mechanisms underlying low-intensity exercise with BFR to improve muscle strength and mass include increased fiber type recruitment, decreased myostatin, stimulation of muscle protein synthesis, and cell swelling, an increase in metabolic stress, which theoretically activates systemic hormone production and fast-twitch muscle fibers, although it is likely that many of the aforementioned mechanisms work together [33]. Specifically, during BFRT, blood flow to the muscle being exercised is mechanically restricted by placing flexible compression cuffs or special straps proximally to the active extremity/extremities (at the upper extremities approximately peripherally at the point of deltoid insertion, at the lower extremities approximately at the top of the thighs peripherally of the gluteal line).

The restriction creates a kind of pressure that reduces blood flow to muscle fibers and, more specifically, to intracellular space. This alters the muscle's biochemistry, increases lactate (lactic acid), and reduces pH, creating a low oxygen supply and intracellular swelling. All the above is thought to threaten the integrity of the cell membrane, which leads to the anabolic response and the increased release of growth hormones [34]. During BFRT, the external pressure applied is sufficient to maintain arterial inflow while occluding venous outflow of blood distal to the occlusion site. It has been suggested that cell swelling, induced by blood-pooling accumulation of metabolites and reactive hyperaemia, is detected by an intrinsic volume sensor, and may consequently lead to an activation of myogenic signaling pathways. This enhanced reperfusion and subsequent intracellular swelling are believed to threaten the structural integrity of the cell membrane, promoting an anabolic response [28].

In addition, during BFRT, there is a limited supply of oxygen to the muscles, which leads to the inactivation of the slow twitch muscle fibers (type I), which need oxygen as an energy source, while on the contrary it contributes to the activation of fast twitch fibers (type II) that have a higher hypertrophic potential than type I [28]. Type II muscle fibers have a relatively larger diameter and higher stimulation threshold. They receive energy mainly from the glycolytic pathway instead of oxidative metabolism, so they are preferentially recruited in a hypoxic environment. Tissue hypoxia from BFRT has been demonstrated to cause preferential recruitment of type II motor units, which typically are only recruited with high-load training [35]. Several studies have shown that the hypoxic intramuscular environment resulting from BFR leads to a high percentage of ATP hydrolysis, pH decrease, lactic acid increase, an increase of heat shock proteins (KSPAs) and protein S6, as well as in the inhibition of myostatin hormone, which inhibits the procedure of muscle mass hypertrophy. The above physiological responses significantly enhance the healing process and muscle hypertrophy [26, 32, 34, 35]. BFRT has also been shown to influence vasculature by promoting postexercise blood flow, oxygen delivery, and angiogenesis. Research indicates that it significantly increases vascular endothelial growth factor (VEGF) expression [36]; promotes vascular function [37]; enhances vascular conductance [52]; and partially alters hemodynamic parameters [38].

1.2 Cuff application

The main goal of the cuff used during BFRT is to provide sufficient pressure to restrict venous outflow while maintaining arterial inflow. Cuff width is a significant factor for determining safe BFRT pressures [39]. Furthermore, wider cuffs require significantly less pressure to achieve arterial occlusion pressure (AOP) [40]. Cuff pressures during BFRT were commonly greater than 200 mm Hg; but recent studies have found that similar positive outcomes could be achieved with pressures as low as 50 mm Hg, with less risk of adverse effects [35]. AOP is defined as the minimum pressure required to stop the flow of arterial blood into the limb. To calculate this, Doppler ultrasonography was placed on the radial or dorsalis pedis artery. The cuff is inflated until no pulse is detected, and then it is slowly released [41]. AOP can vary for each individual, even side-to-side, depending on limb circumference. Recent evidence reports two types of BFRT: personalized and practical. Personalized BFRT utilizes an advanced surgical tourniquet that allows the user to dial in a specific percentage of AOP and maintains this pressure throughout the training session. This has proven beneficial, especially in the research setting where it provides standardized results. On the other hand, practical BFRT includes a blood pressure cuff or elastic band to provide external pressure at a nonspecific value below AOP. Even though practical BFRT is not a standardized method as much as personalized BFRT, there is evidence that shows positive results when used for muscle hypertrophy [42, 43].

1.3 Safety

As far as safety is concerned, BFR training still requires further discussion, especially when performed with vulnerable people (patients, elderly). The idea of physically restricting blood flow to an extremity may raise red flags, especially regarding the cardiovascular system. It is well known that prolonged ischemia can cause necrosis of muscle tissue. Furthermore, a major concern with BFRT is the potential for thrombus formation [44]; because of the pooling of blood in the extremities. Of the evidence available, systematic reviews of BFR safety indicate it is not associated with additional cardiovascular stresses or morbidity [45–48].

Muscle damage through ischemic-reperfusion injury also occurs when there is blood flow restriction during exercise. Although ischemia reperfusion injury is most associated with long durations of severe ischemia [49]; the combination of short duration BFR with muscle contraction could elevate the possibility of muscle damage with this type of exercise. The risk of muscle damage while using BFRT has been analyzed by several investigations. Creatinine kinase, myoglobin, and interleukin 6 have not been shown to be elevated after BFRT more than traditional exercise [50]. There are case reports where rhabdomyolysis has developed after training; however, it is not known whether BFRT is the causing factor in thrombus formation. A previous survey out of Japan reported a rhabdomyolysis rate of 1 of 12,642 patients [51]. Overall, it appears that muscle damage is a minor risk with BFRT. To date, evidence shows that BFRT is not more risky than high-load resistance training, although careful selection of suitable patients and professional supervision is necessary to reduce the risk of side effects [48].

2. BFRT in patients with cardiovascular comorbidities

Research examining the safety of BFR exercise and training has thus far concluded that BFR exercise is a safe and novel method not only for training athletes and healthy persons but also it could be a beneficial training method for athletes/patients (post-surgery or injury situations) and for vulnerable populations and individuals with varying comorbidities where exercise options are limited [34, 52].

Furthermore, Abe et al. [53]; and Conceição et al. [54]; reported positive effects of BFRT regarding muscle strength, mass, and cardiorespiratory capacity when it is combined with low intensity walking or cycling. Abe et al. examined the acute and chronic effects of walk training with and without KAATSU on MRI-measured muscle size and maximum dynamic (one repetition maximum) and isometric strength, along with blood hormonal parameters. Eighteen healthy men volunteered to participate in this study. Nine men performed BFR-walk training, and nine men performed walk training alone (control-walk). Training was conducted two times a day, 6 days/wk., for 3 wk. using five sets of 2-min bouts (treadmill speed at 50 m/min), with a 1-min rest between bouts. For the BFR-walk training group, a restriction pressure of 160–230 mmHg was selected for the occlusive stimulus, as this pressure has been suggested to restrict venous blood flow and cause pooling of blood in capacitance vessels distal to the restriction point, as well as restricting arterial blood flow [55]. They conclude that BFR with slow-walk training induces muscle hypertrophy and strength gain, despite the minimal level of exercise intensity. Moreover, Conceicao et al. assessed the effects of BFR endurance training compared with conventional endurance training and resistance training in functional, morphological, and molecular responses. They examined 30 healthy men who were randomly assigned to the endurance BFR group, to the endurance conventional training group, and to the resistance conventional training group. All the groups performed eight weeks of training protocol. The endurance BFR group underwent 30 minutes cycling at 40% of VO_{2max}, four days per week, while the conventional group performed 30 minutes cycling at 70% of VO_{2max}, four days per week. In the BFR endurance group, cuff pressure was set at 80% of the maximum tibial arterial pressure (approximately 95 mmHg). The resistance training group performed four sets of ten leg press reps at 70% of 1RM with 60 seconds rest, four days per week. They suggest that BFR endurance training could increase muscle strength and induce similar hypertrophy stimulation to resistance training, while cardiorespiratory capacity could be improved even with a significantly lower workload compared to conventional endurance training. Altogether, this suggests that BFRT could be a potentially safe training method, particularly for older adults or clinical cohorts incapable of exercising at high training loads.

Moreover, Cezar et al. showed that eight weeks of wrist flexion exercise training with 30% of maximum dynamic force with vascular occlusion (70% of the resting SBP) was sufficient to reduce blood pressure in medicated hypertensive subjects [56]. Twenty-three women were randomly assigned to three groups: one was the control group and the other two underwent eight weeks of training performed twice a week, including three series of wrist flexion exercises with or without vascular occlusion. Blood pressure was assessed before each session and based on that measurement (blood pressure at rest), occlusion pressure was determined for use during exercise in the BFRT group. The cuff pressure was equivalent to 70% of the subject's resting systolic pressure (maintained from the beginning of the exercise period until the end of the last series). The exercised with occlusion group showed a pre- to post-test reduction in systolic and diastolic blood pressure, mean arterial pressure, and double product, whereas the other groups showed no significant hemodynamic changes.

Despite the positive adjustments of low-intensity aerobic exercise with BFR techniques, no research has been done to evaluate the effects of this type of exercise program on cardiovascular patients. Only one study has looked at short-term hemodynamic adjustments after low-intensity aerobic BFR in elderly hypertensive women, highlighting the potential benefits of this type of exercise in hypertensive patients [57]. Specifically, Barili et al. examined the acute responses of cardiorespiratory and oxidative stress parameters to low intensity aerobic exercise (LIAE) with blood flow restriction (BFR) in hypertensive elderly women. Each subject performed in random order three experimental protocols: (a) high intensity aerobic exercise (HIAE): 50% of the estimated maximum oxygen consumption; (b) low intensity aerobic exercise (LIAE): 30% of the estimated maximum oxygen consumption; and (c) low intensity aerobic exercise with blood flow restriction (LILIAE+BFR): 30% of the estimated maximum oxygen consumption and occlusion pressure equivalent to 130% of the measured systolic blood pressure at rest. Blood samples were collected at three different times: at rest, immediately after each exercise protocol, and after 30 min of recovery. The findings support the indication of low-intensity aerobic exercise with BFR, with potential benefits for the hypertensive elderly population.

Only five research attempts have examined the effect of low resistance BFRT in cardiovascular patients with positive results in terms of muscle strength, mass, and hypertrophy as well as the functionality of these patients [52, 58–61]. However, three of these studies are characterized by serious methodological problems as they are pilot studies and do not draw definitive conclusions [58–60]. In particular, they reported positive results in improving muscle strength and functionality without increasing the risk of adverse effects through hemostatic and inflammatory responses. Madarame et al. [60] investigated the haemostatic and inflammatory responses to BFR exercise in nine stable patients with ischaemic heart disease. The patients performed four sets of bilateral knee extension exercises with a load of 20% 1RM either with or without BFR. In each exercise session (total two separated at least by one week), one set of 30 repetitions was followed by three sets of 15 repetitions with 30 seconds of rest between each set. During the BFRT, the cuff was attached to the proximal portions of the thighs and compressed at a pressure of 200 mmHg. The cuff was kept throughout the session, including rest periods between sets, and was released immediately after the session. Blood samples were obtained before, immediately after, and 1 hour after the exercise. They suggest that low-intensity resistance exercise with BFR would be relatively safe for stable IHD patients, at least in terms of haemostatic and inflammatory responses.

Similar results were reported by Kambic et al. [58], who assessed the safety and efficacy of BFR resistance training in patients with coronary artery disease (CAD) compared to usual care. Twenty-four participants were included in this study: 12 (control group) performed conventional care (aerobic exercise training), while in the intervention group (n = 12), BFRT was added on usual care. Subjects in the BFR resistance training group trained for eight weeks, performing a total of 16 unilateral leg extension exercise sessions. During each week, two exercise sessions were performed with a 48-hour rest period in between. Each training session consisted of three sets of 8, 10, and 12 repetitions in the first, second, and third sets, respectively, with a 45-second inter-set rest interval. The load was set at 30% of 1RM. The cuff was inflated between 15 and 20 mmHg greater than resting brachial systolic pressure, and the pressure was maintained throughout the entire training session and was released at the end of the last set. Findings report that BFR resistance training is safe and associated with significant improvements in muscle strength and may therefore be provided as an additional exercise option to aerobic exercise to improve skeletal muscle functioning in patients with CAD.

Nakajima et al. [52]; also showed improvement in muscle strength and endurance in patients with cardiovascular disease after a low-resistance BFR program for three months with two workouts per week, while Fakuda et al. [61]; evaluated muscle activation in the biceps using low-resistance BFR compared to low-resistance exercise and showed that the BFR subgroup showed statistically significantly greater activation than the low-resistance exercise subgroup, suggesting that BFR could be a valuable tool for improving muscle hypertrophy in cardiovascular patients. However, it should be noted that the last two studies have been published in a newspaper dealing only with BFR (Int. J. KAATSU Training).

3. Conclusion

Prevention of muscle atrophy and enhancement of muscle strength and hypertrophy can facilitate and accelerate the rehabilitation process and prevent further re-injury. Blood flow restriction training has been shown to be an especially promising tool in the recovery of injured and postoperative patients. The loss of skeletal mass in vulnerable patients, such as elderly or cardiovascular disease patients, is accompanied by a decline in physical function and activities of daily living. Given the fact that these patients are often unable to tolerate high-load routines, BFRT may be used in these individuals to prevent muscle weakness and improve their daily living.

As far as cardiovascular patients are concerned, daily exercise is necessary to improve the quality of their lives. However, exercise in its classic form may be prohibitive in such groups (e.g., it is impossible to exercise high resistance to increase muscle strength). Hemostatic and inflammatory responses are the major concerns for patients with CVD when performing an exercise. However, recent literature [60]; proposed that BFRT with low load resistance will be safe as well as effective for this group of patients. In conclusion, we could assume that the innovative type of exercise with blood flow restriction could be a safe and effective tool in improving daily life in vulnerable groups, but further research is needed in order to determine the long-term adverse effects and the optimal training routines.

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Chapter 3

Leading Wrist Injuries in a Golfing Population. Golf Swing Biomechanics a Significant Cause of Pathology

Conor P. O'Brien

Abstract

Golf participation has increased significantly over the past 50 years. Injury rates have mirrored this increase with amateur and elite golfers suffering a similar injury incidence to rugby players. The upper limb is the second most common anatomical site of injury in this population. Wrist injury and specifically the ulnar side of the leading wrist is the most prevalent. Leading wrist injuries affect the tendons, fibrocartilage, bones and neural structures that are located on the ulnar side of the wrist and hand as well as the soft tissue aponeurosis and bony and ligamentous canals that traverse the wrist joint. The most commonly injured lateral wrist structure is the Extensor Carpi Ulnaris tendon. This is particularly liable to injury due to the forces placed on it during the golf swing. Other structures on the medial side of the leading wrist associated with golf related injury and pathology include Triangular Fibro-cartilage, the hamate bone, the bony canals through which the nerves travel, as well as the flexor aponeurosis and Flexor Carpi Ulnaris tendon. Risk injury to the medial aspect of the leading wrist is increased by the newer golfing theories and techniques which endeavour to create increase golf club head speeds by storing greater energy by a phenomenon called "lag". Lag results in greater speed as the club head releases at impact but results in injury to the medial wrist anatomical structures. Swing biomechanics, and their alteration and augmentation are a major factor in medial wrist injury. Diagnosis of these pathologies requires careful history and examination, as well as the use of radiology and electrodiagnostic medicine to confirm the pathology and degree. Treatment is targeted to the specific disability. Classical treatments are mostly employed and usually involve rest and anti-inflammatory treatments. Newer therapies such as Platelet Rich Plasma injection and Deep Oscillation therapy have proven beneficial. Splinting is often employed on return to play. Early diagnosis and cessation of the offending activity often allays the need for surgery. The rhyme that "minutes to diagnosis means weeks to recovery" is particularly apt for medial wrist golf injuries. Surgery will be required in long standing or chronic cases. Return to play, unlike many sports injuries, will require careful golf biomechanical assessment and alteration in swing dynamics. The objective of this chapter is to identify how the new biomechanical manipulation of the wrist and specifically the leading wrist has resulted in increased injuries to this anatomical structure. The type of injury, diagnosis and treatment is discussed in detail. Club head speed is generated through a combination of improved golf club equipment, golf payer fitness and manipulation of the golf club by the left wrist resulting in increased golf club lag and torque which all contribute to wrist injuries.

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Keywords: golf injury, leading wrist/swing biomechanics, Tenosynovitis, Carpal Tunnel Syndrome, ECU Tendon, Tendinitis, Tendinosis, hook of Hamate, Guyon's Canal Syndrome, Dupuytren's contracture, Flexor Carpi Ulnaris tendon, Nerve Entrapment

1. Introduction

Golf participation has exploded in the past 2 decades. In the early part of the century, it was calculated that Golf is played by over 55 million people throughout the world. In 2018 there were 38,864 golf courses in 290 of the world's 449 countries [1]. Golf has a particular traditional home in Great Britain and Ireland with 494 courses populating the island of Ireland. The majority of golfers reside in America, where over 23.4 million golfers were recorded in the USA in 2018. This had risen to 34.2 million by January 2021, with 9 million participating in golf at ranges and using indoor simulators. There are approximately one million individuals playing golf twice a week in England and have done so for the past five years [1, 6].

The Golf Industry is an $84 billion economic engine that drives nearly 2 million jobs in the USA producing a total economic output in California alone of $15.1bn in 2019.

Golf is both a recreational pastime and a competitive sporting pursuit. Golf started to thrive as a spectator sport in the 1920's and boomed in earnest in the 1960's with the arrival of live golf on TV. Its charm and allure might be the lack of age and gender barriers. Fundamentally, it is a game of skill and guile requiring some athletic ability.

The rise in popularity of golf is multifactorial. Golf as a sport has a dedicated viewing population unlike many sports and many non-golfers happily enjoy the trials and travails of professional golfers which appear on TV channels on a weekly basis. In many ways a 4 day professional sporting event is like a drama or soap opera with villains and heroes in equal measure performing on perfectly manicured fairways. Golf is peculiar in spawning a dedicated TV channel, The Golf Channel, watched by millions of viewers on a weekly basis. The recent pandemic delayed Masters played in Augusta, Georgia, USA in the Autumn of 2020 which had a viewership of over 15 million. The exercise associated with golf is of great health benefit [2] providing the perfect physiological work out to sustain health and longevity [3].

Golf too may be considered the perfect exercise for improving health and longevity. Recent recommendations have suggested that the perfect exercise would involve aerobic activity intermingled with resistance activity and anaerobic activity [3]. It is reported that this exercise prescription positively affects all cause and specific cause mortality in American adults. It appears that carrying or pushing golf clubs around an 18-hole course provides an almost perfect exercise prescription [2]. The association of golf participation and improved physical health and mental wellbeing and the contribution to increased life expectancy has prompted a number of experts to recommend policy makers encourage golf as a beneficial pastime [4].

The worldwide reach of golf and its ability to transcend barriers of age, race and gender and its general appeal has seen the reintroduction of golf to the 2016 Olympic Games.

In parallel with increased participation, injury rates among golfers have also increased. Research has suggested that almost 7 in 10 amateurs and 9 in 10 professionals will suffer a golf-related injury at least once in a lifetime of golf participation [5].

2. Golf injury incidence

Increased participation, just short of a million people play golf twice a month in England for the past 5 years [6] has resulted in increased injury rates more frequently in elite golfers. [7] Annual Injury incidences of between 2 and 4% are reported among golfers. Put more simply a golfer can expect to sustain an injury for every 100 hours of golf participation with an overall incidence rate of injury of 15.8 injuries per 100 golfers and with a range of 0.36 to 0.60 injuries per 1,000 hours per person. 46.2% of injuries are reportedly sustained during the golf swing, and injury is most likely to occur at the point of ball impact (23.7%) [8]. Golf carries a significant injury rate with levels exceeding other non- contact sports. Perhaps golf is in fact a contact sport, with contact being made with turf and ball through a metal implement, frequently in a ferocious and repetitive manner.

There is a significant variation in the incidence and type of injury suffered by amateur or recreational golfers in comparison to their professional counterparts. In a review of over a thousand amateur golfers, the survey confirmed that more than 60% of amateur golfers sustained one or more golf related injuries over the course of their playing career. The injury rate was higher in the over 50 year old amateur with a 65% injury rate in comparison to the under 50 group, which had an injury incidence of 58% [9]. There was a slightly higher incidence of injury at 67.5% among single figure handicappers rather than their double-digit colleagues. A typical injury resulted in the amateur golfer missing five weeks of playing time [5–7].

More than 80% of professional golfers report a golf-related injury at some point in their career. It is estimated that between 10% and 33% of professional golfers are actually playing while they are carrying an injury during their professional career. Most professional golfers will experience 2 significant golf-related injuries during their career. Over a career, 9 weeks for professional men and 3 weeks for professional women are lost due to injury. On returning from injury more than 50% of professional golfers are compromised by their injury and often play through pain [10–12].

Recent research has indicated that general exercise has an injury rate of 5.3 per 1,000 persons, golf having a similar injury rate to rugby at 1.5 per 1000 persons [13]. The injury rate is significant but the over-arching benefits of playing golf outweigh the risks, particularly to physical and mental well-being [2, 3].

3. Types of golf injury

All golfers are prone to injury. Amateur golfers have a lifetime incidence of injury ranging from 25.2% to 67.7%. Professionals golfers have higher rates between 31% to 88.5% over a lifetime.

Many studies on golf injuries have found that low back injuries account for 15.2% to 34% of all golf injuries, followed by injuries to the elbow (7% to 27%) and shoulder (4% to 19%). The wrist accounts for 10% of all golf injuries. In professional golf, wrist injury incidence has been reported to be up to 54% (7), the leading wrist being most commonly compromised [14].

The change in the injury profile is associated with increased playing hours as well as the nature of golf. Newer golf clubs with composite heads and lighter shafts have allowed the golfer to swing faster in the constant and increasing race by club manufacturers to achieve greater distance.

The majority of golf injuries are referred to as "over-use injuries" caused by the repeated action of swinging the golf club and hitting the golf ball and turf. This activity not only takes place on the golf course where the average long shot golf rate is 40 to 50 swings per round but also on the practice tee and driving range where 100's of balls are hit. Lighter clubs and the availability of golfing practice facilities have also impacted the increased injury rate. Specific risk factors for overuse golf injuries are age, ability, and swing mechanics [15].

4. Overuse injuries

Overuse injuries affecting the musculoskeletal system are caused by repetitive trauma which result in micro trauma to soft tissue structures such as tendons, muscles ligaments as well as bones. The factors pertaining to these overuse injuries can be divided simply into: 1) Intrinsic causes; 2) Extrinsic causes.

1. **Intrinsic** risk factors can be modifiable or non-modifiable. Modifiable factors in golfers would include fitness, skill level and patterns of practice session. One of the major issues for a golfer is that often he or she is their own coach. In many cases this type of practice reinforces an intrinsic mistake in the swing biomechanics rather than corrects the imperfection. In these cases, "practice makes permanent rather than perfect". Non-modifiable factors would include age, gender and body morphology, general health and joint or spine pathology. Quality of practice and play is always preferable to quantity. In golfers a faulty grip is frequently a fundamental flaw leading to overuse injury.

2. **Extrinsic** factors include the conditions a golfer is exposed to. These include equipment and coaching. If either is inappropriate injuries will result. All golf coaches should take golf biomechanics, prior injury and skill level into account. Practicing in the cold or when not warmed up will increase the risk of injury. Training error is a frequent culprit. Failure to warm up, hitting too many balls, hard surfaces, inappropriate equipment or an alteration in swing mechanics can all result in excessive loading and injury. This coupled with insufficient or inadequate recovery time, (golfers frequently play when injured) causes inflammation to tissues and injuries. A trained PGA golf professional will ensure that these common mistakes are avoided, however, most golfers are their own coaches and training errors mixed with other extrinsic and intrinsic issues result in injury.

Swing mechanic and alteration in technique on the quest for greater distance off the tee are probably the greatest causes of overuse injuries in the modern golfing population.

4.1 Physics of a Golf swings

The golf swing is a means of transferring energy to a stationary ball. The energy is transferred to the ball which then travels down the fairway.

The modern golf swing can be broken up into a number of components (**Figure 1**):

- Set-up
- Back swing
- Transition
- Down swing
- Impact
- Follow-through

The function of the golf swing is to apply the face of the golf club in a consistent, stable and square fashion allowing force to be impacted onto the golf ball from the club face producing linear momentum which is transmitted to the ball. The force applied to the ball is a function of the mass of the object (golf club) and its velocity

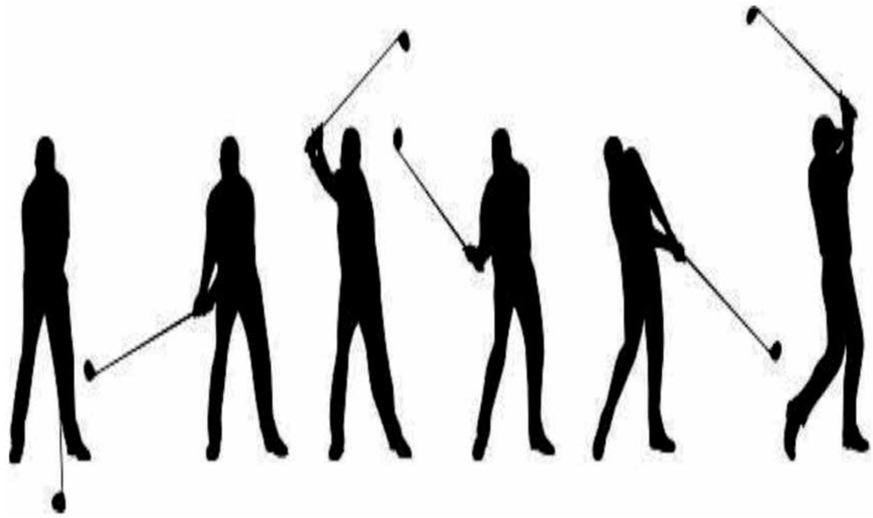

Figure 1.
The phases of a golf swing.

(mass × velocity = momentum). The rules of golf remove the first variable [the mass of the club), the second element has amused and exercised golf teachers and technologists for centuries.

At first look the conundrum of a golf swing appears simple. However, it involves a number of complex laws of physics:

1. Newtons 3rd Laws of Motion

2. Potential and Kinetic Energy Transfer

3. Circular motion and its constituent parts

4.1.1 Newton's 3rd law of motion

In the first instance energy is transmitted from the golf club to the golf ball based on Newton's 3rd Law of Motion i.e. The Law of Action and Reaction.

One object exerts a force on a second object, the second object exerts an equal opposite force on the first object. As club hits ball it applies force causing it to go in motion. In return, the ball also applies a reciprocal and equal force back to the club. This force slows your club down. The interplay of these actions and reactions result in a golf ball flying towards a target. Not all the energy is transmitted to the ball, with some being diverted up the club to the wrist. This is further increased by imperfect or missed shots.

During a golf swing energy is transferred between both potential and kinetic. The back swing creates kinetic energy which is converted into stored or potential energy at the top of the swing and then converted back to kinetic energy on the down swing. This happens because of the law of conservation of energy.

4.1.2 Energy transfer

Potential Energy (PE) is stored energy. It is energy an object possesses due to its position or the arrangements of its parts. This potential or stored energy is created at the top of the golf swing.

$$\text{PE} = \text{mass} \times \text{gravity} \times \text{height}. \quad (1)$$

Hence the higher the hands and the club head from the ball the greater the stored energy in the swing.

Kinetic Energy (KE) is energy that occurs when an object is in motion.

This is the energy created by the golf club descending towards the golf ball.

$$KE = 1/2 \text{mass} \times \text{velocity squared.} \qquad (2)$$

The Law of Conservation of Energy states that: Energy is neither created nor destroyed, it is conserved. Hence the back swing creates kinetic energy at the top of the swing. This is stored as Potential energy during the transition phase and then transferred back to kinetic energy on the down swing before it is transmitted to the golf ball at impact.

4.1.3 Circular motion of a golf swing

Unlike other ball hitting sports such as cricket, hurling, tennis and baseball the golf swing is a circular motion attacking a stationary object, the golf ball.

The circular motion is subject to other physic parameters:

- Double pendulum Effect
- Centipedal forces
- Torque

4.1.3.1 The double pendulum effect

A physical pendulum is a solid object that swings back and forth on a pivot under the influence of gravity. The golfer has 2 anchors, the shoulder and the wrists. In a golf swing, the connection between arms and club creates a double pendulum effect. The arms make up one pendulum that pivots around the shoulders, while the club makes a second pendulum that pivots around the wrists, which acts as the pivot. The two pendulums can swing independently but work together to make the swing feel effortless.

4.1.3.2 Centripetal force

Centripetal Force is a force that makes an object move in a curved motion, like a rollercoaster hugging the curve around a loop. The golf club swinging in an arc from the shoulder to the ball. The hands hold the club and prevent it flying off in a straight line, in a centrifugal fashion. In essence the golfer pulls the wrists and club handle inward while swinging the golf club and golf head outward.

The faster the club curves and the bigger the arc in a golf swing (radius) the greater the force of the club on the ball, and the farther the golfer should be able to hit the ball.

$$\text{Centripetal Force} = \text{mass} \times \text{velocity}^2/\text{radius.} \qquad (3)$$

$$\text{Centripetal Force} = \text{weight of club} \times \text{swing speed}^2/\text{swing arc.} \qquad (4)$$

The mass and velocity are also a function of gravity.

4.1.3.3 Torque

In physics Torque is a measure of the force that can cause an object to rotate about an axis. It is a rotating force in a circular motion as opposed to a simple force which causes an object to accelerate linearly. Torque is the force that causes an object to acquire angular acceleration in a golf swing.

Torque is the rotating force in circular motion as you swing back, coiling your body, and then start the downswing. This creates the stored or potential energy at the top of the swing. If you hold the club and prevent it releasing on the down swing you increase this stored energy. The hands and wrists are resisting the angular acceleration of the golf club. Increased torque and stored energy are ultimately released by the club face at the bottom of the swing.

$$\text{Torque} = \text{Force} \times \text{distance}. \tag{5}$$

These elements of classical physics have fascinated golfers who seek greater distance in their golf shots. The mass dynamics and weight of golf clubs and their structure are subject to the rules of golf (1) and can be considered a constant. Velocity is the variable element.

Golfers have pondered on this singular element for centuries. Swinging faster or manipulating the club in the down swing through releasing the club later will add greater speed. Similarly firing the right side of the body or manipulating the club face through the hands remain the other options available to the golfer seeking greater distance. Each augmentation compromises the leading wrist and are associated with injury.

5. Biomechanics of the modern golf swing

Modern biomechanics techniques have allowed a clear understanding of the physical requirements of the body for the execution of a golf swing. Simply put, a golf club made up of a stick or shaft attached to a heavier head hits a ball towards a target by swinging the stick.

The motion involves a complex manipulation of shaft and club by the golfer to promote maximum force on the ball in an effort to propel the ball towards a target. Once described by Winston Churchill as" a game whose aim is to hit a very small ball into an even smaller hole with weapons singularly ill-designed for the purpose".

The golf club exerts a force on the golf ball by creating a greater force on the down swing which is transferred to the ball. This force is a function on the mass of the club and the speed it is travelling at. This in turn is a function of the distance travelled to the ball and gravity. Extra speed can be generated by the double pendulum affect. Holding the wrist angle for a long as possible in the down swing increases stored energy by a concept referred to as lag. As the stored energy is released in the down swing at 30 degrees the club is released towards the ball greater speed is created. This results in a greater force being applied to the ball.

Newton's second law of motion, the acceleration of an object is dependent upon both force and mass. Thus, if the colliding objects have unequal mass, they will have unequal accelerations as a result of the contact force that results during the collision.

Newton's laws of motion are naturally applied to collisions between the golf club and the golf ball. In this collision both ball and club experience forces that are equal in magnitude and opposite in direction.

The force experienced by the club head is equal to the force experienced by the golf ball.

The forces upon the ball and club head are equal, but accelerations are unequal due to the size of the two objects at the moment of contact or collision. In simple terms club head and ball experience equal forces, yet the ball experiences a greater acceleration due to its smaller mass.

Golfers are well aware of this and refer to it as the "Smash Factor". This relates to the amount of energy transferred from the club head to the golf ball. The more efficiently energy is transferred the greater the acceleration. Smash Factor is ball speed divided by club speed.

The higher the smash factor the better the energy transfer. A golf swing of 100mph and a smash factor of 1.5 would create a ball speed of 150 mph. This can be affected by a number of other elements such as club lift and grip size, but ultimately the greater the club head speed the greater the Smash Factor and the further the ball travels. Hence for the same 100 mph club, a ball speed of 10mph speed difference will affect ball distance. A 10 mph in ball speed equates to a 20-yard increase in distance hitting a driver.

The upshot of Newton's laws of motion and the golf swing are simple. The greater the force applied to the smaller golf ball by the bigger golf club, the greater the acceleration, and the further a ball will travel. The acceleration of the club is produced by two pendulums working in concert i.e. the shoulder element and the wrist element.

6. Biomechanics of the leading wrist

The leading wrist is placed on the upper golf grip and the trailing wrist on the lower element. Both hands are joined together by either interlocking or overlapping the index finger of the leading and small fifth finger of the trailing hand.

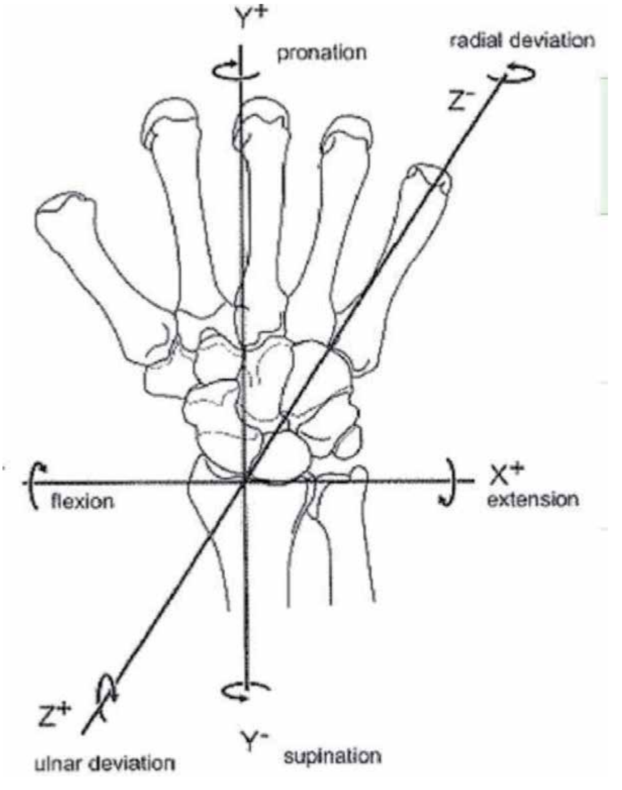

Figure 2.
Directions of leading wrist motion during a golf swing.

Figure 3.
Classic left-hand grip showing less than one and a half knuckles (left) and a strong left-hand grip showing 3 or more knuckles (right).

The leading wrist is placed in different anatomical positions to achieve a consistent contact on the golf ball. Each phase of the golf swing puts specific stresses and strains on the leading wrist and hand, which can result in different types of injuries [16–18].

There are 3 basic wrist motions during the golf swing. They are subtle and subject to significant variation [19] of motions from player to player (**Figure 2**).

- Ulnar/Radial Deviation
- Flexion/Extension
- Supination/Pronation

At address the leading wrist is positioned in an ulnar deviated flexed position. It is pronated in strong grips (showing 3 or more knuckles), supinated in weak grips (showing one or less knuckles), (**Figure 3**) Classical teaching advises a neutral grip showing 1.5 or 2 knuckles.

In the back swing the leading wrist travels into a radial deviated, flexed and pronated position.

In the down swing the leading wrist travels into an ulnar deviated, supinated and extended position.

7. Leading wrist ulnar/radial deviation in the golf swing

At address, the leading wrist is usually held in ulnar deviation of the order of 17%.

During the backswing, the left wrist transitions to a radial deviated position and then travels back to the ball transitioning again from radial to a predominant ulnar deviated position at impact (**Figure 4**).

Modern golf coaches often teach their pupils to hold the wrist in a radial deviated position for as long as possible on the down swing. This is referred to as a cocked position (**Figure 5**). When held in this position stored energy is increased. This cocked or radial deviated wrist position is created by maintaining an angle between the shaft and the left forearm in the downswing. The longer the wrists can maintain this angle, the greater the lag and resulting stored energy. This referred to “lag” as the club head is lagging behind the shaft caused by the wrist position, which is called wrist torque by golf teachers (**Figure 6**).

This manoeuvre is based on research which has shown that greater club head speed is achieved if an active wrist torque is applied to the club during the latter

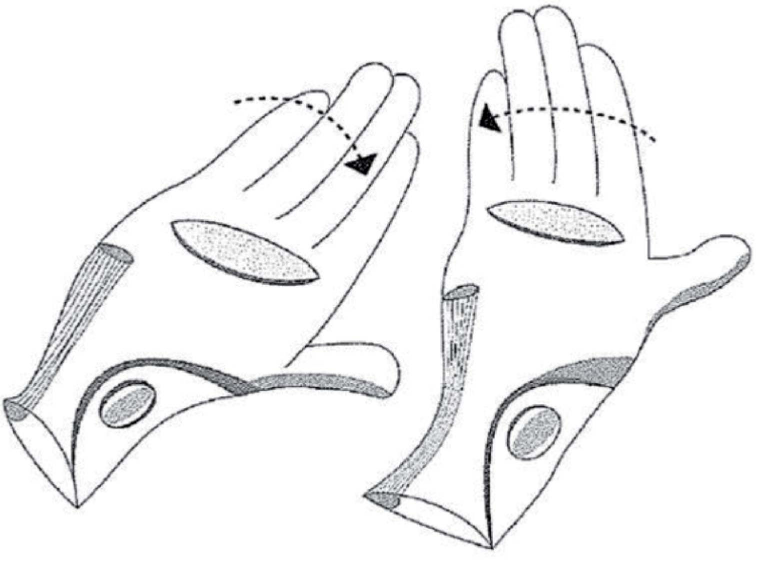

Figure 4.
Leading wrist ulnar deviation at address and impact (right) and radial deviation at the top of the back swing (left).

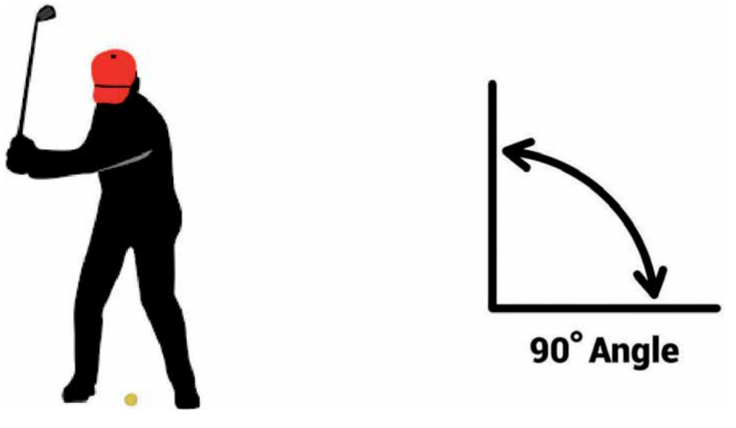

Figure 5.
The angle between the shoulder, wrist and club head is maintained close to a right angle in the down swing to 30 degrees below the horizontal line through the shoulder joint, at which point the hands are released.

Figure 6.
The leading wrist in a flexed and radial deviated position maintains the angle between club shaft and arm to the bottom of the down swing, resulting in the head of the club "lagging" behind the hands storing energy.

stages of the downswing [19]. To produce a club head speed of 100 miles per hour, the optimal timing of the activation of wrist torque occurs when the arm segment is at approximately 30° below the horizontal line through the shoulder joint [20].

Therefore, significant timing of the shot is required to manoeuvre in releasing club head back square to the ball. This requires a careful return of the leading wrist from radial to ulnar deviation prior to impact.

8. Leading wrist flexion/extension in the golf swing

Flexion/Extension motion of the leading wrist is a significantly individual watermark of every swing. Elite golfers also vary dramatically from player to player.

Classical golf swing teaching suggests that the wrist is placed in a neutral or slightly extended position at address (**Figure 7**).

At the top of the back swing it stays in a neutral flexion/extension pattern. This referred to as” square at the top”.

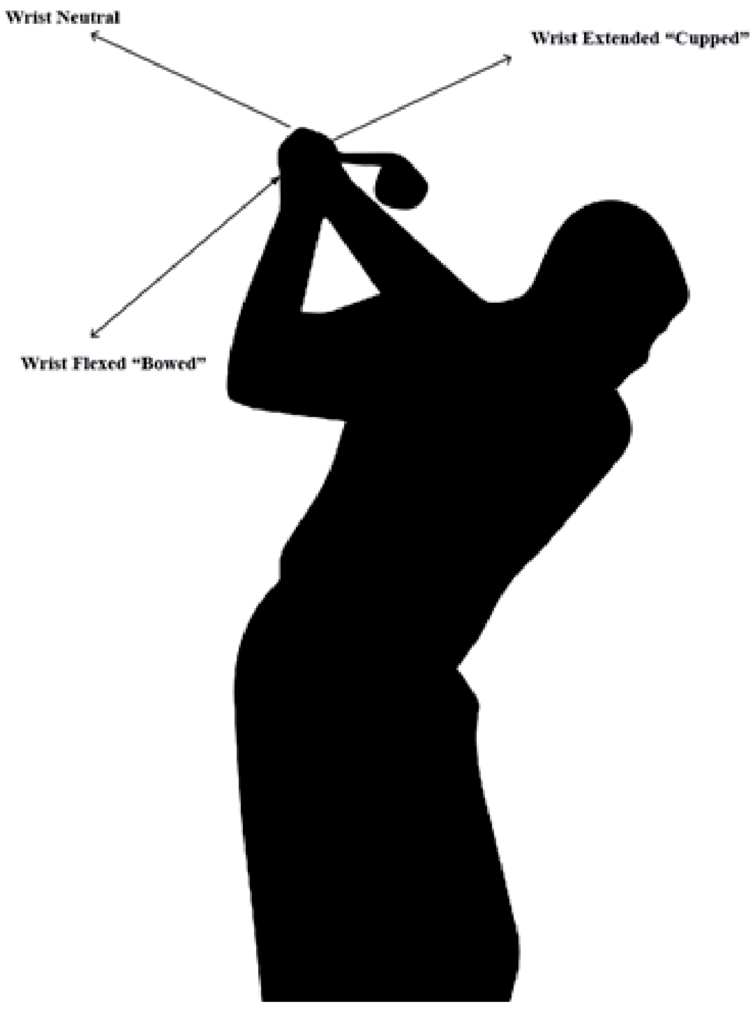

Figure 7.
Wrist positions at the top of the Back swing.

In classical teaching the leading wrist descends in the down swing to the ball in a flexed position in which it impacts the ball. Not everyone follows this teaching.

9. Figure leading wrist flexion on down swing and impact

Consistent players such as Jack Nicklaus was "square at the top" for most of his career. Ben Hogan placed his leading wrist in an extended or "cupped "position (**Figure 7**) at the top of his swing before transitioning to a flexed position at impact. This has been replicated by current touring pro Mathew Perry and is seen as a way of avoiding placing hook spin on the ball. Dustin Johnson is in a more extreme flexed or "bowed" position (**Figure 7**) at the top of the swing and maintains that position on the down swing using the large trunk muscles to return the club face square to the ball at impact. This move has been followed by many golfers looking for extra distance.

10. Leading wrist pronation/supination in the golf swing

Classical golf teaching used the wrist and hands to generate club head speed at impact. In the back swing the leading wrist pronated turning the back of the leading wrist and forearm to face towards the sky at the top of the backswing. At the top of the back swing the 1st row of carpal bones are held in a pronated position at the top of the swing. During this downswing phase the leading wrist is adjusting back towards a neutral position, with the 1st carpal row of bones traversing from a bowed, pronated position towards supination. The leading wrist rotates towards supination and continues in this motion through impact where the palm of the leading wrist motions to face towards the sky in the follow through phase.

At impact the club head makes contact with the ball and the leading wrist accelerates allowing the leading wrist to unhinge into further supination in a whip-like motion, the right hand frequently rolling over the left hand and wrist thus creating extra club head speed at impact. This move is referred to as "rolling the wrists" at impact.

These pronation and supination motions are not commonly seen in modern golfers. These "handsy" moves are considered to be inconsistent. They are regularly seen in good wind players who need to manipulate the face of the golf club in relation to changing wind directions. The majority of modern elite players and coaches tend to manipulate the radial, ulnar and flexion and extension motions.

11. Elite golfers at the top of the back swing

There are many versions of the wrist flexion/extension pattern in modern golf swings, ultimately returning the leading wrist to a flexed position at impact. Each technique creates greater swing speeds and allows individual players square the club face at impact. All place varying degrees of stress on the leading wrist. These can be summarised into 3 patterns employed by leading professional golfers [21]**.** All have one thing in common; a flexed wrist at square club face at impact, the body moving at speed providing the acceleration to square the club face.

11.1 Flex and maintain

John Rahm has a weaker grip or neutral grip at address showing 1 and ½ knuckles in his leading hand. He flexes his wrist at the top of the swing and maintains that flexed position on the down swing and rotates his body to square up the club face at impact.

11.2 Flex, flex and rotate

Dustin Johnson has a stronger grip at address showing 3 knuckles with his wrist held in flexion. At the top of the swing he further flexes his leading wrist. On the way down he turns his body aggressively to square up the club face at impact.

11.3 Extend and flex

Matt Wolff has a weak to neutral grip at address, extends his wrist at the top of the swing and with great skill and co-ordination rapidly converts his lead wrist to a flexed position on the down swing before he releases the club face into a square position at impact.

Bryson De Chambeau who is considered the longest hitter on the PGA tour has very specific statistics [22].

11.4 Flexion/extension

13 degree of flexion at address, 11 degrees of extension at the top of the swing and 20 degrees of flexion at impact.

11.5 Ulnar/radial deviation

20 degrees of ulnar deviation at address, 14 degrees of radial deviation at the top of the swing and 15 degrees of ulnar deviation at impact.

12. The effect of wrist manipulation on the medial aspect of the leading wrist

At impact the golf ball, club and ground collide resulting in a counter force that is transmitted up the shaft of the club to the wrist and hands which are on the golf club grip. The majority of golf injuries occur on the downswing and at impact [23].

The golf swing requires complex movement of many components of the body. The co-ordination of muscle sequencing is particularly important and is noted to be the most efficient in the elite golfer. The manipulation of the leading wrist has been a source of a crusade for many golfers as they seek the perfect golf swing. The leading wrist has the ability of storing the kinetic energy which is released at impact, thus resulting in greater power delivery to the ball and greater accuracy [20–24], but it comes at a cost.

With a late hit, skilful golfers apply torque to the leading wrist in an effort to store more energy prior to impact with the golf ball. This stored energy by holding the leading wrist in a forced flexed and ulnar deviated position throughout the first part of the down swing could be considered a compensatory methodology and an effort to compensate for faulty swing mechanics. This may be a purist view, however, the manipulation of the wrist to improve stored energy prior to impact places further extreme pressure onto the leading wrist and particularly the lateral aspect of the wrist. The rapid transitions from a radial deviated, flexed pronated position through a relatively neutral position at impact and onwards to a supinated and ulnar deviated position is the cause of trauma to this anatomical location.

Many skilled golfers manipulate the club face with the hand and wrists as the face of the club impacts with the golf ball. These subtle variations impart different spins onto the golf ball affecting its flight and trajectory as it seeks it target on the green. A "hold off "shot imparts a left to right spin on the ball in a right-handed golfer. This is achieved by holding the left wrist firm (holding it off) at impact, preventing the natural supination of the left wrist as it transitions to impact and the follow through phase of the swing. Resisting this natural movement places great stresses on the medial structures of the left wrist which are activated to resist this natural anatomical motion.

Golfers who have quiet hands and wrists during the golf swing rarely sustain wrist injuries. Wrist manipulation may be a trade off between distance and injury.

13. Anatomical site of injuries in elite and professional golfers

The anatomical site and specific location also varies between professional and elite golfers and their amateur counterparts. There are also gender differences. For professional male golfers, the most frequently injured site is the low back at 25% of injuries, with the left wrist accounting for 16% and the left shoulder accounting for 11%. Among female professionals, the most commonly injured site is the left wrist (in 31% of cases) and the low back in 22% of cases. In general terms, therefore, the leading wrist is the most commonly affected structure among professional and elite golfers with a combined incidence of 37%, the low back at 24%, the shoulder at 10%, the elbow at 7%, the knee at 7%, the ankle and foot at 5% and the neck at 3% [25].

14. Anatomical site of injuries for amateur golfers

In amateur golfers, the low back is the most commonly injured site with an incidence in males of 36%, the elbow causing injuries in 33% of cases, the wrist or hand 21% and the shoulder 11% with the knee accounting for only 9% of injuries. In female amateur golfers, the elbow is the most commonly injured anatomical site at 36% of all female injuries, the low back accounts for 27% of injuries, the shoulder 16% and the wrist and hand 15%, the knee accounting for only 11% of injuries. When combining the data, it suggests that the most commonly injured site for amateur golfers is the lumbar spine accounting for 35% of all injuries, whereas the wrist or hand is the most common location for elite or professional golf injuries.

15. Cause and pattern of injury in elite and amateur golfer

There is also a difference between amateur and professional golf injury aetiology. In amateur golfers, excessive play or practice, direct trauma from hitting the ground or an object during a golf swing are common causes. The most common cause, however, in amateur golfers, and particularly high handicap golfers, is injuries that result from poor swing mechanics [24–26]. Professional and elite golfers are particularly prone to overuse injuries due to repeated and repetitive swinging of a golf club. This can be further complicated by alteration in swing techniques. The changes and improvement in golf equipment, with lighter shafts and composite heads on drivers and fairway metals, have also contributed to increased swing speeds. This, in association with alteration in swing techniques, can make the elite golfer more prone to injuries. In simple terms, the sheer number of swings that an elite golfer takes every week is a multiple of that of an amateur golfer. It would not be uncommon for a professional golfer to hit two or three hundred golf balls on a daily basis. This is a combination of practice, warm up and almost daily playing schedule.

16. Upper limb injuries in a golfer

The upper limb is the most commonly injured anatomical site in elite golfers. An injury site can be devastating for the competitive amateur golfer, or the professional golfer, as it can result in time away from the game, as damage to shoulder, elbow or wrist makes coordinated swinging of a golf club difficult and occasionally impossible The majority of golf injuries are overuse injuries of the wrist flexor or extensor tendons. However, the reminder of the shoulder joint accounts for between 4% and 19% of all golf injuries with similar rates among the professional and amateur players. Elbow injuries account for 7% to 27% of all golf injuries. Amateur golfers frequently injure this structure with reports as high as 33% in comparison to professionals whose injury rate for the elbow is 7% injuries [25–28].

17. Shoulder injuries

The shoulder itself is made up of three bones, namely the humerus, the scapula and the clavicle. The rotator cuff is made up of four different muscles: the supraspinatus, infraspinatus, subscapularis and biceps muscles. Each muscle is intimately involved in the golf swing and is liable to injury. Outside of the rotator cuff, the strong deltoid muscle stabilises the shoulder and is an essential component in creating normal shoulder abduction during the golf swing. The pectoral muscles are also particularly involved in the golf swing in both the takeaway and downswing motion. The latissimus dorsi muscle is also a critical muscle for the initiation of the downswing. Each structure can be injured directly or in combination during the golf swing and this joint accounts for 10% of professional injuries and 12% of amateur golf-related injuries.

Elbow injuries are particularly common among amateur golfers where they account for a third of all injuries but less than 10% in the professional ranks. The elbow joint is a hinge joint formed between the humerus, the radius and the ulna. It can only be flexed and extended. During the golf swing it also pronates and supinates. Extensor and flexor tendons are inserted to the elbow. The extensor apparatus is located on the outside or lateral aspect of the elbow and the extensor tendon can frequently be injured. This injury is known as a tennis elbow but is in fact more common in the golfing population than its counterpart, the golfer's elbow. The flexor tendon is inserted into the inside or medial aspect of the elbow and inflammation of this area is referred to as a medial epicondylitis or Golfer's elbow. Unusually, a tennis elbow is more common than a golfer's elbow in the golfing population.

Other tendons can also be injured around the elbow and the triceps tendon can be injured directly due to trauma from poor impact with the ground or from overuse. In cases of chronic medial epicondylitis, the ulnar nerve can be compromised resulting in pins and needles into the 4th and 5th digit of the hand. In cases of poor playing technique, the supinator muscle can become inflamed. This lies just below the elbow joint. The radial nerve runs through this structure and if the muscle becomes hypertrophied or injured it can result in local entrapment of the radial nerve. This often results in sensory alteration in the 1st webspace of the hand and weakness in wrist extension. When the radial nerve and its branch (the posterior interosseous nerve) become involved the condition can mimic tennis elbow. In these instances, surgical release of the nerve is often required. This condition is often referred to as "resistant tennis elbow" as the symptoms mimic the classical tennis elbow which is inflammation of the extensor tendon.

18. Functional anatomy of the wrist joint

The bony wrist joint (**Figure 8**) is made up of the articulation of the distal radius and ulna bones with the carpal bones. The carpal bones are arranged in two rows, the 1st or proximal row and the second or distal row.

The proximal row comprises of the scaphoid, lunate triquetrum and trapezoid bones.

The second carpal row consists of the pisiform, trapezium capitate and hamate bones.

The first row of bones is a more mobile articulation in comparison to the second row which acts as one. The scaphoid communicates through both rows.

There are 3 axes of motion at the wrist joint; Flexion/Extension; Ulnar/Radial deviation; Pronation/Supination (see **Figure 2**). According to the "link" concept of wrist biomechanics a chain of communication exists between the radius, lunate and capitate bones, with the head of the capitate bone acting as the centre of rotation. The proximal row in the form of the lunate can act as an intercalated unit as it has no direct tendon attachment. The distal row of carpal bones act as a complete unit. The scaphoid bridges both rows. When the wrist is in ulnar deviation the scaphoid is pushed into extension, and radial deviation pushes it into flexion.

The bones are held together in a lattice of extrinsic and intrinsic wrist ligaments.

The extensor tendons at the level of the wrist are divided into six extensor compartments (**Figure 9**) that are designated by Roman numerals from lateral to medial:

i. Extensor pollicis brevis, abductor pollicis longus.

ii. Extensor carpi radialis longus, extensor carpi radialis brevis.

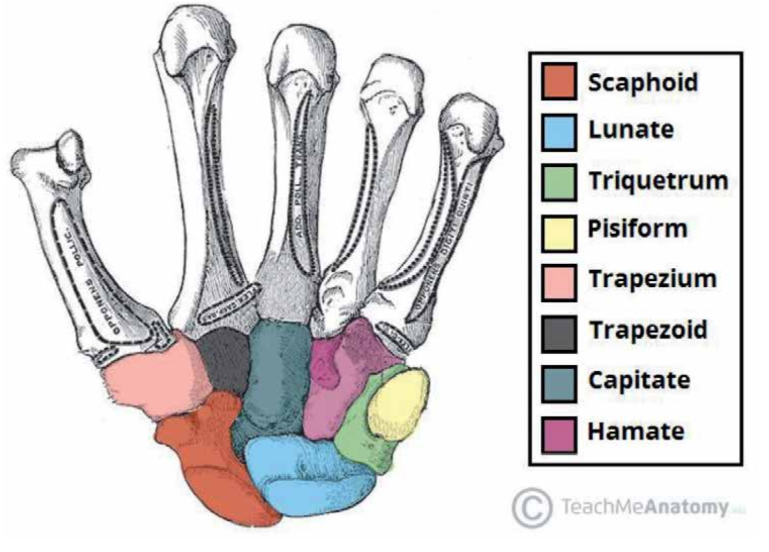

Figure 8.
Bony anatomy of the wrist, showing the 2 carpal rows.

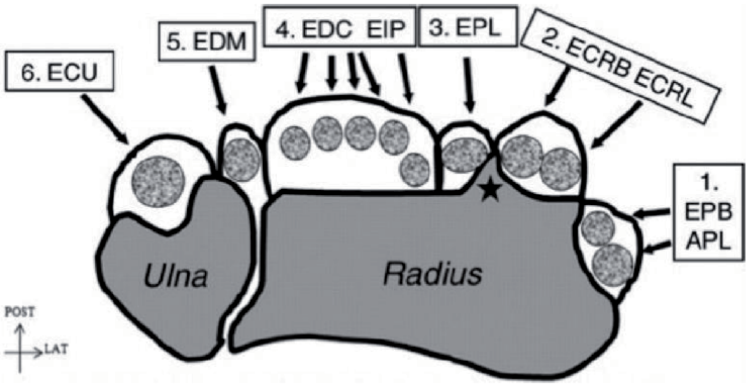

Figure 9.
The 6 extensor compartment of the wrist joint.

iii. Extensor pollicis longus.

iv. Extensor digitorum, extensor indicis

v. Extensor digiti minimi

vi. Extensor Carpi Ulnaris

The 6th compartment is the most compromised during the golf swing. The first extensor compartment is most affected in skiing, fishing and racket sports with a common occurrence of De Quervain's Tenosynovitis.

The flexor tendons of the wrist are divided into two main structures: 1) the flexor digitorum profundus (FDP) and the flexor digitorum superficialis (FDS) tendons.

FDP tendons help bend the index, middle, ring, and small fingers at the fingertip joint. FDS tendons help flexes the index, middle, ring, and small fingers at the middle finger joint. 9 of these flexor tendons travel into the wrist through the carpal tunnel. Each of the flexor tendons perform an important function in gripping the golf club in a consistent fashion to allow a natural swing of the club.

19. Wrist injuries in golf

Wrist injuries are common [25–27] and particularly prevalent in elite golfers [28, 64].

Golfers who sustain injuries to their wrist regularly fail to rest after practice sessions and do not allow adequate time for soft tissue recovery and adaptation after a heavy practice session. It is not uncommon for an elite golfer to hit balls every day. Enthusiastic amateurs can be seen hitting "buckets" of balls in an effort to groove a repetitive swing. A standard bucket of balls in a driving range contains 50 to 60 balls when a round of golf rarely exceeds 40 full shots. This simple training error often under pins wrist injuries.

These wrist injuries are often extended and exacerbated by "playing through the pain" which must always be discouraged. This behaviour is most prevalent in men who outweigh injuries in female golfers by 2 to 1 [12, 27]. This area is also more frequently affected in the professional ranks as the golf swing is a means of income, much in the same way as other manual occupations such as painters and decorators [29] suffer from overuse injuries to the upper limb (11). In a 30-person cohort 43%

of hairdressers reported overuse injury symptoms to hands and wrists form their work activity [30].

In golf it is almost impossible to consistently hit a golf ball with an injury to the wrist or hand which is the second most common site for golf injuries and a result of impacting the ball incorrectly due to poor swing mechanics [8–10].

Patterns of injury differ based on level of play and time spent playing or practicing golf. Among golf professionals, the hand/wrist is the most commonly injured upper extremity structure. The elbow is more commonly injured than the wrist in amateur golfers [31].

20. Common leading wrist pathologies in a golfing population

The medial aspect of the leading wrist in a golfer is particularly prone to injury due to the forces and stress applied to this location during the modern golf swing. The most common structure to be injured is the Extensor Carpi Ulnaris tendon and its tendon sheath and sub-sheath.

Extensor Carpi Ulnaris (ECU) tendinitis & tendinosis.
ECU tendon Subluxation.
Triangular Fibro-cartilage injury.
Hook of Hamate injury.
Guyon's Canal Syndrome.
Carpal Tunnel Syndrome.
Dupuytren's contracture.
Flexor Carpi Ulnaris tendon.
Proximal entrapment of the ulnar nerve.
Proximal entrapment of the median nerve.

20.1 Extensor carpi ulnaris tendon Injuries in golfers

The extensor carpi ulnaris tendon (**Figure 10**) originates from the lateral epicondyle of the humerus and the dorsal surface of the ulna, passes through the groove dorsally at the ulnar head within a fibro-osseous tunnel of extensor retinaculum in the 6th compartment (**Figure 11**). It has its own tendon sub-sheath for its stabilisation there and inserts on the base of the 5th metacarpal medially angled to its position in the groove of ulnar head. It acts to adduct (or ulnar deviate) and extend the wrist joint.

The Extensor Carpi Ulnaris tendon (ECU) is particularly vulnerable to injury in the golfing population because of the complex nature of the golf swing. During the golf swing the leading wrist goes through a complex motion involving ulnar and radial deviation i.e. extension and flexion and pronation and supination. These manoeuvres send forces through the wrist joint culminating with the impact of club on ball (**Figure 1**). The anatomical location of the ECU tendon in the 6th extensor compartment (**Figure 12**) held in a tendon sheath makes it liable to injury due to the excessive tensile loading and subsequent breakdown of the loaded tendon [32, 33]. ECU Tendinopathies, and tendon injuries account for significant time away from sport and lost time in practice and competition [9–11, 34, 35].

20.1.1 Types of ECU tendon injury

ECU tendon injuries come in many varieties and severities but can be simply divided in to 3 major categories of injury.

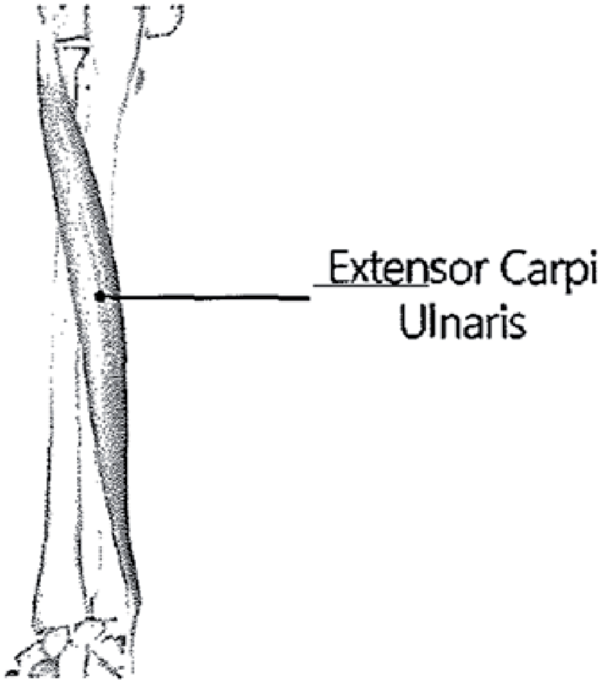

Figure 10.
ECU muscle and tendon origin and insertion.

Figure 11.
The double pendulum effect of the golf swing. The first pendulum is the arm acting around the pivot of the shoulder joint and torso. The second pendulum is the golf club acting around the wrist joint.

There are 3 types of injury that occur to the ECU tendon in the golfing population. Each is associated with overuse caused by excessive play and practice accompanied by poor swing technique [36].

1. ECU tenosynovitis or tendinitis

2. ECU Tendinosis

3. ECU Subluxation, (of which there are 3 varieties)

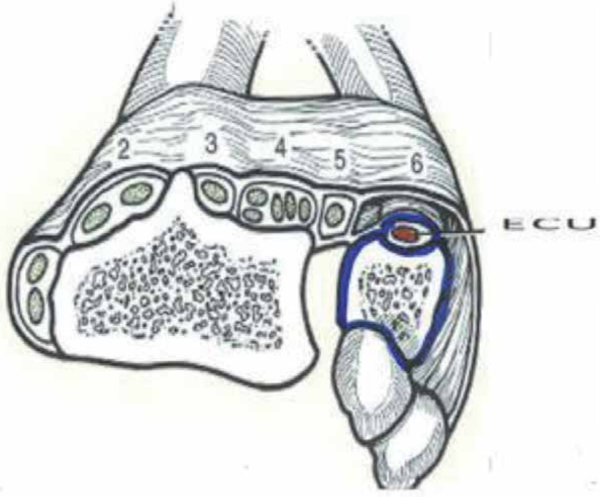

Figure 12.
ECU tendon, tendon sheath and sub sheath in the 6th extensor compartment of the wrist.

Injury to the ECU tendon in the leading wrist of a golfer is common due to the forceful return of the ball as the leading wrist travels from a radial deviated position at the top of the backswing to an ulnar deviated position at impact with the second carpal row transitioning into a supinate position. Injury and subluxation of the ECU tendon are exacerbated by ulnar deviation and supination [37], which is the classical position of the leading wrist at impact during a golf swing. Hence the frequency of this injury in golfers.

20.1.1.1 ECU tendinopathy

Tendinopathy or tendinosis refers to the breakdown of collagen in a tendon. Tendinopathy is often the long consequence of long-term inflammation caused by tendinitis. This causes burning pain in addition to reduced flexibility and range of motion. The collagen loss being a function of tenocyte malfunction secondary to chronic and reoccurring inflammation and injury. ECU tendinopathy occurs over time due to repetitive insults. The Tendinopathy is a pathological adaptive response resulting in degeneration due to the tendon's collagen loss in response to chronic overuse. Loss of function as well as pain on activity are cardinal complaints.

20.1.1.2 ECU tendinitis

Tendinitis is the inflammation of the tendon and results from micro-tears that happen when the musculotendinous unit is acutely overloaded with a tensile force that is too heavy and/or too sudden. ECU tenosynovitis can occur when the extensor retinaculum tears. It can result in mechanical friction between the ECU tendon and the ulnar groove [36, 37]. It usually starts as tendon irritation manifesting as pain and can progress to friction between the tendon and the ulnar grove. In the golf swing the ECU is irritated by the motion to and from ulnar and radial deviation with the wrist in a supinated position. Symptoms include wrist pain and loss of grip strength.

20.1.1.3 ECU tendon subluxation

If the tendon sheath and sub sheath rupture or stretch, the ECU tendon can then migrate to the medial or ulnar side of the wrist. This is caused by a rupture on the

Figure 13.
Axial MR and graphic image of split ECU tendon tear with partial rupture of sub-sheath with medial subluxation of the tendon.

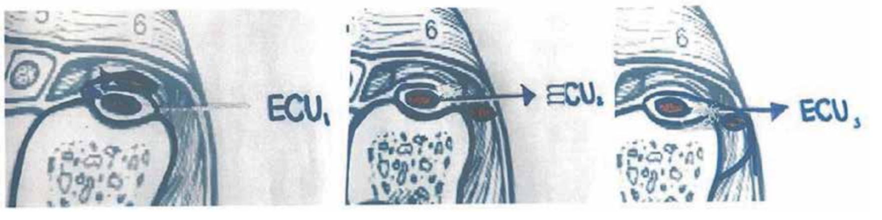

Figure 14.
The 3 types of ECU sub sheath injury resulting in tendon subluxation.

Figure 15.
Coronal MR image showing ECU tear and tenosynovitis.

ulnar or radial side of the tendon sub-sheath, or if the sub-sheath is stretched due to stripping of the periosteum (**Figure 13**). Each type results in subluxation and relocation producing a snapping sensation at the wrist during the golf swing. There are 3 types of ECU tendon sub-sheath injury.

Type 1 (**Figure 14**) rupture occurs on the lateral side of the sub sheath. The tendon subluxes through the radial side of the sheath and returns to rest on the ulnar grove on top of the remaining sheath.

Type 2 (**Figure 14**) rupture occurs on the medial side resulting in a tendon subluxing in an ulnar direction before returning to the ulnar groove without resting on top of the sheath.

Type3 (**Figure 14**) subluxation occurs if the ECU sheath does not rupture but the force causes ulnar periosteum stripping: The ECU sheath pulls the periosteum off the ulna on the ulnar side and forms a false pouch into which the tendon dislocates before relocating back onto the ulnar groove (**Figure 15**).

21. Differential diagnosis of ECU tendon injury in a golfing population

Injury to the ECU tendon is a challenging diagnosis and great care is needed in confirming the pathology. This is in part due to the symptomatology and presentation of injury with players reporting pain on the ulnar aspect of the wrist and hand accompanied by a loss of dexterity and occasionally sensory alteration affecting the fingers. Other conditions to consider in the differential diagnosis include:

- Triangular Fibro-cartilage injury
- Hook of Hamate injury
- Guyon's Canal Syndrome
- Carpal Tunnel Syndrome

21.1 Diagnosis

The diagnosis of ECU tendon pathology in a golfer requires a high index of suspicion as many patients battle on through the pain thereby worsening the pathology. Excluding the other common injuries can be achieved by a combination of careful history, clinical examination and the use of special tests such as Electrodiagnostic Medicine and radiology.

Dynamic ultrasound is very useful in diagnosing and differentiating the type of tendon pathology. It is the ideal tool to confirm a subduing tendon as it observes the subluxation during ulnar and radial deviation and in flexion and extension motion [38]. The direction of subluxation and the type of sub-sheath injury being confirmed by dynamic imaging. In cases of significant subluxation in professional golfers, surgery is often warranted to repair ECU and its supporting structures.

21.2 Treatment

Treatment for these varieties of ECU tendon injury should initially follow the normal treatment for tendinitis such as rest NSAID medication and splinting. Deep Oscillation Therapy has also been shown to be a promising treatment in swelling and symptom reduction] [39]. Ultrasound guided injections may also be required in resistant cases. In cases of tendinosis a similar approach is made with the addition of Platelet-Rich Plasma (PRP) injections in resistant cases. This is a minimally invasive surgical alternative that uses components from a patient's own blood to regrow tissue and relieve pain and promotes tendon regeneration by reducing inflammation and promoting the expression of anabolic genes and proteins [40].

Rest and splinting are the cornerstone for treating a subluxing ECU tendon, with regular revaluations with Ultrasound. If the subluxing ECU tendon fails to respond to conservative therapy, surgical reconstruction of the roof of the 6th dorsal extensor compartment using a portion of the flexor carpi ulnaris is performed [41]. Type I subluxation frequently requires surgery.

Return to play will require appropriate alteration in golf grip and swing biomechanics. Therefore, the return to play protocol for this injury in the golfing population should always include an assessment from a registered golf professional. In some instances, customised splinting of the wrist will prevent reoccurrence and allow a golfer return to a bespoke practice regimen. The message of qualitative rather than quantitative practice should be reinforced to avoid a training error reoccurrence, with 30–40 balls a good rule of thumb per practice session.

21.3 Conclusion

Wrist injuries in golf are common and significantly interfere with a player's ability to play and enjoy this common sporting pursuit. The ECU tendon is a frequent cause of wrist pain in the golfer. The sports medicine physician should have a high index of suspicion when dealing with this patient population. A combination of detailed history of injury and golf activity coupled with ultrasound, radiology and electrophysiological evaluation will result in a high diagnostic yield. Treatment should encompass alteration and improvement in golf swing and grip biomechanics as well as any practice or training errors.

22. Other common leading wrist pathologies in a golfing population

22.1 The triangular fibrocartilage injury of the wrist

The triangular fibrocartilage complex (TFCC) (**Figure 16**) is a load-bearing structure between the lunate, triquetrum, and ulnar head. It is a hammock-like structure made up of cartilage and ligaments. It stabilises the bones in the wrist, acts as a shock absorber and enables smooth movements. Forced ulnar deviation and positive ulnar variation are associated with injuries to the TFCC. A "weak" golf grip and swing biomechanics abnormalities makes injury to this structure more common.

The TFCC complex is prone to degeneration and wear-and-tear injuries. Injury occurs when compressive loads are placed on the TFCC during marked ulnar deviation. This occurs in the golf swing when the radial deviation of the wrist at the top

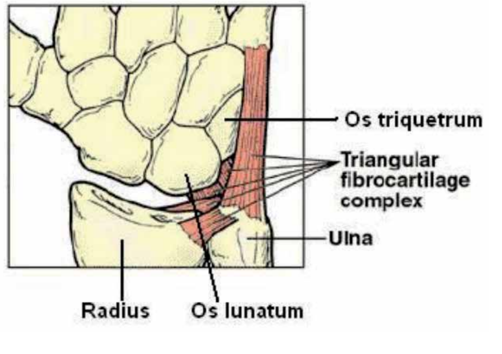

Figure 16.
Triangular fibrocartilage (TFCC).

of the back swing converts into ulnar deviation under significant force at impact. The triangular fibrocartilage disc attachment on the radial side is to hyaline cartilage. This makes the area vulnerable to injury as it is weaker when compared to the ulnar side whose attachment is bony.

Injury to the TFCC can lead to pain, weakness and instability. Patients with TFCC injury will present with ulnar-sided wrist pain that may present with clicking or point tenderness between the pisiform and the ulnar head.

The TFCC can be strained or torn from over-swinging or from "hitting down on the ball". Hitting out of heavy rough or on hard practice matts are also extrinsic culprits in the development of this injury in the golfing population.

Diagnosis is confirmed by assessment of the sixth extensor compartment. At this location, the TFCC is examined in combination with the ECU tendon. The ECU relies on the TFCC for movement and hence both structures can be injured in combination.

Radiology may reveal avulsion of ulnar styloid, and ulnar variance in cases of the TFCC injury. High-resolution dynamic ultrasound (US) has emerged as a useful and valid tool for the diagnosis of this disorders [36–38].

22.2 Hook of the hamate

The hamate bone (**Figure 17**) is one of the largest carpal bones and is located on the ulnar side of the palm of the hand and forms part of the distal carpal row. It has a protrusion called the "hook of hamate" which with the pisiform bones form the bony boundaries of Guyon's Canal through which the ulnar nerve enters the wrist joint. Hook fractures can occur from a direct injury to the bone or from an indirect blow that occurs most commonly in sports [42].

In golf, most hook of hamate fractures occur because of the position of the golf club resting on the hook when hitting "down" on the ball, when it is buried in rough or embedded in a divot. These injuries are also common when hitting buckets of balls from a mat at the driving range. Many of the older ranges are built on concrete

Figure 17.
Hook of the hamate bone.

and injuries occur when the club head stops abruptly on the matt covering the concrete. The force of the impact is conducted through the club shaft and grip into the base of the hand and hamate bone, resulting in injury. That force is transmitted directly to the wrist and can cause a fracture of the hook of the hamate. These injuries occur more commonly in the following wrist [right hand in a right-handed golfer]. While fractures are rare and underreported, they are also frequently misdiagnosed as the initial trauma may seem trivial and present with a working diagnosis of a wrist sprain. Palpation of the hamate with or without ulnar nerve symptoms are cardinal findings. Plain radiology will confirm the diagnosis and conservative treatment such as rest and splinting usually resolves the problem.

22.3 Carpal tunnel syndrome [CTS]

Carpal Tunnel Syndrome (**Figure 18**) is the entrapment of the median nerve and repetitive use of the hands and wrists seen in golf contribute to the development of CTS. Repetitive activity such as golf swinging and practicing can result in flexor tenosynovitis as one or more of the 9 flexor tendons that travel through the Carpal Tunnel in the company of the median nerve become inflamed. Inflammation in the affected tendons in the wrist result in swelling of the sheath. This fluid will compromise the function of the nerve resulting in the symptoms of distal median neuropathy.

Golfers can be difficult to convince that the tingling fingers, numb hands or aching thumb or wrist pain is a result of Carpal Tunnel Syndrome. CTS is considered a disorder that only affects those who do intense repetitive activities all day long at work [43, 44], such as block laying, hairdressing [26] or computer keyboard work. However, in modern society golf driving ranges and facilities are readily available and frequently recreational golfers work harder on their golf than many other vocational pursuits.

Sports, pastimes and hobbies can play a major role in contributing to this repetitive strain induced hand and wrist condition. The repetitive activity causes inflammation to some of the 9 flexor tendons that travel through the Carpal Tunnel. This inflammation results in swelling which ultimately affects the function of the median nerve. CTS diagnosis is made by a combination of electrodiagnostic nerve conduction studies and ultrasound examinations. Treatment of this common condition which affects between 5% and 21% of the population [43–49] involves

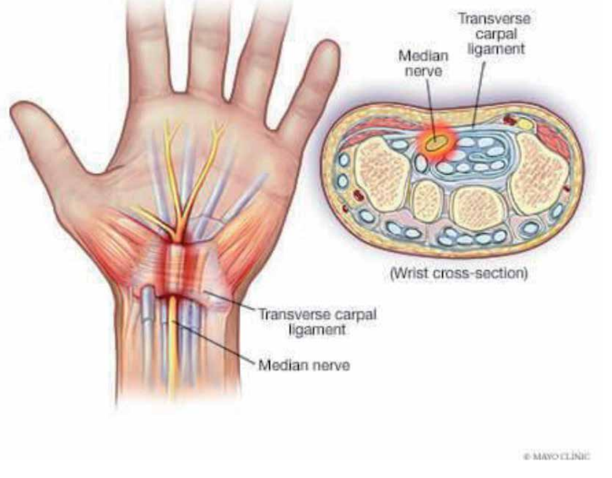

Figure 18.
Carpal tunnel syndrome.

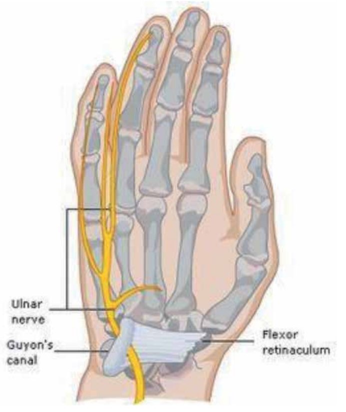

Figure 19.
Guyon's canal syndrome.

a combination of treatments including splinting the wrist, injection therapy and surgery. In the golfer, correction of golf biomechanics and golf club customization are helpful in preventing reoccurrence.

22.4 Guyon's canal syndrome

Guyon's canal syndrome (**Figure 19**) is a condition where there is compression and irritation of the ulnar nerve at the wrist. The ulnar nerve is responsible for strength and sensation on the little finger's side of the fourth finger and the entire fifth finger. Golfers with this condition may present with pain at the base of the wrist, loss of finger function and grip pressure as well as sensory alteration in the 4th and 5th fingers.

The hand may become clumsy when the muscles controlled by the ulnar nerve become weak. Weakness can affect the small muscles in the palm of the hand and the muscle that pulls the thumb into the palm.

Golfers are prone to irritation at Guyon's canal from local trauma to the nerve associated with an improper golf grip and trauma from the butt of the golf club impacting at the base of the wrist [50].

Hard playing surfaces and hitting down on the ball are risk factors.

Diagnosis is made by Electrodiagnostic testing of the distal ulnar nerve. Ultrasound is also used to out rule other space occupying lesions such as a ganglion cyst or schwannoma.

This syndrome is much less common than carpal tunnel syndrome (CTS), yet both conditions can occur at the same time. The numbness by Guyon's syndrome usually spares the thumb, index and long fingers.

23. Less common wrist related pathologies in a golfing population

23.1 Dupuytren's contracture

Dupuytren contracture (**Figure 20b**) is a benign, myeloproliferative progressive disease of the palmar fascia which results in shortening, thickening, and fibrosis of the fascia and aponeurosis of the palm. It results in nodular formation on the palmar fascia which creates fibrosis resulting in one or more fingers become permanently bent in a flexed position. Dupuytrens contracture is caused by progressive

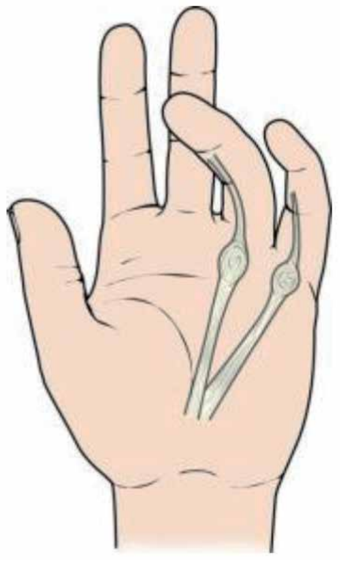

Figure 20.
Dupuytren's contracture caused by shortening, thickening, and fibrosis of the fascia and aponeurosis of the palm, results in nodular formation and a flexion deformity at the 4th and 5th digits, making a consistent grip of a golf club difficult.

thickening and shorting of the palmar fascia. This occurs due to slowly progressing fibrosis in the fascia that results in a flexion deformity at slowly the metacarpophalangeal (MCP) and proximal interphalangeal (PIP) joints usually affecting the 4th and 5th digits. The disease begins in the palm as painless nodules that form along longitudinal lines of tension. The nodules form cords that produce contracture deformities within fascial bands and tissues of the hand.

The disorder has varying pattern of genetic predisposition across different regions and populations and is also known as the Viking disease, and Celtic hand, with 30% of the over 60-year-old male Norwegian population and 20% of a similar British population suffering from this condition [51].

It is expressed in an autosomal dominant fashion. This *condition* is *most* commonly seen in *populations* of *Northern European/Scandinavian descent* [52]**.** It is *relatively uncommon* in *Southern European* and *South American populations*. *Males* are *affected* by a *2:1 ratio compared* to *women*.

The condition is associated with diabetes, seizure disorders, smoking, alcoholism, HIV, and vascular disease Ectopic manifestations beyond the hand can be seen in Ledderhose disease of the plantar fascia Peyronie disease (Dartos fascia of the penis), and Garrod disease (dorsal knuckle pads) [51–53].

Numerous authors going back as far as the 17th century have noted the association between traumatic events and the appearance of Dupuytren's contracture. Initially by Plater in 1614, Goyrand in1835 and, Guillaume. Dupuytren, a French Surgeon in 1833 who the condition is named after [53–56].

Golf has never specifically been cited as a caused of the condition but is a common disability encountered in the older golfer population. The disability causes technical issues gripping and swinging a golf club due to its anatomical location at the base of the wrist and the role of the 4th and 5th digit in gripping a club. Fatigue and hand pain has been reported in elite golfers with this condition and an inability to grip the club consistently.

In a 2017 survey of 504 Dupuytren's sufferers, the Dupuytren's society reported a significant proportion described difficulty golfing due to the pathology. In this observational study 8% of sufferers without a contracture reported a difficulty, 11% of single hand contracture and 23% of bilateral contracture suffers reported disfunction while golfing [57].

Up to one-fifth of patients seeking treatment for primary Dupuytren's contracture were reported to suffer from an injury-induced Dupuytren's contracture. It was noted that the injury to the wrist and hand seems to trigger the development of less progressive form Dupuytren's contracture in younger age group [58].

In diagnosing Dupuytren Contracture the clinician needs to distinguish the condition from other diseases of the hand including stenosing flexor tenosynovitis, ganglion cysts, ECU tendon subluxation, Guyon's Canal Syndrome and soft tissue masses. Diabetes, seizure disorders, smoking, alcoholism, HIV, and vascular disease should be considered during a careful history due their association with this condition.

Clinically the condition usually progresses at a slow rate over the course of several years and individuals may not be aware of the condition until it starts to cause functional disability. Pits and grooves in the palm of the hand are an early sign followed by the development of nodules in the medial palm. These nodules are often painless. Pain may be present distally at the knuckles pads of the proximal interphalangeal (PIP) as contracture evolve. The disorder is not always progressive and in at least 50–70% of patients, it may stabilise or even regress.

Investigations include radiology, which is usually normal and serology to out-rule metabolic or infective pathologies which are associated such as Diabetes Mellitus, Alcoholism and HIV infection, if there is a clinical suspicion.

Ultrasound [38] is the diagnostic tool with the highest yield as it confirms the presence of thickening of the palmar fascia and nodule formation.

Treatment includes physical therapy during the early stage of the disease. Some patients may also benefit from a brace to stretch the digits and maintaining range of motion of the fingers is necessary to prevent adhesions. This is particularly important in the golfing population. Corticosteroid injections may be beneficial and should be performed using Ultrasound guidance. Needle aponeurotomy is typically reserved for mild contractures. Collagenase injection which is a relatively new, minimally invasive treatment derived from Clostridium histolyticum has shown good initial results. The treatment is not available in all jurisdictions and should only be performed by a hand surgeon who can deal with any potential side effects of this treatment. Surgical fasciectomy is reserved for those cases who have failed conservative therapy and have a persisting disability.

A significant proportion of older golfers suffer from this disability that causes pain, discomfort and impairs the player's ability to consistently grip a golf club, and regularly interferes with the enjoyment of the game. Golf due to trauma may provoke the injury and once present exacerbates the condition. Early identification, finger stretching, as well as the use of topical anti-inflammatory medication assist in reducing symptoms in golfers with mild or non- progressive disease.

Golfers frequently continue to play with this condition. In these instances, the Dupuytren's sufferer should undergo a careful assessment of equipment. Golf shaft weight and grips should be reviewed by a PGA golf professional. In particular, correct or augmented golf grips can facilitate safe and enjoyable golf for the Celtic Hand golfer. Thickening grips can help mitigate overactive hands through the hitting zone thus reducing stress on the palmar aponeurosis. Golf grips come in 4 basic diameters and can be refined by a golf professional by the addition of wraps under the grip, further customising the all-important handle of the golf club. Larger grips also improve shock absorption and reduce transition of force to an already compromised palmar fascia. Small grips result in an increase in grip pressure and a propensity to grip the club in the palm. Holding the club too high across the palm increases the risk of hand injury or the exacerbation of an existing condition. The golfer should ensure his grip is biomechanically correct and the club is held in the fingers rather than the palm of the hand. This can be achieved by regripping the club in the last three fingers of the leading hand at address, prior to swinging. This helps to stabilises the club at impact and limits the stress on the palm of the hand. These small manageable changes will contribute to lessening the affect that this condition has on recreational and elite golfers.

24. Unusual causes of leading medial wrist injuries in golfers

Rare causes of leading wrist injury in golfers include damage to the Flexor Carpi Ulnaris tendon and proximal entrapment of the ulnar and median nerves, these are rare in golf but are commonly encountered in the general sporting population and among gym users (**Figure 21**).

The Flexor Carpi Ulnaris (FCU) muscle has its origin at the medial epicondyle and it is inserted on the medial side of the wrist into the pisiform, hamate and the base of the 5th metacarpal bone. 5th carpal by a tendinous attachment. The FCU acts as a flexor and ulnar deviator of the wrist. Injury therefore can occur at impact with the ball during the golf swing as the wrist converts into a flexed and ulnar deviated position at impact. In cases of acute trauma, the injury is usually located distally at the level of the pisiform bone insertion. In cases of overuse injuries, the injury is usually proximal to the wrist at the level of the musculotendinous junction. Diagnosis is confirmed by careful palpation of the full length of the tendon. Pain is exacerbated by resisted wrist flexion and ulnar deviation. Ultrasound of the full length of the nerve confirms the diagnosis. The FCU tendon can be also compromised in injuries to the hook pf the hamate bone.

The ulnar nerve can be compromised at the elbow in cases of medial epicondylitis or "golfers elbow". The ulnar nerve travels through the cubital tunnel prior to entering the ulnar groove as it travels caudally. The cubital tunnel is formed by bone, ligament and muscle.

The tunnel's ceiling is formed by the cubital retinaculum, a ligament spanning from the medial epicondyle to the olecranon process that is continuous with the fascia connecting the humeral and ulnar heads of the flexor carpi ulnaris (FCU).

Figure 21.
Proximal entrapment of the median nerve by the pronator Teres muscle.

Injury to these structures or to the flexor tendon insertion at the medial epicondyle can compromise the ulnar nerve resulting in a local irritation or compression of the ulnar nerve, known as Cubital Tunnel Syndrome. Golfers elbow is associated with golf and racket sports. Repetitive activity and holding the elbow in flexion at impact can be aetiological elements in the development of the tendon injury which may be a prequel to the local ulnar nerve irritation. The increased in elbow flexion causes the arcuate ligament to tighten, the FCU to tighten and the ulnar collateral ligament to buckle and encroach into the tunnel compromising the ulnar nerve [59, 60].

This can cause numbness and tingling in the hand and/or ring and little finger, especially when the elbow is bent. Occasionally a player will describe hand pain in the hypothermal eminence when swinging a golf club and weakness when gripping a club and a lack of consistency in golf grip due to muscle weakness in the intrinsic muscles of the hand which receive their innervation from the ulnar nerve.

Diagnosis is made by identifying the clinical signs of an ulnar neuropathy. Electrodiagnostic evaluation with Nerve Conduction Studies and needle EMG. Conservative treatment includes rest and Ultrasound guided injection therapy at the cubital tunnel. In chronic cases surgical release may be required.

Distal median neuropathies can also occur in the golfing population. It is well recognised in racket players [61]. This is referred to as pronator syndrome. The nerve can be compromised at 4 sites in the flexor aspect of the forearm.

The Ligament of Struthers is present in up to 2.7% of the population [62, 63]. Entrapment of the nerve at this site is exacerbated by elbow flexion and extension [63] which is a common manoeuvre in the leading arm of a golfer.

The median nerve travels through the 2 heads of the Pronator muscle just below the elbow joint, and can be compromised at this site. The nerve can also be entrapped by thickening of the bicipital aponeurosis, and finally by the flexor digitorum superficialis. These flexor and pronator muscles are frequently hypertrophied from overuse activities such as repeated golf swinging and practice, particularly in golfers with strong grips (pronated flexed wrists). With this grip the pronator testes muscle has to fire quickly at impact in an effort to square up the club face. The median nerve becoming entrapped at this proximal site. Symptoms are often vague and can suggest a mixed pattern of median and ulnar nerve symptoms. Diagnosis involves electrodiagnostic assessment. Treatment requires rest and alteration in technique and practice protocols. In resistant cases surgery is indicated.

25. Conclusion

Golf is a centuries old game whose popularity as a sport and entertainment grows exponentially internationally year on year. Increased golf facilities and accessibility have resulted in a world-wide explosion of golf participation. With this, golf related injuries have increased dramatically [64] as experienced and novice golfers alike attempt to imitate the extraordinary feats of distance power and accuracy exhibited by elite golfers who are beamed to out TVs week on week. These players now include 9 million participating at ranges and using indoor simulators [65] who hit “buckets “of balls in a finite period of time without the natural break between shots which occurs in a conventional game of golf. Golf teaching has mirrored these changes as golf is no longer considered a game but a sport, where improvement in performance is an essential component rather than the simple pleasures of walking in the countryside while hitting a ball towards a target in the fresh air. These natural changes in society to become better at this activity have spawned a multitude of teaching facilities in the real world and the cyber world where golfers strive for greater distance and accuracy through strength and conditioning and biomechanics.

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Humans are not machines and stress placed on human tissue frequently results in trauma and injury. In the case of the golf swing, sports science and biomechanical advances have improved the performance of golf with the side effect of increased injury, the leading wrist being particularly vulnerable to injury and pathology. The ECU tendon is the most commonly injured leading wrist structure particularly among elite golfers [36, 64]. The sports medicine physician should be aware of this potential and address swing mechanics and the risk reward nature of un-natural motions to the leading wrist in a golfing population to avoid chronic injury, time away from the game [66] and long-term disability.

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Chapter 4

Exercise Prescriptions for Co-Morbid Conditions

Rabbanie Tariq Wani and Hibba Dar

Abstract

Chronic diseases have a high prevalence with increased life expectancy and the only way we can improve the Quality of life with chronic diseases is exercise. Exercise has been recommended as an advice since long time but adherence of clients to such advices have been found variable and not beneficial. Therefore, exercise prescriptions in such situations becvome must and should be issued lifestyle medicine physicians, Exercise physiologists and health coaches. Since exercise has been quantified in such prescriptions it would certainly help to alleviate co morbid conditions.

Keywords: exercise, lifestyle, prescriptions, co morbid, Fitness

1. Introduction

This chapter will contain the relevant information about co morbid conditions and the exercise prescription (Ex Rx) guidelines, recommendations for individuals with metabolic and cardiovascular disease (CVD) risk factors. The Exercise Treatment guidelines and recommendations are prescribed using the *FITT* principle of Ex Rx. There is a knowledge gap in relation to volume and progression for the chronic diseases and health conditions which will be addressed in this chapter. In these diseases, the recommendations provided for healthy populations should be followed with clinical expertise for the lifestyle diseases. The chapter will include all of these while focusing on new tools available for same.

2. Diabetes mellitus

Diabetes mellitus (DM)- a metabolic diseases involves an elevated blood glucose concentration (*i.e.*, hyperglycemia) as a result of faults in insulin secretion and/or an inability to consume insulin. There are four types of diabetes, based on etiologic origin: Type 1 diabetes mellitus (T1DM), Type 2 diabetes mellitus (T2DM), gestational (*i.e.*, diagnosed during pregnancy), and other specific origins (*i.e.*, genetic defects and drug induced); however, most patients have T2DM (90% of all cases) followed by T1DM (5–10% of all cases). The type of diabetes diagnosed depends on the circumstances present at the time of diagnosis, with some people not exactly fitting into a clear single category (such as having T1DM or T2DM), and clinical presentation and disease progression may vary considerably vary between the various types of diabetes [1].

2.1 Exercise testing

Special considerations in patients suffering from DM for exercise testing needs to be undertaken are:

When initiating an exercise program of light-to-moderate intensity, exercise testing is usually not essential for people with DM or prediabetes who are asymptomatic for CVD and low risk (<10% risk of cardiac event over a 10-yr period using the Framingham risk calculator) [2].

Electrocardiogram (ECG) stress testing may be considered for individuals with DM, especially those who have been following sedentary lifestyle and desires to participate in vigorous intensity activities. If positive or nonspecific ECG changes in response to exercise are discovered or nonspecific ST and T wave changes at rest are observed, the client should undergo follow-up diagnostic testing. Thus, the cost-effectiveness and diagnostic value of such intensive investigations remains in question. Silent ischemia in patients with DM often follows the iceberg phenomenon; therefore, annual CVD risk factor assessments should be conducted [2].

2.2 Exercise prescription

The FITT principle of Exercise prescription (**Table 1**) for healthy adults as well individuals with DM will be similar. Involvement in an exercise program is beneficial to individuals with T1DM and T2DM. Maximizing the cardiovascular benefits as a result of exercise is a pivotal for both types of diabetes. In nondiabetic people, exercise enhances sensitivity to insulin in a gradual dose-dependent manner [3]; thus, cellular uptake of glucose that facilitates improved control of blood glucose should occur in individuals with T2DM or prediabetes.

For those with T1DM, a higher insulin sensitivity has a very less influence on function of pancreas and the demand for exogenous insulin [4]. Weight reduction and moistening body weight are often more serious issues for those with pre diabetes and Type 2 Diabetes Mellitus, but a higher body weight and fat can be

	Aerobic	Resistance	Flexibility
Frequency	3–7 d. wk. $^{-1}$	A minimum of 2 consecutive d. wk.$^{-1}$, but preferably 3	≥2–3 d. wk.$^{-1}$
Intensity	Moderate (40–59% VO_2R or 11–12 RPE rating) to vigorous (60–89% VO_2R or 14–17 RPE rating)	Moderate (50–69% of 1-RM) to vigorous (70–85% of 1-RM)	Stretch to the point of tightness or slight discomfort.
Time	T1DM: 150 min. wk.$^{-1}$ at moderate intensity or 75 min. wk.$^{-1}$ at vigorous intensity or combination T2DM: 150 min. wk.$^{-1}$ at moderate-to-vigorous intensity	At least 8–10 exercises with 1–3 sets of 10–15 repetitions to near fatigue per set early in training. Gradually progress to heavier weights using 1–3 sets of 8–10 repetitions.	Hold static stretch for 10–30 s; 2–4 repetitions of each exercise
Type	Prolonged, rhythmic activities using large muscle groups (e.g., walking, cycling, swimming)	Resistance machines and free weights	Static, dynamic, and/or PNF stretching

1-RM, one repetition maximum; PNF, proprioceptive neuromuscular facilitation; RPE, rating of perceived exertion; VO_2R, oxygen uptake reserve.

Table 1.
FITT principle in DM.

prevalent in those with T1DM as well, and an exercise program should be beneficial to both. A recent systematic review and meta-analysis found no substantial evidence that resistance exercises has more benefit than aerobic exercise in impact on cardiovascular status in individuals with T2DM. Therefore, selecting one form of exercise over other may be less important than involved in any form of PA [5]. Further, there is evidence that aerobic and resistance training together improves blood glucose control more than either one form of exercise alone [6]. Whether the added benefits are caused by a greater overall energy expenditure [7] or are specific to the combination of aerobic and resistance training has not yet been fully resolved.

3. Dyslipidemia

Dyslipidemia is a derangement of lipids in the blood. It is further defined by the presence of elevated levels of total cholesterol or low-density lipoprotein (LDL-C), elevated levels of triglycerides (TG), or low levels of high-density lipoprotein (HDL-C). Among the causes of dyslipidemia, the most common cause is poor lifestyle choices which includes diet; however, genetic constitution plays a significant contributing role, and increased levels of cholesterol often cluster within familial groups [8]. Lifestyle modifications are the basis of treatment for dyslipidemia even for patients who may ultimately require medicines to manage their dyslipidemia. Exercise has its remarkable effects on dyslipidemia, although the effect is often minimal. Aerobic exercise training persistently reduces LDL-C by 3–6 mg/dL (0.17–0.33 mmol/L) but does not appear to have a consistent effect on HDL-C or TG blood levels [9]. The American College of Sports Medicine makes the following recommendations regarding exercise testing and training of individuals with dyslipidemia.

	Aerobic	**Resistance**	**Flexibility**
Frequency	Minimally 3 d. $wk.^{-1}$; preferably ≥5 d. $wk.^{-1}$	2–3 non-consecutive d. $wk.^{-1}$	≥2–3 d. $wk.^{-1}$ with daily being most effective
Intensity	With an exercise test, use 40–80% of exercise capacity using HRR, VO_2R, or $VO_{2peak.}$ Without an exercise test, use seated or standing HR_{rest} + 20 to +30 beats. Min^{-1} or an RPE of 12–16 on a scale of 6–20 [10].	Perform 10–15 repetitions of each exercise without significant fatigue; RPE 11–13 on a 6–20 scale or 40–60% of 1-RM.	To the point of feeling tightness or slight discomfort
Time	20–60 min	1–3 sets; 8–10 different exercises focused on major muscle groups.	15 s hold for static stretching; ≥4 repetitions of each exercise
Type	Arm ergometer, upper and lower (dual action) extremity ergometer, upright and recumbent cycles, recumbent stepper, rower, elliptical, stair climber, treadmill	Select equipment that is safe and comfortable for the patient to use.	Static and dynamic stretching focused on the major joints of the limbs and the lower back; consider PNF technique.

1-RM, one repetition maximum; HRR, heart rate reserve; HR_{rest}, resting heart rate; PNF, proprioceptive neuromuscular facilitation; RPE, rating of perceived exertion; VO_2R, oxygen uptake reserve; VO_{2peak}, peak oxygen uptake.

Table 2.
FITT principle for Dyslipidaemia.

3.1 Exercise testing

In general, an exercise test is not mandatory for asymptomatic patients prior to beginning an exercise training program at a light to moderate intensity. One should be meticulous when investigating people with dyslipidemia because undiagnosed CVD may be present. Special consideration should be given to the underlying prevalence of chronic diseases and health conditions (*e.g.*, Metabolic syndrome, obesity, hypertension) that may require modifications to standard exercise testing protocols and modalities.

3.2 Exercise prescription

An important difference in the FITT principle of Exercise Prescription for clients with dyslipidemia as compared to normal adults is that weight maintenance as per height and age should be highly emphasized. Further, aerobic exercise for the purpose of increasing energy expenditure (EE) for weight loss becomes the basis of the Exercise treatment, and the FITT recommendations (**Table 2**) are in line with the recommendations for healthy weight loss and maintenance of 250–300 min/wk. [11].

Resistance and flexibility exercises are adjuncts to an aerobic training program because these modes of exercise have less consistent beneficial effects in patients with dyslipidemia as compared to healthy adults [12]. Generally, flexibility training is recommended for usual health benefits only.

4. Hypertension

Hypertension is defined by the 7th Report of the Joint National Committee (JNC7) on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure as having a systolic blood pressure (SBP) ≥140 mm Hg at rest and/or a diastolic blood pressure (DBP) ≥90 mm Hg at rest, confirmed by at least two measures taken on two separate days, or consuming antihypertensive drug for the purpose of BP control [13]. Primary hypertension is responsible for 95% of all hypertensive cases and is a risk factor for CVD and premature mortality. The known factors responsible for primary hypertension include genetic constitution and lifestyle factors such as high-fat and high-salt diets and physical inactivity [14]. Secondary hypertension is responsible for the remaining 5%. The principal causes of secondary hypertension are diseases like chronic kidney disease (CKD), renal artery stenosis (RAS), pheochromocytoma, excessive aldosterone secretion, and sleep apnea [15]. The rate of switch from prehypertension to hypertension is related to age, initial BP, and comorbidities. Apparently, hypertension is not a feature of human aging but the result of poor lifestyle choices [16]. The ACSM recommends for Hypertensive clients:

4.1 Exercise testing

Hypertensive patients may have an extraordinary BP response to exercise, even if resting BP is under control [17]. Recommendations over exercise testing for hypertensive patients vary depending on their BP level and the presence of other CVD risk factors, target organ disease, or clinical CVD [18, 19]. For most asymptomatic hypertensive and prehypertensive individuals' adequate control of BP prior to engaging in light-to-moderate intensity exercise programs such as walking is sufficient with no need for evaluation by a physician or exercise testing [20]. Recommendations include the following: Hypertensive patients whose BP is not controlled (*i.e.*, resting SBP ≥140 mm Hg and/or DBP ≥90 mm Hg) should consult

	Aerobic	Resistance	Flexibility
Frequency	≥5 d. wk.$^{-1}$	2–3 d. wk.$^{-1}$	≥2–3 d. wk.$^{-1}$
Intensity	Initial intensity should be moderate (40–59% VO_2R or HRR); progress to vigorous (≥60% VO_2R or HRR) for greater health benefits.	60–70% of 1-RM; gradually increase to enhance strength and muscle mass.	Stretch to the point of feeling tightness or slight discomfort.
Time	30 min. d^{-1} (150 min. wk.$^{-1}$); increase to 60 min. d^{-1} or more (250–300 min. wk.$^{-1}$).	2–4 sets of 8–12 repetitions for each of the major muscle groups.	Hold static stretch for 10–30 s; 2–4 repetitions of each exercise.
Type	Prolonged, rhythmic activities using large muscle groups (e.g., walking, cycling, swimming).	Resistance machines and/or free weights.	Static, dynamic, and/or PNF

1-RM. One repetition maximum; HRR, heart rate reserve; PNF, proprioceptive neuromuscular facilitation; VO_2R, oxygen uptake reserve.

Table 3.
FITT principle for hypertensive patients.

a doctor prior to starting an exercise program to determine if an exercise test is needed. Individuals with stage 2 hypertension (SBP ≥160 mm Hg or DBP ≥100 mm Hg) or with target organ disease (*e.g.*, left ventricular hypertrophy, retinopathy) must not begin exercise regimens, including exercise testing, prior to due evaluation and adequate BP management by a physician. Intensive evaluations may vary depending on results of the exercise test and the lifestyle vital signs of the individual. Exercise testing is performed for the specific purpose of designing the Exercise Prescription, it is always recommended that individuals take their usual antihypertensive medications as recommended [20]. Individuals on β-blocker therapy are likely to have an sub-optimal HR response to exercise and reduced maximal exercise capacity. People on diuresis may experience hypokalemia and other dyselectrolytemia, cardiac dysrhythmias, or potentially a false-positive exercise test.

4.2 Exercise prescription

Aerobic exercise of adequate intensity, duration, and volume that promotes an increased exercise capacity leads to reductions in resting SBP and DBP of 5–7 mm Hg and decrease in exercise SBP at suboptimal workloads in hypertensive patients [21]. Decrease in cardiac wall thickness and left ventricular mass in hypertensive patients who participate in persistent aerobic exercise training [22] and a lower left ventricular mass in prehypertensive patients and a moderate-to-high physical fitness status have also been reported [23]. Emphasis is laid on aerobic activities; however, these may be augmented with moderate intensity resistance training (**Table 3**). Some evidence exists that resistance exercise alone can lower BP, although the evidence is inconsistent. Flexibility exercise should be performed after a considerable warm-up or during the cool-down period following the guidelines for healthy adults.

5. Metabolic syndrome

A consensus definition of Metsyn [10] includes hyperglycemia (or current blood glucose medication use), elevated BP (or current hypertension medication use), dyslipidemia (or current lipid-lowering medication use), and national or regional cut points for central adiposity based on waist circumference; however, differences in specific value within these criteria remain. It is further agreed that an individual is categorized as having Metsyn when he or she displays at least three of the defining risk factors.

5.1 Exercise testing

Metsyn *per se* does not require an exercise test prior to beginning a low-to-moderate intensity exercise program. If an exercise test is performed, the general recommendations can be adhered to, with particular consideration for dyslipidemia, hypertension, or hyperglycemia when present. Because many patients with the Metsyn are either overweight or obese, exercise testing recommendations specific to those individuals should be followed [24]. The lower potential for exercise in overweight or obese individuals' stresses upon to start with low initial workload (*i.e.*, 2–3 metabolic equivalents [METs]) and then make step up approach per testing stage (0.5–1.0 MET). Presence of increased BP warrants protocols for assessing BP before and during exercise testing [25].

5.2 Exercise prescription/special considerations

The FITT principle of Exercise prescriptions in Metsyn is usually in line with the recommendations for healthy population regarding diverse array of exercises. Similarly, the min amount of PA to improve health/fitness outcomes is in line with the public health recommendations of 150 min/week or 30 mins of moderate intensity PA on most days of the week [26]. However, due to the aggravated CVD and DM risk factors, along with the likely presence of chronic diseases and health conditions that accompany Metsyn, the following Exercise Prescription considerations are recommended: When developing the Ex Rx for Metsyn, focus is to be given to each risk factor present, with the most conservative criteria used to set initial workloads. Gradually and as tolerated, longer duration and higher intensities may be required to achieve substantial health and fitness outcomes. To reduce the impact of the Metsyn, risk factors for CVD and DM, initial exercise training should be performed at a moderate intensity (*i.e.*, 40–59% O_2R or HRR) totaling a min of 150 min/wk. or 30 min/d most days of the week to allow for optimal health/fitness improvements. When appropriate, progress to a more vigorous intensity (*i.e.*, ≥60% O_2R or HRR). Reduction of body weight, an important target in Metsyn [27]; therefore, gradually increasing PA levels to approximately 250–300 min/week or 50–60 min on 5d/wk. may be necessary when appropriate. Daily and weekly amounts of PA may be accumulated in multiple shorter bouts (≥10 min in duration) and can include various forms of moderate intensity lifestyle PAs. For some individuals, progression to 60–90 min/d of PA may be mandatory to promote or maintain weight loss. Resistance and aerobic training together, can produce greater decreases in Metsyn prevalence as compared to aerobic training alone. Reported participation in ≥2 d/wk. of muscle strengthening activity reduces the risk of acquiring dyslipidemia, IFG, prehypertension, and increased waist circumference, all part of the Metabolic syndrome [28].

6. Overweight and obesity

Overweight and *obesity* are defined by a body mass index (BMI) of 25–29.9 kg/m^2 and 30 kg/m^2 or greater, respectively. Although the prevalence of obesity has steadily increased over the last three decades, recent data indicate a plateau in the overall prevalence of obesity. Statistics relating to young adult population indicate that 32% of children and adolescents are overweight or obese. Data on overweight/obesity prevalence among the adult and pediatric populations and its health implications have augmented awareness in the value of identifying and treating individuals with excess body weight [29]. Overweight and obese patients are linked to an increased risk of the development of chronic diseases including CVD, DM, some forms of cancer, and musculoskeletal problems. The body weight dynamics is dependent on energy balance that is determined by EI and EE. For an individual who is overweight or obese to reduce body weight, EE must exceed EI. Continuous weight loss of 3–5% is likely to result in clinically meaningful reductions in several CVD risk factors, including TG, blood glucose, and HbA1C levels, and the risk of developing T2DM. Lifestyle modifications for loosing weight combine reductions in Energy Intake (EI) with increase in EE (energy expenditure) through exercise and other forms of PA often result in an initial 5–10% reduction in body weight. Apparently, PA has a modest impact on the amount of weight loss, relative to initial weight loss intervention in comparison to reductions in EI [30]. The ACSM's recommends that (a) <150 min/wk. of PA promotes minimal weight loss, (b) >150 min/wk. of PA results in modest weight loss of ~2–3 kg, and (c) >225–420 min/wk. of PA results in a 5- to 7.5-kg weight loss. However, there is literature that suggests it may take more than the consensus public health recommendation for PA of 150 min/wk. or 30 min of PA on most days of the week to prevent weight gain after weight loss. There is some evidence for ~200–300 min/wk. of PA during weight maintenance to reduce weight regain after weight loss, and the more the better [31]. The ACSM makes the following recommendations regarding exercise testing and training for individuals with overweight and obesity.

6.1 Exercise testing

Exercise testing is often not necessary in the overweight/obese population prior to beginning a low-to-moderate intensity exercise program. Overweight and obese individuals are at risk for other comorbidities (*e.g.*, dyslipidemia, hypertension, hyperinsulinemia, hyperglycemia), which are associated with CVD risk. The timing

	Aerobic	**Resistance**	**Flexibility**
Frequency	5–7 d. wk.$^{-1}$	2–3 d. wk.$^{-1}$	≥2–3 d. wk.$^{-1}$
Intensity	Moderate intensity (i.e., 40–59% VO_2R or HRR; RPE 12–13 on a 6–20 scale).	60–70% 1-RM; may progress to 80% 1-RM. For older individuals and novice exercisers, begin with 40–50% 1-RM.	Stretch to the point of feeling tightness or slight discomfort.
Time	≥30 min. d-1 of continuous or accumulated exercise. If intermittent exercise performed, begin with a minimum of 10 min bouts.	2–4 sets of 8–12 repetitions for each of the major muscle groups.	Hold static stretch for 10–30 s; 2–4 repetitions of each exercise.
Type	Prolonged, rhythmic activities using large muscle groups (e.g., walking, cycling, swimming).	Resistance machines, free weights, and/or body weight.	Static, dynamic, and/or PNF stretching.

1-RM, one repetition maximum; HRR, heart rate reserve; PNF, proprioceptive neuromuscular facilitation; RPE, rating of perceived exertion; VO_2R, oxygen uptake reserve.

Table 4.
FITT principle for obesity.

of intake of medications to treat comorbidities relative to exercise testing should be kept in mind, particularly in those who take β-blockers and antidiabetic medications. Low exercise capacities in individuals who are overweight and obese may necessitate a low initial workload (*i.e.*, 2–3 METs) and a step wise increase as per testing stage of 0.5–1.0 MET. Exercise equipment must be adequate to meet the weight specification of individuals with overweight and obesity for safety and calibration purposes. The appropriate cuff size should be used to measure BP in overweight and obese individuals to minimize the potential for inaccurate measurement.

6.2 Exercise prescription

The goals of exercise during the active weight loss phase are to (a) maximize the amount of caloric expenditure to accelerate the amount of weight loss and (b) integrate exercise into the individual's lifestyle to prepare them for a successful weight loss maintenance phase (**Table 4**).

7. Cardiac diseases

People with cardiac disease are benefitted from taking part in lifestyle modifications. Cardiac rehabilitation (CR) is used to implement exercise and lifestyle modifications and consists of a holistic intervention to reduce risk and promote an active lifestyle for individuals with cardiovascular disease (CVD) [32]. CR is typically delivered in both inpatient (previously termed *phase I CR*) and outpatient (previously termed *phase II CR*) settings and reduces the death rate and incidence of disease in persons with various cardiac diseases by stabilizing, slowing, or even reversing the progression of the atherosclerosis. The benefits provided by CR are significant at population as well as individual level as subsequent health care costs may be reduced following participation [33], with cost-effectiveness greater in patients with a higher chance for subsequent cardiac events. The following are the indications and contraindications for Exercise prescriptions:

7.1 Indications

Stable angina
Coronary artery bypass graft surgery
Post-myocardial infarction (stable)
Stable heart failure caused by either systolic or diastolic dysfunction (cardiomyopathy)
Valvular heart disease/surgery
Peripheral arterial disease
At risk for coronary artery disease with diagnoses of diabetes mellitus, dyslipidemia, hypertension, or obesity

7.2 Contraindications

Uncontrolled hypertension — that is, resting systolic blood pressure > 180 mm Hg and/or resting diastolic blood pressure > 110 mm Hg
Uncontrolled atrial or ventricular arrhythmias
Orthostatic blood pressure drop of >20 mm Hg with symptoms
Uncontrolled sinus tachycardia (>120 beats · min – 1)
Significant aortic stenosis (aortic valve area < 1.0 cm2)
Unstable angina
Uncompensated heart failure.

Third-degree atrioventricular block without pacemaker.
Active pericarditis or myocarditis
Recent embolism (pulmonary or systemic)
Acute thrombophlebitis
Aortic dissection
Acute systemic illness or fever
Uncontrolled diabetes mellitus
Severe orthopedic conditions that would prohibit exercise
Other metabolic conditions, such as acute thyroiditis, hypokalemia, hyperkalemia, or hypovolemia (until adequately treated)
Severe psychological disorder

7.2.1 Exercise testing

The American College of Cardiology (ACC)/American Heart Association (AHA) 2002 recommends exercise testing [34] early (2–3 wk) or later (3–6 wk) after hospital discharge is beneficial for framing of an exercise prescription in patients who had MI without (Class I recommendation) or with (Class IIa recommendation) coronary revascularization. An exercise test may also be used after certain period of time in patients who undergo supervised exercise training and CR (Class IIb recommendation). The following points of exercise testing should be noted: The test should be limited to symptoms and use standard exercise testing procedures. The test should be completed while the patient is on medications. e.g., the timing of a β-blocker with respect to the exercise test because it influences the HR response and ultimately on the HR-based Ex Rx. The following section on Ex Rx provides methodology for guiding exercise intensity.

7.2.2 Exercise prescription

The Ex Rx techniques used for the apparently healthy adult population may be applied to many patients with CVD. This section provides recommendations of the Ex Rx for patients with known CVD (**Table 5**).

	Aerobic	**Resistance**	**Flexibility**
Frequency	≥5 d/wk. to maximize caloric expenditure.	2–3 d/wk	≥2–3 d/wk
Intensity	40–75% VO_2R or HRR.	Moderate (50–69% of 1-RM) to vigorous (70–85% of 1-RM) to improve strength; <50% 1-RM to improve muscle endurance.	Stretching to the point of tightness or slight discomfort.
Time	30–60 min/d. To promote or maintain weight loss, 50–60 min/d or more of daily exercise is recommended.	2–4 sets, 8–12 repetitions for strength; ≤2 sets, 12–20 repetitions for muscular endurance.	Hold static stretch for 10-30secs; 2–4 repetitions of each type exercise.
Type	Prolonged, rhythmic activities using large muscle groups (e.g., walking, cycling, swimming).	Resistance machines, free weights and/or body weight.	Static, dynamic, and/or PNF stretching.

1-RM, one repetition maximum; HRR, heart rate reserve; PNF, proprioceptive neuromuscular facilitation; VO_2R, oxygen uptake reserve.

Table 5.
FITT principle for cardiovascular diseases.

8. Patients with heart failure

Chronic HF consists of exertional dyspnea and fatigue in the setting of HFrEF (*i.e.*, systolic dysfunction), a preserved left ventricular ejection fraction (HFpEF, *i.e.*, diastolic dysfunction), or a combination of the two. The prevalence of HF is increasing such that decompensated HF is the single most common admitting diagnosis and results in more than 1 million hospitalizations annually [35]. 25% of patients are readmitted within a month and 66% within one year of their initial HF hospital admission [36]. The merits of exercise training in patients with HFrEF include improved clinical outcomes (*e.g.*, hospitalizations) and health-related quality of life [37]. Exercise also helps to augment capacity of exercise (10–30%, as measured by O_2peak), central hemodynamic function, autonomic nervous system function, and peripheral vascular and skeletal muscle function in patients with HFrEF. These adaptations help patients to exercise to an increased peak work rates or exercise at a suboptimal level with a lower HR, less perceived effort, and less dyspnea and fatigue. Emerging data indicates that patients with HFpEF also benefit from exercise training, as evidenced by improved skeletal muscle function, quality of life, and exercise capacity [38].

8.1 Exercise testing

Symptom-limited exercise testing is safe in patients with HFrEF and when combined with the indirect measurement of expired gases provides not only useful information pertaining to electrocardiographic and hemodynamic responses to exercise but prognostic information as well [39]. Age-matched healthy individuals, patients with HFrEF exhibit a lesser peak HR, peak stroke volume, and peak cardiac output response to exercise. Vasodilation of the larger vessels and resistance vasculature are weakened, reducing regional and local blood flow. Exercise tolerance

	Aerobic	Resistance	Flexibility
Frequency	Minimally 3 d/wk.; preferably ≥5 d/wk	2–3 nonconsecutive d. $wk.^{-1}$	≥2–3 d/wk. with daily being most effective
Intensity	With an exercise test, use 40–80% of exercise capacity using HRR, VO_2R, or VO_{2peak}. Without an exercise test, use seated or standing HR_{rest} + 20 to +30 beats/min or an RPE of 12–16 on a scale of 6–20 [10].	Perform 10–15 repetitions of each exercise without significant fatigue; RPE 11–13 on a 6–20 scale or 40–60% of 1-RM.	To the point of feeling tightness or slight discomfort.
Time	20–60 min	1–3 sets; 8–10 different exercises focused on major muscle groups.	15 s hold for static stretching; ≥4 repetitions of each exercise
Type	Arm ergometer, upper and lower (dual action) extremity ergometer, upright and recumbent cycles, recumbent stepper, rower, elliptical, stair climber, treadmill.	Select equipment that is safe and comfortable for the patient to use.	Static and dynamic stretching focused on the major joints of the limbs and the lower back; consider PNF technique.

Table 6.
FITT principle for patients with heart failure.

falls to 30–40% as compared to controls. An exercise regimen that starts at a lower work rate and uses stepwise increase in work rate per stage is commonly used. Both O_2 peak and the slope relationship between minute ventilation and carbon dioxide production (E– CO_2 slope) are related to prognosis and can serve as a guide as to when to consult Cardiologist [39].

8.2 Exercise prescription

The two main goals for exercise training in patients with HF are to reverse exercise intolerance and decrease subsequent risk for a clinical event, the principle of specificity of training dictates the use of exercise modalities that were used in trials that reported improved functional and clinical benefits (**Table 6**). Therefore, exercise regimens should always include aerobic activities.

9. Conclusions

Exercise used to be recommended as an advice earlier which did not find any beneficial outcomes in clients. Exercise prescription for diseases like Diabetes, Dyslipidemia, Metabolic Syndrome, Cardiovascular diseases are essential and they augment existing medical management of the diseases mentioned and therefore provide a holistic approach towards treating co morbid conditions. It is essential that exercise is issued as prescription and not simply as advices which becomes one of the factors of not taking it seriously by individuals. The FITT principle is the basic guiding method on whose basis the exercise prescriptions are issued. There are lot of diseases for which Exercise Prescriptions are issued, but discussion on such diseases are beyond scope of this chapter.

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Chapter 5

Soft-Tissue Techniques in Sports Injuries Prevention and Rehabilitation

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Abstract

Participation in sports, in addition to its positive effects, leads to injuries caused by contact with the opponent or the high loads that develop on the musculoskeletal structures during the sports activities. Sports injuries mainly include (a) acute injuries such as muscle strains and ligament sprains, tendon injuries, dislocations and subluxations, fractures, and skin injuries but also (b) overuse injuries such as tendinopathies and painful myofascial syndromes. Many therapeutic techniques are used to treat these injuries, such as therapeutic exercise, various electrotherapy procedures and soft tissue techniques. Soft tissue techniques aim to promote health and well-being through their mechanical effects on the body's soft tissues such as friction, compression, tissues sliding and myofascial release. Sports soft-tissue procedures are applied either directly with the hands of therapists such as classical massage or with the use of special equipment such as tools made of stainless steel (ERGON instrument-assisted soft tissue mobilization), elastic ischemic bandages (Kinetic flossing technique) and cups (cupping therapy). The following chapter analyzes the therapeutic effects of the above therapeutic interventions by presenting recent scientific evidence that supports their effects on the soft tissue's dysfunctions of the human body and various pathological conditions.

Keywords: sports injuries, sports massage, IASTM, muscle flossing, cupping therapy

1. Introduction

Sports participation, both at the amateur and professional levels, is widespread among all age groups. However, the rising number of athletes and increasingly intense competition have yielded both positive results, such as better quality of life and performance, and adverse effects, such as a higher risk of sports injuries. The etiology of sports injuries includes a set of intrinsic and extrinsic risk factors, such as the specific characteristics of each athlete and environmental influences. Intrinsic risk factors include biological characteristics, such as gender, age, weight, height, strength and flexibility asymmetries, anatomical asymmetries, incomplete recovery from previous injuries, joint instability, and the athlete's psychological state. Extrinsic risk factors include the type of sport, environmental conditions, the level of sport (amateur/professional), the athlete's skill level, training errors, the playing surface, the lack of protective equipment, and the specific kinetic protype of each sport.

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Sports injuries are endemic to high-energy sports due to tissues being overloaded during specific sports activities. More specifically, repeated exposure to the high mechanical loads associated with sports activities induces pathological postural adaptations and causes injuries to myofascial structures. Such adaptations and microtraumas alter the physical properties of the connective tissue, leading to myofascial scarring and fibrosis. Furthermore, inflammatory responses to this tissue damage can alter the structure of myofascial tissues, leading to pain and hypersensitivity and thus limiting an athlete's joint range of motion, strength, and performance. The structural adaptations discussed above can adversely affect an athlete's functionality, decreasing their performance and increasing the risk for sports injuries.

Various therapeutic strategies have been used to prevent and treat the sports pathologies and dysfunctions associated with biomechanical deficits and overuse. The most popular therapeutic interventions in sports include soft tissue techniques applied directly by the therapists by using their hands (sports massage) or by using specific equipment, as in the case of instrument-assisted soft tissue mobilisation (IASTM) techniques, as well as muscle flossing techniques and cupping therapy. Sports massage, IASTM, flossing, and cupping techniques are applied to an athlete's soft tissues to treat myofascial dysfunctions, alleviate hypersensitivity in myofascial tissues, release scar tissues and adhesions, decrease pain, improve functional performance and joint range of motion (ROM), reduce delayed-onset muscle soreness (DOMS), and accelerate recovery. This chapter reviews the studies regarding the effectiveness of the aforementioned soft tissue techniques for sports-injury prevention and rehabilitation and for improving athletes' functional capacities and physical properties.

2. Soft-tissue techniques in sports-injury prevention and rehabilitation

2.1 Sports massage

Sports massage involves performing soft tissue-manipulation techniques on athletes to maximise performance and prevent or repair injuries. The sports massage techniques aimed at maximising performance and preventing injuries are divided into pre-competition (i.e. before the sports event) and post-competition massage techniques. When a sport includes breaks, massage is often performed during such breaks [1].

2.1.1 Sports massage techniques

Massage aimed at repairing sports injuries is mainly applied in the physiotherapy laboratory during rehabilitation. The techniques of applying pressure and mobilising an athlete's anatomical structures are delivered either by the physiotherapists using their hands or special massage equipment.

Sports massage is predominantly based on the techniques based on the Swedish massage techniques and includes manipulations such as slips-kneading, kneading, twisting, percussion, and vibration [1, 2]. The main difference between sports and classic massage is that the two forms of massage serve different purposes and are therefore applied differently. For example, in most cases, sports massage is applied with more pressure because athletes' bodies require a more aggressive approach due to sports adjustments. In addition, there are manipulations, such as stripping massage (i.e. special transverse-friction massage), that are used almost exclusively in the rehabilitation of sports injuries [1, 2].

2.1.2 Massage in different sporting conditions (before, during, and after the sports event)

The effects and goals of sports massage are divided according to the mechanical, physiological, nervous, reflexive, and psychological outcomes. The massage goals vary depending on the period when they are applied (before, during, or after the sports event). For example, the massage techniques applied before the sports event are mainly meant to prepare athletes by increasing performance and reducing the risk of sports injuries [3].

The positive effects of pre-game massage on athletic performance are based on the theoretical principles that massage yields the following benefits: (a) increased skin and muscle temperature; (b) increased metabolism; and (c) increased blood circulation, which improves oxygen transport to tissues and leads to a better balance in blood flow [4]. The preventive effects of sports massage in terms of injuries have been attributed to (a) improved passive and active elasticity, (b) increased muscle activation and performance, and (c) the psychological stimulation of the athlete [5]. However, some of these theoretical effects of pre-game massage have not been strongly supported by research as relevant research findings have been limited or yielded conflicting results.

The relationship between massage and an increase in surface temperature has been confirmed by previous research. Several studies have shown that massage via the rubbing of the skin and the subcutaneous tissues increases the local skin and intramuscular temperature and leads to hyperaemia [6–14]. It has been reported that even a 6-minute massage of the back significantly increased the area's temperature, which returned to pre-massage levels after 10 minutes [11].

Similar effects were confirmed in a study conducted by the Laboratory of Therapeutic Exercise and Sports Rehabilitation at the University of Patras, Greece, which found that sports massage in the gastrocnemius and quadriceps areas of young basketball players increased the skin temperature of said areas, with the temperature returning to normal after about one hour. This finding is of special clinical interest because increased tissue temperature reduces pain and increases the metabolic rate, which can improve the elasticity of collagen and result in better functionality as well as a possible prevention of musculoskeletal injuries. Finally, increased skin temperature leads to an increase in vascular permeability and better oxygenation [15].

However, although pre-game massage increases surface and intramuscular temperature, such changes may not directly affect local blood and lymph circulation as studies have shown that massage can lead to significant [5, 14, 16, 17], moderate, or even zero increase in blood circulation [18–22].

The conflicting research findings on the effects of massage on blood circulation can be attributed to several factors. First, the positive effects of massage on skin temperature seem to subside relatively quickly [10]. Second, the increase in intramuscular temperature does not seem to exceed 2.5 points in muscle depth, meaning that it does not significantly affect the main vessels of the muscle [11].

In addition, researchers have mainly investigated deep effleurages rather than other manipulations. Moreover, the main techniques used for evaluating blood circulation (venous occlusion plethysmography, the Xenon-washout technique, Doppler ultrasound) have run into significant validity problems. Another researched factor that clearly influences the effect of massage on blood circulation is the intensity of the pressure applied to the tissues. Evidence supports the academic and sensible theory that classic relaxation massage leads to lower blood pressure, while intense athletic massage leads to increased blood pressure [17].

The relationship between massage and improved elasticity has been confirmed by several studies [23–29] that have shown positive muscle-elasticity adjustments after the application of massage. Studies have found that pre-game massage is associated with a relatively short-term (up to 24 hours) improvement in the elasticity of hamstrings [23–25, 29, 30] and plantar flexors of the ankle joint [31] in athletes and non-athletes. Improved muscle elasticity is causally related to the massage techniques applied. Intense and dynamic movements, such as intense deep-friction [30] in combination with eccentric exercise [32, 33], contributes more effectively to a short-term increase in tissue elasticity. This improvement is attributed to the reduction of myotendinous stiffness and increased stretch tolerance [30].

In contrast to elasticity improvements, scholars have not conclusively determined the effects of massage on the production of tension (strength), with some studies reporting a relative increase of post-exercise muscle strength after massage as assessed by various laboratory and functional tests with college students [27] and volleyball athletes [34], and other studies showing a significant reduction in post-exercise strength produced immediately after the application of massage [23–25, 29, 30, 35].

Finally, pre-game massage seems to significantly improve athlete psychology, with massage being associated with a reduction in pre-game stress in athletes, which contributes to better performance [36] by reducing stress hormones (cortisol and norepinephrine) and increasing serotonin levels [36, 37].

2.1.3 Pre-game massage

The manipulations performed to prepare an athlete for a sporting event mainly involve effleurages (superficial and deep), petrissage (flat petrissage), stimulating rolling, and kneading. These manipulations are mainly applied to the athlete's muscular groups that will be overloaded and will receive more use depending on the movement patterns of each sport. Considering that almost all sports, under normal conditions, are related to and depend on the movement of the lower extremities, the pre-game massage is logically focused mainly on the preparation of the muscles of the lower extremities. In addition, pre-game massage should also prepare (a) the body's central point (trunk), which provides the biomechanical basis for the initiation and proper execution of athletic movements, and (b) the upper limbs in cases of sports whose movement patterns include extensive use of the upper limbs (handball, volleyball, basketball, etc.).

Raising the temperature of the soft tissues before exercise is imperative to prepare the muscles for the intense loads that will follow in the game [38]. Massage can improve the temperature of the superficial muscle tissues, thus better preparing the athlete to enter the sports field [39].

The Laboratory of Therapeutic Exercise and Sports Rehabilitation at the Department of Physiotherapy at the University of Patras, Greece, has obtained positive results when it comes to studying massage and pre-game preparations: Charalampopoulou et al. concluded that soft tissue techniques, including IASTM and massage, can raise the skin temperature in basketball players for 15 minutes after the massage application [15].

2.1.4 Massage during the game

In sports that involve a break or breaks between competitive efforts, massage can improve athletic performance by allowing the athletes to temporarily cool-down (physically and psychologically) and preparing (activating) them for the continuation of the competition [4]. The main problems that an athlete faces during intense and competitive exercise are physical as well as psychological. Physical adaptations include muscle pain, increased muscle tone (spasm) of particularly stressed limbs, and edemas-hematomas. Psychological adaptations depend on various factors (the competition's importance, half-time result, etc.) and may include either personal competitive stress for better individual performance or psychological pressure for better team performance and goal achievement (in the case of team sports).

Depending on the manipulations chosen and the way they are performed (slowly superficially, superficially, in-depth), sports massage during half-time can lead to initial cool-down and reduction of the painful muscle tone and muscle excitability and to neuromuscular readiness as the game recommences [40, 41]. Moreover, massage can also reduce competitive stress and calm the athlete [42–44].

The research efforts that have examined this parameter have, despite their disadvantages (no control group, small sample of examinees), highlighted a significant correlation between massage and the improvement of the athlete's psychological parameters [42–44]. In terms of psychological rehabilitation, massage has been associated with a significant improvement in an athlete's sense of physical recovery, an outcome that is very important for the continuation of competitive efforts [45–47].

2.1.5 Massage techniques after the game

The main problems that an athlete faces after the competition (depending on its intensity and duration) are (a) fatigue from the accumulation of metabolism and waste products, (b) the accumulation of edemas and possible hematomas resulting from the excessive use of and strain on the athlete's anatomical structures, and (c) the immediate and delayed onset muscle soreness and the significantly increased muscle tone (spasm) of the limbs. Due to these effects and adjustments, athletes' physical properties (muscular strength, endurance, elasticity, proprioception) decrease significantly, and recovery should indirectly aim to correct these issues.

Post-competition massage as a means of passive rehabilitation can significantly contribute to an athlete's recovery and reduce the aforementioned physiological adaptations, but to a lesser extent than active recovery (e.g., aerobic running) [48–50].

Initially, by increasing blood flow to the muscles [51–53], massage can speed up the removal of useless metabolism products after exercise and improve the transport of oxygen, protein, and other nutrients necessary for muscle recovery and restart, leading to homeostasis [51, 54–56]. In addition, massage can significantly reduce feelings of fatigue and muscle pain as massage can help reduce the concentration of carcinogens (lactic acid) after exercise by improving blood flow to the muscles and subsequently increasing oxidation [57–59]. However, it should be noted that although massage leads to a significant reduction in the levels of lactic acid in the blood after intense exercise (compared to passive rest), active recovery (aerobic running) [49, 50, 59] the combination of massage and active rehabilitation [60] clearly exhibits better metabolic effects. In addition, massage has been shown to contribute positively to athletes' (soccer players') recovery in terms of heart rate and blood pressure compared to passive rest, with soccer players exhibiting better heart-rate recovery after lower extremity massage compared to active and passive recovery modes [50].

In summary, increased lymphatic circulation and venous resuscitation resulting from the application of sports massage after intense exercise can reduce the swelling and hematomas created during the exercise. The aforementioned adaptations, together with the local increase in temperature, can contribute to reduced muscle tone and improved relaxation [61–63]. The reduction of the concentration of hematomas and edemas caused by intense and prolonged exercise leads to a reduction of pain through a corresponding reduction of hydrostatic pressure and irritation of the sensory receptors of pain [64]. These outcomes of post-game massage are well supported by several studies that have shown that massage can reduce the intensity of DOMS in athletes and thus contribute to faster and better recovery [63, 65].

Finally, massage has been found to lead to faster recovery of strength levels compared to passive movement or rest as 5 minutes of massage (rolling, flat kneading) resulted in better grip strength of healthy people (non-athletes) after maximum exercise [16, 66]. Two additional studies examining the recovery of isokinetic power in the quadriceps muscle described improvement and increase of isokinetic power after 6-minute and 10-minute massages [67, 68].

2.1.6 Therapeutic sports massage

The soft tissue techniques of sports massage used to treat sports injuries are mainly applied in the physiotherapy laboratory during the rehabilitation phase. These techniques are performed by the sports physiotherapists as well as the athletes themselves in the case of self-massage with special equipment, such as a foam roller.

An important difference between therapeutic sports massage and the classic therapeutic massage has to do with the fact that in the case of therapeutic sports massage, the massage is not applied exclusively to the massaged area in a relaxed position but can also be combined with active (concentric-eccentric) or passive movement of the involved muscle group [33].

2.1.7 Goals of therapeutic sports massage

The main goals of therapeutic sports massage are the mobilisation of hematomas-edemas in the subacute phase of sports injuries, the alignment of injured tissue fibres, the release of adhesions, and the recovery of the elasticity of various tissues [69]. The main techniques used to achieve these objectives are the linear techniques of classic massage, except in the case of regaining elasticity and adhesion release, which requires special massage techniques, such as stripping massage, transverse friction massage, and aggressive forms of myofascial massage-mobilisation, such as foam roller, IASTM, and cupping therapy.

2.1.8 Mobilisation – reduction of edemas/hematomas

Massage can play an important role in repairing sports injuries by helping to reduce the concentration of both primary edemas caused by the injury and secondary edemas caused by increased hydrostatic pressure in the injured area [3, 70]. In addition, in cases where the injury has damaged several blood vessels and has led to a significant accumulation of hematomas, massage can mobilise this accumulation of blood and drastically reduce the healing time of an injury through the application of mechanical pressure to the vessels and tissues in general and the subsequent increase in local blood and lymphatic circulation [4, 26, 71–73].

By applying mechanical pressure to the tissues and vessels, massage mobilises the content of the valvular veins and the lymphatic channels in a more central direction (towards the heart), thus facilitating the entry of the interstitial fluid into the vessels [74, 75]. At the same time, vascular congestion can be reduced via the reduction of the median pressure, thus improving the diffusion-supply of the tissues [13].

Improved drainage of fluids in the injured area also restores the normal osmotic pressure of the interstitial fluid, a process that is equally important to the vascular adjustments seen after the application of massage. These theoretical effects of massage on venous return and lymphatic circulation are supported by findings from studies of animals, which have shown that massage significantly increased lymphatic circulation compared to diathermy and active and passive exercise when applied to dogs [76, 77] and pigs [78].

2.1.9 Massage application to reduce swelling/hematoma (aggressive massage techniques)

The massage that aims to mobilise fluid elements (edema/hematoma) in athletes has a clearly accelerated-aggressive form, and its execution (pressure, direction, massaging point) can lead to high pain (VAS scale 7–8) during application. This aggressive massage technique uses straight manipulations and mainly deep slips and special massaging techniques (stripping massage) because circular strokes are not allowed in the acute stage of injuries and in the phase when the fibres of the injured tissue are immature or, even worse, have not been restored yet.

The basic manipulations (effleurage-kneading) begin more centrally than the site of the injury. Through the mobilisation-increase of the venous return of large vessels, the massage techniques are meant to "empty" the injured areas and to create and environment (negative pressure) suitable for the mobilisation of the edema-hematoma located in the periphery of the injured area. Immediately afterwards, massage techniques are once again applied directly to the injury using straight manipulations from the periphery towards the centre. Through direct mechanical effect, swelling and hematomas are directed towards the trunk or from deeper to more superficial layers, which ultimately facilitates hematomas removal. These manipulations have been described in a study by the Laboratory of Therapeutic Exercise and Sports Rehabilitation at the University of Patras, Greece, in which aggressive massage techniques were performed to speed up the recovery of a professional football player after a 1st degree hamstring strain. The results of the study were encouraging as recovery time was reduced to almost half of the usual time and the footballer resumed full training and participation in games in 15 days. The soft tissue techniques used to remove the edema were stripping massage, cupping therapy, and IASTM techniques [79].

The application of the manipulations described above leads to significant pain due to pressure on the injured tissues and increased hydrostatic pressure, which, in turn, increases the irritation of the sensory receptors of pain. However, the aggressive approach drastically accelerates the reduction of the accumulation of metabolic substances and blood-hematoma and enables the process of fibre re-adhesion to begin sooner. The application time ranges between 5 and 10 minutes, and the pressure/intensity of the techniques must be alternated (mild to intense/deep-surface) to be more tolerable for the athlete. Immediately after the mobilisation of the edema-hematoma, cryotherapy should be applied to reduce (via vasoconstriction) the amount of the mobile fluids that will return to the massaged-injured area.

2.1.10 Massage for aligned fibre re-adhesion and reduction of scar tissue

In the subacute phase of the injury, when the swelling-hematoma has been removed and tissue re-adhesion and scar tissue deposition begins, massage also plays a critical role in facilitating the proper repair of the injured area. The application of straight manipulations (deep kneading, soothing rolling, tapping linear strokes) in the direction that the fibres of the injured anatomical area are normally arranged in creates a tendency for linear re-adhesion as well as reduction of adhesive deposition and scarring.

Proper alignment and reduction of the amount of hard connective tissue in the injured area reduces the loss of elasticity and strength experienced in the presence of adhesions [1, 2, 80], thus reducing the risk of the recurrence of injury [2]. In addition, massage can "dissolve" fibrous deposits that can impede the flow of interstitial fluid by clogging tiny pores of the fascia, which restores the circulation of interstitial fluid [3].

These significant effects of massage on tissue repair have been supported by research on animals that have technically suffered muscle strain and received massage as basic treatment in randomised studies. The massaged muscles had normal microscopic illustrations in contrast to the non-massaged muscles, which showed histological adaptations such as (a) dislocation of the myofibrils, (b) significant deposition of connective tissue, (c) persistent hematomas, (d) increased number of fibroids in the connective tissue, and (e) enlargement of the blood vessels accompanied by the thickening of their walls [63].

2.1.11 Massage application in delayed-onset muscle soreness (DOMS)

DOMS generally describes the tenderness and pain of muscles that develop hours or even days (24–72 hours) after specialised and demanding sports training (eccentric-plyometric) [81].

This negative adaptation after intense exercise leads to decreased elasticity of the anatomical structures involved (upper and lower extremities) and to clearly reduced muscular strength [5, 65]. Several theories for DOMS have been proposed, including the activation of free nerve endings by (a) lactic acid accumulations, (b) muscle and ligament injuries, (c) exit to the intracellular space of intramuscular enzymes, and (d) prostaglandins [81]. Histological examinations of muscle cells after eccentric loadings have revealed structural cellular adaptations (migration of cellular elements) that cause local edema and inflammation [65, 82].

In addition, connective tissue injury is evidenced by the high concentration of hydroline and hydroxylysine in athletes' urine after eccentric exercise [81]. Theoretically, and based on the previous chapters, the fact that massage can move fluids from the intercellular and interstitial spaces and reduce the accumulation of metabolic products [48, 51, 54–56] may have a positive effect on reducing DOMS. This is confirmed by several studies that have shown that massage can significantly reduce muscle sensitivity because of eccentric-plyometric muscle activity and contribute to improving the rate of tissue healing and the reduction of cellular inflammation by improving the supply of nutrients and oxygen to the tissues [34, 56, 65, 83–85].

Moreover, massage can lead to faster recovery of muscle strength, which is significantly reduced after eccentric exercise [20, 81, 86, 87].

Finally, several studies have recorded reduced muscle soreness, lower perception of fatigue, and improved perceived recovery [16, 20, 45, 88] at variable intervals after the massage, ranging from 24 to 96 hours.

2.1.12 Effects of massage on the inactivation of trigger points

The creation of painful trigger points is one of the painful syndromes and injuries of the musculoskeletal system that have been observed after intense exercise. These points refer to localised areas of high sensitivity that are usually located within a stretched muscle bundle. The clinical feature of these myofascial trigger points is that they cause intense focused pain during compression as well as other symptoms, such as reported pain, muscle dysfunction, and autonomic phenomena.

The causes of such pain triggers include biomechanical body abnormalities, injuries, chronic inflammation, and psychological factors but may also be the result of tissue overuse during exercise [89, 90]. Beyond focused pain, the negative adaptations caused by the existence of areas of excessive tension and ischemia include reduced elasticity and deficient strength production and muscle function in general [89]. In addition, pain triggers have been blamed for causing painful muscle spasms (cramps) during exercise [91].

The treatment of such pathological signs of pain includes, among others, techniques that combine cryotherapy and stretching (stretch and spray), electrotherapy (tens, ultrasound), and massages of various kinds [90, 92].

The treatment of painful trigger points has been part of classic massage techniques and therapy techniques that rely on ischemic compression of trigger points, leading to the deactivation of said points and to the reduction of pain symptoms. In particular, the application of massage in the form of either classic-Swedish massage [93, 94] or ischemic pressure [95] significantly reduced the intensity of pain in patients with painful trigger points in the trunk (lumbar and cervical region) [96] and the thigh muscles (hind thighs) [97].

2.1.13 Application of ischemic pressure to deactivate painful trigger points

Ischemic pressure deactivates painful trigger points via two main mechanisms: ischemia and the following hyperaemia as well as local and focused tissue stretching. Ischemic pressure initially creates a reduction in local perfusion; once the pressure is removed, hyperaemia occurs in the area, which can help clear the muscle of inflammatory derivatives and pain metabolites, thus desensitising the nerve endings. In addition, constant local pressure on the trigger points will lead to continuous stretching that can potentially "solve" painful adhesions and reduce muscle spasms [89].

In a study by Fousekis et al. at the University of Patras, ischemic pressure techniques were applied to amateur soccer athletes on painful lower-back trigger points to evaluate the effectiveness of these techniques in pain. From the very first week of application, the participants reported a decrease in pressure sensitivity according to VAS and a pain reduction as ischemic pressure was effective for treating trigger points [98].

2.2 Instrument-assisted soft tissue mobilisation (IASTM): the ERGON IASTM technique

Mobilisation techniques using special tools made of stainless steel are a form of aggressive mobilisation of soft tissues. There are several variations of such tools (Myobar, Fibroblaster, Smart Tools, Rockblade, Hawkgrip), but the Graston and ERGON tools are the most prevalent ones in research.

Soft tissue techniques using special equipment require tools designed to adapt to the various tissues, shapes, and curves of the body. These tools are used for the following purposes: (a) to detect and release scar tissue, adhesions, and fascial sclerosis; (b) to increase blood circulation; and (c) to reduce muscle tone and pain [99–101].

Significant advantages have been reported in using such tools rather than one's hands when evaluating the abnormalities of tissues, although a stainless-steel tool is inferior to the human hand in the first stage of the standard evaluation, which involves tissue palpation for the assessment of temperature, humidity, edema, and muscle spasms in the superficial tissues of the body [102].

Massaging the tissues with special tools enhances a therapist's sense and information about the condition of the tissues as the fatty areas of the therapist's fingers that come in contact with the patient's body compress the tissues, while the tools have a narrower edge to separate them [102, 103].

According to the manufacturers, the tools act as percussion instruments: when in contact with hard fibrous tissue, they transmit an echo (vibration sensation) to the therapist's hand, improving their ability to recognise and evaluate adhesions and fibrous deposits [101, 102]. In addition, the use of such tools allows the mobilisation of deep and hard structures without overloading the therapist's fingers.

In particular, IASTM techniques in conjunction with cross-friction massage can reduce scar tissue deposition after an injury, reduce the hardness of preformed connective tissue deposits, and facilitate the healing of chronic overuse injuries by re-damaging tissues and linearly re-connecting them [96, 101, 104–107].

IASTM techniques also appear to lead to changes in microvascular morphology and hyperaemia [108] and to increased fibroblastic mobilisation and activation, an adaptation that leads to regeneration and repair of the injured collagen [101, 104, 107]. These adaptations have been supported by studies with animals and individual case studies with humans [100, 101, 103–106, 108, 109].

For example, a study of mice that underwent controlled rupture of the medial lateral ligament in their knee and were treated with an IASTM treatment showed that the ligaments that received the Graston massage were stronger (43.1%), harder (39.7%), and could absorb up to 57.1% and more load until break point compared to untreated ligaments. In addition, specific ligaments during the microscopic analysis showed better arrangement and alignment of the newly formed collagen [108].

Such findings were attributed by the same researchers to increased perfusion and the change in the microvascular morphology observed after the application of IASTM techniques to the inner lateral ligaments of mice [109].

2.2.1 IASTM technique applications

There are several IASTM techniques, the most well-documented being the Graston and ERGON techniques. ERGON IASTM TECHNIQUE is an innovative therapeutic approach that combines static and dynamic manipulations of the body's soft tissues with special clinical equipment meant for the treatment of pathological conditions. The technique takes its name from the Greek word "ergon," which etymologically means "what a person produces with their work, manual or mental, scientific or artistic."

With the ERGON IASTM TECHNIQUE, the therapist can induce short-term and long-term adaptations to the soft tissues of the human body. The techniques follow specific application rules and parameters. Poor application of techniques and non-compliance with the correct parameters may lead to the opposite result and cause injuries to the treated area.

2.2.2 IASTM diagnostic applications

The general evaluation of the patient is followed by the evaluation of the injured anatomical area using the ERGON TOOLS. A scan of the soft tissue is performed with a special diagnostic application technique, namely the Ergon Technique Scanning Procedure (ETSP). ETSP is based on a specific use of the ERGON TOOLS that allows detecting scar tissue, adhesions, and fascial hardening/shortening.

2.2.3 IASTM in sports rehabilitation

Several studies have shown the beneficial effects of the ERGON IASTM TECHNIQUE in sports rehabilitation. In recent years, techniques that rely on stainless steel tools have been gradually accepted by therapists. More and more researchers are developing treatment protocols to investigate the usefulness of such techniques in various musculoskeletal and sports pathologies.

2.2.4 Effects of ERGON IASTM on edema mobilisation.

A study by the Laboratory of Therapeutic Exercise and Sports Rehabilitation at the University of Patras, Greece, involved performing aggressive massage techniques to speed up the recovery of a professional football player after a 1st degree hamstring strain. The results of the study were encouraging because the combination of stripping massage, cupping therapy, and IASTM techniques reduced the recovery time to a to almost half of the standard recovery time [110].

2.2.5 Effects of ERGON IASTM on pain reduction

Myofascial pain reduction after IASTM application has long been theoretically connected to the following three mechanisms: (a) local temperature and blood flow increase, (b) localised tissue manipulation and stretching, and (c) reduction of fascial adhesions and restrictions [111–114].

The importance of ERGON techniques for reducing pain has been investigated by Fousekis et al. in 2016, who reported an immediate reduction in pain and pressure sensitivity in soccer players with trigger points in the lumbar area [98].

Furthermore, deep pressure may mask the perception of pain, possibly in connection with endorphins [115, 116]. Using IASTM, applying deep pressure becomes easier as the tools' edges are harder than the tips of a therapist's fingers.

2.2.6 Effects of ERGON IASTM on increasing skin temperature

In sports rehabilitation, increasing blood circulation and tissue temperature are strategic goals for the proper preparation of athletes before a game or a practice session.

The tool angle used when treating tissue should be considered for a more targeted treatment of specific pathologies. Research shows that a greater angle of application results in higher tissue temperature for longer periods of time. More specifically, temperature value and permanence have been examined at 20^o, 60^o, and 90^o application angles. The temperature increased with each application angle but was higher at the 60^o and 90^o angles. It is worth noting that at 60^o and 90^o angles, the temperature rise was almost the same. In conclusion, if the goal of the treatment is to maintain increased temperature for a long time, a greater angle, such as a 90^o angle, is advisable [79].

In addition, soft tissue techniques using IASTM have been shown to be more effective at raising temperature in basketball players after 15 minutes of application compared to the use of massage and foam rollers [15].

2.2.7 Effects of ERGON IASTM on increasing elasticity

One of the most noteworthy outcomes of ERGON IASTM techniques is the effect that such techniques have in the therapy of remote areas – that is, when techniques are applied in one anatomical area to induce adaptations in a different one.

This therapeutic approach is based on the existence of 12 specific myofascial meridians (fascia lines) that control the human body, as proposed by Thomas W. Myers [116]. Fibres are interconnected along each myofascial meridian collagen, resulting in the continuity of many functions, such as muscle relaxation.

Myofascial release techniques that use the ERGON IASTM TECHNIQUE improve the elasticity of muscles in adjacent areas. Two studies showed improved elasticity in hamstrings and hip abductors following treatments in the trunk and the upper part of the lateral line (ribs and quantratus lumborum), respectively.

One study showed improved elasticity in hamstrings following treatment aimed at the trunk area of the body. More specifically, 60 university students with shortened hind thighs performed the "sit and reach test" once a week for one month. Participants were divided into three groups: in the first treatment group, manipulations were performed on the hamstrings; in the second treatment group, on the trunk; finally, the third group was the control group, with participants receiving no treatment. In each session, the participants from all groups were evaluated in terms of hamstring elasticity using an angle meter in the straight leg raise (SLR) test. Statistical analysis showed that both treatment groups improved hamstring elasticity in four weeks [117].

A second study showed improved hip-abductor elasticity following treatment in the upper part of the lateral line (ribs and quantratus lumborum). Participants received one treatment per week for six weeks to increase the elasticity of hip abductors. The techniques were applied to the upper part of the lateral line (ribs and quantratus lumborum), to the lower part of the lateral line (the iliotibial band), and, finally, to the entire lateral line. Elasticity improved almost to the same degree in all three groups [118].

Furthermore, the effect of soft tissue mobilisation on the remote parts of the myofascial meridian can extend to the interconnection of non-adjacent anatomical areas. As shown in a study conducted by the Laboratory of Therapeutic Exercise and Sports Rehabilitation at the Department of Physiotherapy at the University of Patras, Greece, there was a significant improvement in hip abductor elasticity and an increase in the hip abduction ROM following applications on scalene muscles [111].

Therefore, in their clinical practice, therapists should include the IASTM treatment of remote areas and points that connect through the fascia lines during the acute phase of the injury. Such immediate interventions will ensure that the elasticity of the treatment area is improved or maintained without the pain and discomfort that would otherwise be caused by direct treatment of the actual injured area.

2.2.8 Effects of ERGON IASTM on the restoration of the biomechanical function of joints

The ERGON IASTM techniques improved the ROM and athletic performance in in 15 professional volleyball athletes, who underwent ERGON treatment once a week for a total of three weeks. The athletes performed specific tests before and after each intervention, which included measuring the ROM of flexion and the internal and external rotation using an angle meter as well as carrying out shoulder functional assessments using the functional throwing performance Index test (FTPI) and the one-hand shot put performance test (OSP). The results showed that the intervention with the ERGON IASTM TECHNIQUE led to better outcomes in improving the ROM compared to the foam roller and the elastic bandage [119].

ERGON techniques can also be combined with neuromuscular exercises aimed at improving the supraspinatus tendinosis. The study by Fousekis et al. in 2017 provided primary evidence that the mobilisation of soft tissue in combination with specialised therapeutic exercise can offer faster therapeutic results in the ROM and in the reduction of pain [120].

In conclusion, the ERGON IASTM TECHNIQUE is a new technique that, based on the latest research evidence, can contribute significantly to sports rehabilitation. More specifically, it enables therapists to improve the ROM, reduce pain, improve the performance of athletes, increase the temperature of the tissues, and improve blood circulation within a few sessions.

2.3 Muscle blood flow occlusion: the kinetic flossing technique

The elastic ischemic bandage is another popular tool in the rehabilitation and prevention of sports injuries. Initially, applications of the ischemic bandage were aimed at improving the performance of athletes. The technique involves an elastic band, made of rubber-latex material, with which the therapist applies an ischemic pressure to the treated limb. The size of the bandage depends on the size of the anatomical structure. Techniques are usually performed in combination with kinesiotherapy or joint mobilisation techniques.

The technique results in multiple effects that require further research. Seemingly, it produces several hemodynamic and biomechanical adaptations.

Hemodynamically, there is an immediate reduction in local blood flow. The removal of the bandage is followed by sharp hyperaemia that increases fibroblastic activity. These normal hemodynamic adjustments after the application of the bandage contribute to (a) the regeneration and restoration of the injured collagen, (b) the removal of inflammation derivatives and pain metabolites, and (c) the desensitisation of the nerve endings and thus to the reduction of local pain and sensitivity [121, 122].

Biomechanical adaptations include compressing and decompressing tissues and correcting the position of the joints and the posture of patients [123, 124].

Research has shown that ischemic bandaging has positive impacts on improving the ROM. More specifically, researchers have evaluated the use of the ischemic bandage for the dorsal flexion ROM and noted an immediate improvement [123, 125].

Also, two more studies have found a significant increase in the ROM of the humerus joint after using the ischemic bandage [125, 126]. The use of the ischemic bandage has also been shown to have positive impacts on athletic performance. More specifically, the application of 2′ on the ankle joint brought about an improvement in jumping ability and in acceleration in 52 and 69 athletes, respectively, with this improvement being maintained for 45′ [127, 128]. Finally, a study performed in 2018 found that the use of the ischemic bandage had a positive impact on DOMS [129].

In conclusion, the muscle flossing technique seems to be a basic or additional treatment tool for the rehabilitation and prevention of sports injuries. Although it is a new technique that needs to be researched further, the ischemic bandage seems to improve the peripheral joints ROM, DOMS, and athletic performance.

2.4 Cupping therapy

The negative pressure massage technique involves the use of suction cups, which, when applied to targeted areas of the body, lead to myofascial decompression, in contrast to the adaptation observed during classic massage manipulations, when the soft tissue layers are compressed.

There are various techniques for applying cupping therapy. The most prevalent are the static application, which involves small incisions being made in the skin (wet cupping), and the dynamic application, which involves the suction cups being moved to adjacent tissues after application.

Theoretically, the effectiveness of the technique is based on the decongestion and suction of blood and other components that accumulate in deep tissues, the removal of which leads to increased arterial and lymphatic circulation and relief from painful muscle hypertension. During the application of this technique, the created negative pressure leads to the decompression of the myofascial area and the movement of blood and other components to the superficial tissues. This can help in pathological conditions in which congestion of inflammatory extravasations and toxins, such as deep accumulations of blood and swelling or the presence of myofascial adhesions and fibrosis and the presence of pain trigger points [130, 131].

The main mechanism behind the use of cupping therapy involves vascular-blood adaptations. In particular, the decompression of the injured areas and the removal of inflammatory agents and blood can lead to a local increase in blood and lymphatic circulation and thus to better oxygenation and tissue metabolism [130]. Cupping therapy has also been associated with a decrease in pathological conditions, such as migraines [132] fibromyalgia [133], neck pain, arm pain and back pain [131, 133–135], and carpal tunnel syndrome [136]. The reduction of pain observed after the application of cupping therapy is based on the reduced irritation of the pain receptors due to the reduced concentration of edema and hematomas in the tissues [5].

In addition, local vasodilation can lead to increased parasympathetic activity and local muscle relaxation [130, 137]. It should also be noted that no research has shown negative adaptations in the human body due to the use of cupping [131, 138]. A study by Liu et al. to control the skin temperature after cupping therapy at acupuncture points in patients with neck pain showed an immediate rise in temperature after the suction cups were removed from the skin. Afterwards, the temperature decreased gradually, with the temperature returning to pre-treatment levels after 30 minutes [139].

2.4.1 Clinical applications of negative pressure massage (cupping therapy)

2.4.1.1 Static application

For static application, suction cups are placed on the skin to create negative pressure for a period of 5–15 minutes, depending on the athlete's tolerance. The application is done without using an emollient. The patient will initially feel a superficial discomfort that will gradually change into a feeling of deep heat.

The application can be done for all areas of the human body as there are cups of many sizes.

Cupping therapy can be used either for pain trigger points or for an area of general sensitivity (e.g. back pain).

Local application can help move hematomas-swellings from deeper layers of tissue to the surface and is used in the treatment of muscle strains. This technique is applied in combination with stripping massage (using hands or IASTM tools) and is particularly effective in mobilising post-traumatic edema-hematomas.

Initially, cupping therapy is applied directly to the injured tissues to move the edema-hematomas to the surface. This is followed by deep massage applied from the periphery towards the centre of the body by hand or using special tools, such as the ERGON TOOLS. This step is performed to mobilise accumulations. The research by Fousekis et al. describes in detail the procedure that was used for an athlete with a hamstring strain, which reduced the recovery time by 50% [110].

2.4.1.2 Dynamic application

In addition, the local application of cupping therapy can be used in combination with stretching to increase elasticity. For example, to increase the elasticity of the

IT band, 4–5 suction cups can be applied along the band, which allows the band to be stretched. Immediately after the removal of the cups, strong circular signs of ecchymosis appear on the body, pointing to the hyper-circulation of the area and a mild skin injury. Depending on the metabolism of each athlete, these signs take 2–7 days to disappear.

Cupping therapy is also used in combination with kinesiotherapy and simultaneous movement of the cups on the tissue. For example, to increase the elasticity of the hamstrings, the cups can be applied to the treated area, and while the athlete performs a self-stretch, the therapist moves the cup in the area.

Dynamic cupping therapy is becoming increasingly known for improving the elasticity of the injured area and improving the range of motion [140].

In the dynamic treatment, while the suction cup is being moved, it is necessary to use a special massage emollient. Immediate vasodilation leads to increased blood flow, which facilitates healing as well as lengthening and improving short muscle movement [139].

Research conducted to evaluate the elasticity of the hamstrings showed a significant increase in motion range of the hip and the knee via the SLR test, although the strength of knee flexion was not increased according to the tests performed on an isokinetic dynamometer [141].

Scholars have reported that cupping therapy is useful in reducing pain. A study by Fousekis et al. in 2016 demonstrated the effectiveness of cupping procedures in reducing pain in soccer players with painful trigger points in the lumbar area of the spine, with the participants showing an immediate reduction in pain and pressure sensitivity [98].

2.4.1.3 Massage using cupping therapy

Massage that involves the use of cups is gradually becoming more widespread in the treatment of myofascial problems in athletes. In addition, it is used as an aggressive approach to reduce swelling and hematomas. For the application of this type of massage, the use of emollient is required so that the cups can be moved smoothly.

The application is done by initially placing the suction cups upon the treatment area. When it comes to areas of intense spasms, suction cups can remain in static application for a few minutes (5–15) before being moved. The application for the reduction of edema and hematomas and their suction towards the surface of the skin can be done either locally as mentioned earlier or by movement. In the latter case, the application must be carried out in two phases, as is done in muscle stripping massage. The first phase involves placing the cups on the periphery of the injury and the moving the suction cups towards the centre at a very slow pace. The second phase involves applying the cups directly on the injured area and again moving the suction cups towards the centre in an attempt to move the deep hematomas and swellings to the centre and towards the surface.

3. Conclusions

Soft tissue techniques have been used since ancient times for the treatment of various pathologies. Their goal is to promote health and wellness through the body's response to mechanical effects such as compression, sliding and decompression of tissues. Therapists apply various techniques either manually or with the use of tools to achieve therapeutic goals. Techniques are divided, depending on the goal, in appeasing and stimulating. Mechanisms activated during soft tissue techniques as well as the effects of the techniques on different pathological conditions have been and still are being systematically researched. It is crucial for therapists to select the appropriate technique to evaluate and treat tissues. For this, good knowledge of the parameters of each technique is needed as well as setting specific treatment objectives such as improving elasticity, increasing ROM, reducing pain and spasm, and increasing athletic performance. Massage, ERGON IASTM TECHNIQUE, KINETIC FLOSSING and cupping therapy are commonly used for the rehabilitation of various musculoskeletal conditions. In order to achieve optimal results, these are often part of treatment protocols which include additional techniques and/or therapeutic exercise. All four have been proven to serve well either as basic or secondary treatment options for sports injuries prevention and rehabilitation.

More specifically, sports massage is beneficial before, during and after the game. Before the game, therapists apply specialized techniques to prepare muscles for the intense loads, especially on the limbs, or/and to prepare the central body (trunk) which constitutes the biomechanical basis for the initiation and proper execution of movement. During the game, sports massage mainly serves as psychological support for tackling competitive stress as well as for improving performance at the next phase of the game. Through stimulating aesthetic receptors, it reduces painful muscle tone and muscle excitability while at the same time improving the sense of physical recovery. Massage after the game increases blood circulation, reduces the feeling of fatigue, and muscle pain, reduces the intensity of DOMS in athletes and consequently contributes to faster and fuller recovery. Massage after the game has been found to lead to faster recovery of strength levels compared to passive movement therapy. It can also play an important role in repairing sports injuries through reducing the concentration of edemas caused especially when in combination with cupping therapy, and IASTM techniques. Finally, massage is particularly useful in scar tissue treatment and painful trigger points mobilization.

ERGON IASTM TECHNIQUE allows sports physiotherapists to detect abnormalities of the soft tissue such as scars, adhesions, restrictions, trigger points via the initial scanning procedure. Post injury, ERGON IASTM TECHNIQUE is effective in mobilizing edemas, in combination with aggressive soft tissue techniques, thus speeding up recovery time. It reduces the pain through local increase of the temperature and of tissue elasticity by minimizing adhesions. Its most significant contribution is the increase of elasticity. Research done at the Laboratory of Therapeutic Exercise and Sports Rehabilitation at the Department of Physiotherapy of the University of Patras, Greece, has shown the technique's effect in elasticity increase throughout an entire myofascial line/meridian in cases of application only in one of its parts. Lastly, ERGON contributes to the restoration of biomechanic function in combination with therapeutic exercise.

KINETIC FLOSSING is a relatively new soft tissue mobilization technique showing multiple benefits for musculoskeletal rehabilitation. Therapeutic mechanisms include hemodynamic and biomechanical adaptations. Its effects include increasing ROM, enhancing athletic performance, and reducing DOMS.

Cupping Therapy is a well-known technique used from ancient times in many cultures which utilizes negative pressure for soft tissue decompression as well as mobilizing blood and superficial tissues. Its clinical value lies in drawing hematomas-edemas from deeper layers of tissue towards the surface and removing these in combination with other forms of aggressive soft tissue techniques. In addition, cupping therapy increases elasticity of tissues and improves ROM of injured joints, and contributes to pain reduction.

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Section 2

Sports Performance

Chapter 6

Sports Science and Efforts towards Sub-Two Hour Marathon Performance

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Abstract

Performance in different athletic activities has continued to improve over time, with some athletes from diverse parts of the world registering new world records from time to time. With stiff competition from athletes from different parts of the world, constant upgrading of sports science based approaches to training and competition are employed to achieve more success. However, some approaches used to improve sports performance may pose ethical concerns and may challenge sports as a concept of celebrating natural human abilities. This book chapter interrogates the factors associated with efforts towards improvement of performance in endurance sports events, with a specific focus on marathon races, and the future implications for training, competition, and the nature of sports. While the interplay between nature and nurture determines the unique psychophysiological responses to training and competition, technological exploits leading to advanced sports products coupled with favourable natural and/or manipulated internal (body) and external environmental conditions will ensure continued improvement in performance. However, there is a need to censor commercial interest as well as safeguard safety and the nature of sports as a medium to celebrate natural human abilities.

Keywords: athletic competition, athletic performance, athletic training, endurance running, Olympic motto

1. Introduction

The Olympic motto "Citius – Altius – Fortius" which expresses the aspirations of the Olympic Movement as captured in the Olympic Charter [1], resonates perfectly with the innate human desire to do and accomplish more in life. The three Latin words mean Faster - Higher – Stronger (modified by adding '-Together' in 2021) and were first expressed by Dominican priest Henri Didon during the opening ceremony of a school sports event in 1881 [2]. These words were adopted by Pierre de Coubertin, who was present that day, as the Olympic motto and included in the first Olympic Charter in the 1890s. It expresses the aspirations of the Olympic

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Movement in its athletic and technical sense as well as from a moral and educational perspective [2]. This desire has led human beings to seek ways to work efficiently and improve their performances in the diverse aspects of life. Over the years, many sports practitioners have turned to sports science to develop and use a variety of ergogenic aids. Great efforts have been made to discover innovative ways that can help athletes to achieve an edge over their opponents in the sports arena [3]. Techniques or substances used for the purpose of enhancing sports performance are referred to as ergogenic aids and they act by improving energy production, energy control, or energy efficiency [4]. These come in many forms including –but not limited to, physical, mechanical or technological, nutritional, psychological, and pharmacological methods that either directly improve physiological variables associated with exercise performance or remove subjective restraints that may limit physiological capacity [5, 6]. As the variety of ways athletes seek to improve their chances of winning are becoming increasingly difficult to distinguish from doping concepts [7, 8], there are growing legal, ethical, and safety concerns that threaten the integrity and survival of sports as a socio-economic institution and one of the largest industries, with an estimated global turnover worth over 1.3 trillion USD in 2017 [9, 10]. The aforementioned is exemplified by running sports -both short-distance and long-distance events. This chapter focuses more on distance running, particularly on the marathon.

1.1 Historical perspective of endurance running

Distance running is said to have been used as a means of hunting for food, survival, and mode of transportation during early civilisation [11, 12]. However, it developed into an endurance physical exercise and a popular major athletic sport that it is today. As an exercise, it serves to improve cardiovascular system, strengthens bones, improves knee health, boosts mood or self-esteem, and alleviates stress [11, 13–15]. As a sport, distance running comes in different forms, including track events and road races, the marathon being the most popular. The history of the marathon race dates back to the ancient Greek civilisation. In 490 B.C., a Greek soldier named Pheidippides ran from Marathon to Athens, Greece (roughly 25 miles), to deliver news of a military victory against the Persians at the Battle of Marathon, immediately after which he kneeled, fell over and died -probably because he had not trained for the extensive running feat [11, 16]. During the onset of the modern Olympic Games in 1896, a "marathon" race was organised to pay tribute to Pheidippides, spanning from Marathon Bridge to Olympic Stadium in Athens, with an estimated distance of 24.85 miles [17]. The marathon race was later established as 26.2 miles at the London Olympics in 1908. Many more marathon races continued to be organised within and outside the Olympic Games. The Boston Marathon was first held in 1897, this being the oldest marathon after the initial event in the first modern Olympic Games in 1896 [17]. The road-running sports industry has continued to expand with an estimated value of $1.4 billion in 2015 in the U.S. alone, with the running shoe business alone said to be worth about $3 billion [11, 18, 19]. An increasing number of people are taking part in marathon races both for recreation, fun, and as a professional pursuit, with some of the major events such as the Abbott World Marathon Majors registering more than 50,000 runners each year [11].

1.2 Efforts towards sub-two hour marathon

Performance in the marathon race has gradually improved over time, with top athletes recording times just short of two-hour mark (by less than 5 minutes in the recent times since September 2003) [20]. According to the World Athletics records, the all-time top 100 performances thus far range from 2:05:47 by Marius Kimutai in Amsterdam on 16 October 2016 to 2:01:39 by Eliud Kipchoge in Berlin on 16 September 2018 [20]. It is important to note that athletes from the East African region account for about 90% of all-time marathon performances, with Kenyans accounting for 47% and Ethiopians 41%. This phenomenon has continued to attract researchers all over the world, with no consensus on the reasons behind the world dominance in distance running performance, although several factors have been proposed [21, 22].

With race performance times edging closer and closer to two hours in recent times, it is believed that it is a matter of time before a sub-two-hour marathon performance is achieved. Efforts have been made to achieve this sooner [23], particularly by athletes from East Africa, with their agents working hard towards this elusive mark. One such effort has been made by the World and Olympic champion Eliud Kipchoge, who ran the world's first sub-two-hour marathon, clocking 1:59:40 in Vienna in 2019. However, the performance was not recognised in the official world records because of what was said to be the 'use of pacemakers who were getting in and out of the race', pacing laser beams, as well as 'placing of refreshment into his hand instead of him picking them', which are privileges that are not found in normal race conditions [24, 25]. Kipchoge who had set the marathon world record of 2:01:39 in Berlin in September 2018 was recorded saying that "Running Berlin and running Vienna are two different things; Berlin is running and prepping a world record, Vienna is running and making history in this world, like the first man to go to the moon" [26]. The feat was accomplished running on a straight flat course through the Prater Park with curved turns at each end. The event was organised by Sir Jim Ratcliffe, the INEOS chairman and CEO [27], a few years after similar efforts by Nike in 2017 fell short of the target by 26 seconds [28]. With the race hyped up through the 'No Human is Limited' slogan, he aimed to inspire humanity to realise that we can stretch our limits in our lives and we can do more than what we think we can do, to inspire others to believe they can overcome their own personal barriers. Even though the performance is not recognised as a world record, it gets a step closer towards realisation of similar performances in a competitive race situation.

2. Sports science and training methods

Over the years, athletes and coaches have sought better training methods to improve their performance. Running a marathon race requires adequate preparation in terms of training. Although exceptional cases of people who ran and finished a marathon race reportedly without known training for the same have been recorded, they are just a few unique cases. One of these is the original marathon race by the Greek soldier Pheidippides cited above, with the apparent lack of training for the race leading to his sudden death soon after the race –after delivering the important message which may have been the key motivation. The other recorded cases are the first African Olympic marathon athletes who participated in the third Olympic Games hosted at St. Louis, USA in 1904. The event was hosted by the USA as a part of a "World's Fair" where various Olympic events were slotted between other attractions at the Fair. With disappointing international participation (Athletes from only thirteen countries entered), the organisers invited everybody at the "World's Fair" to participate. Among those who took this opportunity were two African workers, Len Tau and John Mashiani, who were at the Fair participating in "Anglo-Boer War Historical Libretto" show, a revue that re-enacted scenes from the Anglo-Boer War (1899–1902). Len Tau, who ran barefoot, finished ninth in the marathon, and Jan Masiani thirteenth. They became not only South Africa's first Olympians, but also the first athletes from Africa to participate in the Olympic Games. It is said that Len

Tau was chased off course by a stray dog, and it is estimated that he lost up to six minutes in the process and thus, could have performed much better [29]. Although the escapades of Pheidippides, Len Tau and John Mashiani cited above are hailed as cases of great feats of outstanding performance in marathon races without specific training, it is worth noting that all of them were battle-hardened soldiers [11, 30], probably with the advantage of years of physical training and mental resilience from prolonged wars. This resonates with the fact that early sports' training was intertwined with training of warriors [31].

Over the years, better training plans have been constantly sought, with sports science advancement providing evidence-based methods and procedures to continue achieving more success. The principles of training, such as overload and recovery, have been known since ancient times. The legendary Milo of Croton who was a six-time Olympic Champion in 6th century BC is said to have begun carrying a young calf as a young man on his shoulders each day and walk around a large stadium. And as the animal grew, Milo also grew stronger and eventually he was able to carry a fully-grown bull [32]. It has long been understood that gains in fitness occur when we rest and adapt to the challenges of our workouts [33]. Before the 1900s, most distance runners mainly used continuous forms of training by doing a few long runs and incorporating periods of long walks into their weekly routine, often incorporating a short (half-mile) speed run in early morning and in the evening. The term 'scientific training' was gradually used to refer to the training of athletes, but most training methods continued to rely heavily upon the accumulated experience of successful athletes and trainers [13]. In the early 20th century, interval training -a form of repetition training started becoming popular among runners [11, 34]. In the 1930s, "hill repeats" and "fartlek" (involving varying the speed throughout a run, often alternating fast and slow or fast and medium on varying terrains) emerged as training methods. In the more recent times (late 20th century and early 21st century), the concept of 'Lactate Dynamics Training' or the 'New Interval Training' which combines some aspects of fartlek and interval training is gaining traction. Fartlek training is a training method that was first developed in the late 1930s by the Swedish coach, Gösta Holmér [13, 34] as a response to the Swedish distance athletes' apparent lack of success against the Finnish teams of the day, and also due to limited access to specially built training facilities in Sweden at that time [34]. The word 'fartlek' itself comes from the Swedish word for 'speed play' and indicates the nature of this training method which provides for a variety of speeds or paces, combining continuous aerobic emphasis training with faster-than-race-pace efforts. Fartlek allows the athletes to run whatever distances and speeds they wish and to 'play' with varying intensity -occasionally running at high intensity, other times at lower intensities -and varying the terrain [34]. It is an incredibly powerful method for all endurance athletes to develop their natural rhythm and accompanying 'lactate dynamics' abilities away from the track with elements of fun and stimulus variations [34, 35].

The new interval training also referred to as lactate dynamics training takes the physiological principles that are similar to fartlek training and adds to it the development of pace and rhythm techniques on the track. It aims at developing race-pace rhythms by raising athlete's awareness through accurate feedback, in the track environment. The 'lactate dynamics training' term is used to specifically classify the training for the lactate shuttle, the dynamic utilisation and clearance of lactate so that lactate is optimally used around the body [34–36]. The emphasis is to avoid suddenly slowing down at the end of the faster repetition and then speeding up at the next repetition -as in classic interval training, but rather to transition smoothly and quickly from the pace of the faster repetition to the pace of the active roll-on recovery. At the end of the roll-on recovery, there should be an equally smooth and rapid transition back to the faster pace of the repetition. The goal is the optimal development of the lactate energy system by training at fluctuating intensities where lactate production, utilisation, and clearance are encouraged. This lactate clearance from the body is accelerated when lactate is shuttled to areas of high oxidative activity while maintaining an active running pace [34–36].

In addition to running exercise, weekly training programs for distance runners of late also incorporate two to three days of interval or circuit-based workouts interspersed with days of long running mileage [11]. They include some other activities in their fitness routines, mainly strength/resistance training to keep their core strong, flexibility exercises, and low-impact activities like water exercise and elliptical or cycling for therapeutic reasons and to target muscles that are not activated by running [11]. This ensures that more parts of the body work together cooperatively to improve running efficiency, thus boosting performance. There is also ongoing discourse among sports scientists on improving training outcomes by matching training loads to athletes' individual hemodynamics and heart function [37–39] as well as leveraging on the much sought after 'endurance running genotype' [40, 41]. Polishing running technique for maximum efficiency by optimising both lower and upper body kinematics has also been subject of continuing biomechanics research [42, 43]. Emerging technology involving electronic pills is also likely to influence performance in distance running and other endurance sports. So far there are reports of the technology having been used on experimental basis in Doha 2019 World Athletics Championships and in Tokyo 2020 Olympic games to monitor endurance athletes' vital signs in real time [44, 45]. These are indications that sports science has impacted and will continue to impact the future of endurance running sports in diverse ways.

3. Sports science and pursuit of better sports apparel and products

Together with advancements in training methods, sports science has led to the evolution of sports products that continue to stretch performance limits over time. Technologically enhanced running shoes, apparel, and sports drinks are some of the fronts where sports science is being applied to improve training and performance in endurance running.

3.1 Role of shoes and shoe technology in running performance

Despite evidence of a few distance runners recording good performance while running barefoot [29, 46, 47], running shoes play a significant role in running performance [48]. One of the exceptions is Len Tau, one of the two first athletes from Africa to participate in an Olympic Games, who is said to have run barefoot and finished ninth during the third modern Olympic Games, St. Louis, USA, despite the lack of specific training for the race and after being chased off-course by stray dogs [29]. According to Lieberman et al. [46] and Rothschild [49], there is evidence of improved intrinsic foot strength and improved physiological economy when running barefoot, but no evidence for injury reduction or improved performance. Several studies support barefoot running and minimalist shoes for the proposed advantages of improved sensory feedback and proprioception and reduced impact forces [46]. Another unique exception that might imply less contribution of running shoes is the case of Jim Thorpe, the first and only athlete ever to win both pentathlon and decathlon Olympic gold medals at a single Olympic Games during the Games of the V Olympiad held in Stockholm, Sweden in 1912. Someone had stolen his shoes just before he was due to compete on the final day, but he found a mismatched pair of replacements, including one from a trash can, and won the gold medal wearing them [50]. Additionally, some Kenyan athletes are known to have won medals while running barefoot, including Sabina Chebichi, who won her first marathon in 1973 while barefoot and wearing a petticoat [47]. Despite these few recorded cases, the importance of running shoes and their roles in safety and performance have been well appreciated over the years.

Running shoes have continued to evolve since early times, with Adolf Dassler making running shoes in the form known today in the early 1920s [7, 11]. Earlier, there were efforts to make special running shoes, including Japanese five-toed shoes, albeit with no recorded impact on performance; however, this inspired the concept of minimalist shoes even present today such as the Vibram Five Fingers. More impactful distance running shoes currently include prime offerings such as the Nike Vapourfly and Alphafly series, Hoka One One Bondi series, New Balance Fresh Foam, Asics Gel-Nimbus, and Adidas Ultraboost [51]. Appreciating the uniqueness of each runner, some companies offer sneakers customised to specific runners' individual gait type and shoes for those who need stability or have flat feet [11, 52]. Adolf Dassler offered shoes that were made especially for running certain distances, some of which had spikes and were used by successful athletes such as Jesse Owens in the 1930s. In the 1960s, New Balance offered what would be the first mass-produced sneaker weighing less than 11 ounces, and then Nike entered the game with its Waffle Trainer in 1974. Later in 2016, the same company came up with carbon fibre plate (CFP) and foam technology shoes with the vaporfly series, and lately (2019) the Alphafly series –used by Eliud Kipchoge during the INEOS 159 Challenge [7, 53]. Other shoe manufacturers, such as Hoka One One carbon X brands, have also adopted CFP and foam technology. Since this innovation, every women's and men's world records from 5 km to the marathon have been broken [7, 48]. This is largely attributable to innovations in shoe technology leading to increased elastic properties of the shoe which is associated with reduction in the energy cost of running. The latest CFP and foam technology running shoes are said to influence performance by optimising the running technique biomechanics and efficiency, reducing potentially harmful impact forces from the foot ground strikes and returning energy to the runner [7, 52]. Their use is said to aid performance in endurance running by reducing mechanical energy resulting from minimal flexion of the forefoot, with the athlete using midsole foot-ground strike as opposed to the common forefoot landing, and maximising the energy returned from the bounce [7, 48, 53, 54]. The stiff carbon fibre plate within the midsole may also help by redistributing positive lower limb joint work from the knee to the joint of the toes above the ball of the foot, as well as by storing and returning energy to the runner [52]. The CFP and foam technology running shoes are acknowledged to increase running economy by more than 4% [55], corresponding to a greater than 2% improvement in performance/run time [7].

However, the use of CFP shoes has provoked debate on the impact of shoe technology on the essence and credibility of sports. Concern has been raised that, although the true impact of CFP shoes on running performance is yet to be scientifically tested in the field, there are indications that the recent improvements in long-distance running times are technologically driven rather than physiological [7, 28]. Moreover, access to this performance-defining technology may become the primary differentiator of sporting performance in elite athletes. The high cost of the technologically improved shoes would be out of reach for most athletes, especially those from underdeveloped countries such as East Africans who have dominated long-distance running worldwide for more than 50 years, thus alienating them [56]. Another downside dimension could be the financial exploitation of athletes as they go all out to invest in specially made running shoes by manufacturers and/or generic counterfeit vendors in the hope of gaining the widely advertised but scientifically unproven benefits in running training and competitions. This is not remote given that several African runners have registered excellent marathon performance running barefoot [29, 46, 47]. In his response to allegations that advanced shoes give him undue advantage, Eliud Kipchoge said that 'records are broken by individuals not footwear'. He however observed that checks and balances are important as running technology evolves [57].

3.2 Apparel innovations and running performance

Over time, diverse commercially available running apparel have been shown to improve performance for both sprints and distance running. These include a range of singlets and shorts as well as bodysuits with properties such as stretchability, water vapour permeability, and thermoregulation compression fabrics. These properties -separately or in combination, aid in training, recovery, and performance. Many renowned athletes are known to have achieved outstanding performances while wearing aerodynamically optimised apparel [58]. These include Eliud Kipchoge during his first and second attempt to run a sub-two-hour marathon, eventually succeeding on the second attempt in 2019 at the unofficial marathon race dubbed the INEOS 159 challenge.

Infrared attire technology is another recent development that is creeping into sports apparel development. Far-infrared ray-emitting clothing is currently being tested and utilised to enhance training, recovery, and performance during actual sports events [59, 60]. A study by Loturco et al. [60] investigated the effects of far-infrared (FIR) ray-emitting clothes on indirect markers of exercise-induced muscle damage and recovery after a bout of plyometric physical performance among soccer players. This study found that FIR clothes may reduce perceived delayed onset muscle soreness after an intense plyometric session. A systematic review by Bontemps et al. [59] revealed that studies investigating the beneficial outcomes of FIR clothes related to exercise performance or recovery are scarce and the results are largely inconclusive. However, the author acknowledges that some studies in this relatively recent field indicate positive outcomes associated with far infrared effects on the body's thermoregulation and hemodynamic function [59]. It is possible, therefore, that this recent development in sports apparel will influence training and performance in a variety of sports, including distance running.

3.3 Sports drinks and nutritional supplements: manipulating the internal environment

Fluid and electrolyte replacements are another area in which sports science has focused on improving endurance running. Electrolytes lost through sweating in a long race include sodium and chloride -in high concentrations, and potassium, magnesium, and calcium in low concentrations. All these electrolytes are essential as they work together to maintain fluid balance in the body at rest and during physical activity. Buffering acidosis is another crucial role of electrolytes such as sodium bicarbonate, thus regulating acid–base balance (blood pH) [61]. Therefore, it is important to replace any lost electrolyte in order to maintain a stable internal environment for optimal metabolic processes. This is recommended for high-intensity exercise with an extended duration of more than 61 min, where heavy sweating is expected, especially in environmental conditions of high ambient temperature and humidity. Moreover, replenishing fuels, in the form of blood glucose, are important for such exercise in order to avoid early fatigue and exhaustion. In this case, it is recommended to athletes to take sports drinks or nutritional supplements that top up carbohydrate reserves and electrolytes during and after long runs [62, 63]. Sodium in a sports drink helps the body absorb and retain body fluids, and utilise carbohydrate. Endurance-specific electrolytes and calorie sports products such as the First Endurance Electrolyte Fuel System (EFS), Gatorade Endurance Formula, Luna Electrolyte Splash, Hammer Motor Tabs, and Powerbar Endurance Sports Drink are designed to offset higher losses of fluids and electrolytes through heavy sweating associated with muscle cramping [62]. There are also supplements such as beetroot juice, caffeine, and glycerol, which are said to boost performance and help the body cope with the demands of marathon training. However, their effects vary among athletes and may depend on training content, physical condition and habits [64].

Recent advancements in sports drinks seem to have triggered a fuelling revolution in the use of hydrogel technology by Maurten, the company that brought a new kind of sports drink mix and gel to the market in 2017. The Maurten sports drink has been widely embraced after being used by high-profile athletes -including Eliud Kipchoge in 2017, when he set a new marathon record twice, as well as in his epic trials to break two-hour barrier [65–67]. For many years, nutritionists and exercise physiologists have recommended that marathon runners consume no more than 45–60 g of carbohydrate per hour. Taking in more has been associated with increased risk of bloating, nausea, diarrhoea, and other gastrointestinal problems that affect 30–50% of runners [67]. However, some researchers believe that higher carbohydrate intake would likely result in better performance than lower intake in events lasting longer than two hours [65, 67]. In 2015, Maurten seemed to make a breakthrough when he discovered a way to encapsulate carbohydrate molecules using hydrogel technology. This is said to allow carbohydrates to move through the acidic stomach and to the intestines, where they can be absorbed more easily and help sustain performance. This lets one fuel more by taking in more calories without increased risk of gastrointestinal problems, and enable one to perform better in the race [65–67]. It is important to note that there are no empirical data so far that scientifically validate this notion. The product company website indicates that a number of studies are currently evaluating their technology and products and they are expecting that the first peer-reviewed paper will soon be published in support of their technology [66]. This will be necessary, just as with many other products of this nature, to reassure the users of the efficacy and safety as well as to dispel the notion of commercial interest as the key force behind the product's popularity.

4. Fluid dynamics: manipulating the external environment

Wearing aerodynamic running kits has been adopted by many athletes and is appreciated as a great way of reducing resistance, hence contributing to better performance times, as one moves through the fluid (water for swimmers, air for runners and cyclists) [24]. This has been taken positively, as even race organisers seem to be quick to judge whether the race times are 'wind assisted' or not [68]. With a long race like a marathon that takes more than 2 hours to complete, air current is a key consideration; thus, the above efforts are needed. While aerodynamic body frames and apparel have been shown to reduce air resistance encountered by runners [69], runners and coaches have also explored running in different positions and formations to take advantage of favourable air currents [24]. This has been augmented by the case of INEOS 159 Challenge, where a formation known as the delta formation, with a group of rotating pacers, was said to have been adopted to remove wind resistance from the main runner, Eliud Kipchoge [24, 70]. Even though the organisers indicated that they extensively tested different formations using manikins, the effects of the formation adopted on the main runner were not specified. Moreover, the choice of the running venue (The Prater Park in Vienna) and a straight and tree-lined course which runs through the heart of the park was said to have been preferred because of its 'optimum conditions' [70], which obviously included relatively calm air. Thus, it was incoherent to think of the running formation as being designed to avoid wind resistance.

We conducted a study to investigate the drafting effects on dummy models of marathon runners using a wind tunnel (San Technologies Co. Ltd) in the Laboratory of Sports Fluid Mechanics, University of Tsukuba, in September 2020. The dummy models were wooden, 0.4 m high and 0.09 m wide. The indoor temperature and humidity were 25.7°C and 68% respectively. The effect of drag force changes in different dummy model positions was evaluated at a wind speed range of 0–56 m/s. The position, distance and angle of the model were changed to test the influence of wind drag force on the main model under different conditions (Group 1–4). A total of 11 tests were conducted in this study. The results showed the following: 1. The wind drag force of the single model was the largest (See **Figure 1** Group 1). 2. When a wooden model is set at 0.3 m and another at 0.7 m in front of the main model at the same time, the wind drag force is very close to when a single model is set at 0.7 m in front of the main model (See **Figure 1** Group 2). 3. When a wooden model is set at 0.35 m in front of the main model, its wind drag force is close to that of two wooden models with a space of 0.045 m in front of the main model (See **Figure 1** Group 3). The influence of the 0° and 45° angles of the wooden model was not significantly different on the wind drag force. 4. Two wooden models were set up side-by-side (no space) in front of the main model. Owing to the influence of the air vortex, some traction force was exerted on the main model (See **Figure 1** Group 4). The wind drag forces were G1 > G2 > G3 > G4. The authors concluded that setting a guard just in front of a runner may be more effective in reducing the wind force than a formation. However, it should be noted that the experiment did not assess a formation similar to that used in the INEOS 159 Challenge.

In another experiment conducted at Kenyatta University, we tested the effects of turbulence induced by moving wooden models in a formation similar to the one used in the INEOS 159 Challenge (Video 1). The models, which were about 2.5 cm wide with a slight oval cross-section (similar to human trunk), were inserted in still water (temperature; 12°C, density; 0.99 g/ml) in a pool and moved at an average speed of 0.41 m/s. Considering the relative size of an adult marathon runner's trunk of about 40 cm in cross-section, the relative speed of the model runners was about 6.56 m/s, which is close to the INEOS 159 Challenge average speed of 6.86 m/s. The effects of the turbulence were observed at the position of the main model by removing it and placing a loose piece of wood in its place. The loose piece of wood was seen pulled along the wood model formation for a distance of 5 meters (Video 1), confirming tail

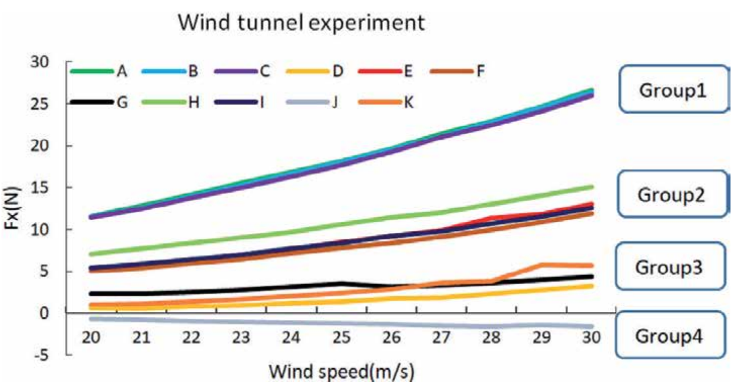

Figure 1.
Wind tunnel experiment results showing wind drag force changes (on the main model) with different positioning of dummy models of marathon runners at different wind speeds.

suction/vortex forces at the position of the main model. Even though the magnitude of forces generated in water are higher than in the air due to difference in densities, the study concluded that the INEOS 159 Challenge formation generated tail suction/vortex forces which may substantially reduce the energy cost of running for the main runner.

With the preceding evidence that air turbulence can be manipulated to improve performance, the dynamics of applying it in an actual race may not be easy. However, we are likely to see more runners trying to apply the concept in the field with their sponsored pacesetters. If several groups of athletes try this at the same event, jockeying and jostling for spaces is likely to ensue, and this could substantially change endurance running competitions from the way we know it.

5. Psychological aspects: power of the mind and motivation

Mental toughness and preparation often separate the best from the rest, as most top athletes are in outstanding physical condition and are technically exceptional [71, 72]. Mental attributes, such as motivation, confidence, focus, perseverance, resilience, and managing nerves are critical in sports performance, even though they are more often neglected in training. Sports science has shown the importance of incorporating mental training directly into an overall sport training regimen to unlock the power of one's mind through various techniques [71, 72]. It is evident that some top marathon athletes, like Eliud Kipchoge, use some of these sports psychology techniques. This is exemplified by hypnosis and self-belief in the 'no human is limited' slogan, as well as the mental boost gained from encouragement by running teammates [70].

6. Legal, ethical, and safety considerations

The advancement of sports apparel and products that continue to stretch performance limits over time have raised legal, ethical, and safety concerns. There are serious implications on rules and regulations, the nature of sports, and the health of athletes that require attention as technology continues to evolve at an ever-increasing rate.

In response to the widespread concern about the impact of shoe technology on the nature of sports as an avenue to promote and celebrate natural human endeavours, World Athletics (WA) has recently (early 2020) modified rules governing competition shoes for elite athletes. This includes sole thickness regulated so as not to exceed 40 mm and not to contain more than one rigid embedded plate [7]. However, the amendment also allowed development shoes to be worn in international competitions prior to their availability to public upon approval of the shoe specifications by WA. Coupled with a popular shoe company releasing a shoe with the said 'maximum' specifications soon thereafter, these raised suspicion on the timing of the new regulations [7]. It has also been noted that the magnitude of race performance improvements by athletes running using CFP shoes which is estimated to be approximately 4% [55] is similar to those expected from substances and methods included on the prohibited list of the World Anti-Doping Agency (WADA), such as blood doping and erythropoietin use [73]. This has elicited a feeling that WA may be abetting "technological doping" and doing little to protect the principle of fairness in sports competition [7]. The scenario is a clear indication that unregulated sports science and technological advancement can threaten the true essence of sports which is based on ethos that exalts natural human effort.

There also exists a controversy related to the ineffectiveness of interpreting the doping concept. It has been observed that the anti-doping process, despite ever-increasing restrictions and control, still produces suboptimal results and is currently not as effective as stakeholders in sports and the public at large would like it to be [7, 8]. With many athletes being reported to have used doping agents post hoc (well after the event), there is increasing scepticism about any outstanding sports performance, which may lead to reserved, truncated, or partially withheld celebration of sports victories. These unfortunate developments will fundamentally affect the nature of sports in the future. Pitsiladis et al. [8] observed that there is an urgent need to increase the quality and efficiency of the anti-doping processes to rebrand and restore the credibility of sports. The authors recommended a holistic anti-doping approach comprising at least three primary anti-doping pillars or 3Ps to prevent doping, protect the clean athlete, and promote performance without doping. There is evidence of implementation of some of these recommendations like in allowing 'clean' athletes from Russia to participate in Tokyo 2020 Olympic Games under ROC after WADA banned Russia from international sports competitions until 2022 due to what was seen as state-sponsored doping cover up scheme [74, 75]. However, it is daunting task to ensure clean sports, but one which must be accomplish through concerted efforts to safeguard the future of sports industry.

With the evidence that air turbulence can be manipulated to generate tail suction/vortex forces which may substantially reduce the energy cost of running, thus improving performance (such as in the INEOS 159 Challenge), we are likely to see more runners trying to apply the concept in the field with their sponsored pacesetters. However, the dynamics of its application to an actual race may not be easy. If several groups of athletes try this at the same event, jockeying for spaces is likely to ensue, which could substantially change endurance running competitions from the way we know it in terms of strategies, tactics, and rules.

Another concern is that advanced sports products are only available to a few privileged members of society. This raises the issue of whether it is ethical or if it amounts to unfairness by disenfranchising the majority of the population who cannot afford the high costs associated with such products. In addition, claims on efficacy and/or side effects of most of these sports products are largely not yet proven, determined, or validated in controlled randomised studies. This raises concerns about possible unfair commercial practices as well as the long-term safety and health of athletes.

7. Conclusion and recommendations

From the aforementioned, it is clear that sports science has continued to play an important role in improving performance in sports in general, and in endurance running in particular. Athletes from diverse parts of the world have continued to register improved performances in different athletic events over time, with occasional new world records. With stiff competition from athletes from other parts of the world and the higher stakes in the sports arena, constant upgrades and innovations in approaches to training and competition will continue to fuel more success. However, some approaches pose challenges to the nature of sports as a concept of celebrating natural human abilities. Efforts towards improving performance in marathon/road races and other endurance sports events have been accompanied by technological advancements in sports products such as running shoes, apparel, and sports drinks, which are out of reach to the majority of the population. Moreover, such new sports products have been introduced and widely popularised even before verification or validation through independent controlled studies, posing ethical and safety concerns. Manipulations of racing environments to create and take advantage of favourable air currents/vortex forces have been noted and are likely to impact the nature of endurance races in the future.

The interplay between nature and nurture determines the unique psychophysiological responses to training and competition, and technological exploits leading to advanced sports products coupled with favourable natural and/or manipulated training and competition environmental conditions will ensure continued realisation of the Olympic Motto 'Citius, Altius, Fortius' (Faster, Higher, Stronger). However, there is a need to constantly adjust the rules of the game to censor commercial interest and safeguard the safety of athletes and the nature of sports as a medium to celebrate natural human abilities. This is even more apparent as the IOC moves to expand the Olympic Motto by adding '–Together', to mitigate the effects of differences in access to sponsorship, sports products, and technology, as well as training environments among people of diverse natural athletic talents and backgrounds.

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Conflict of interest

The authors declare no conflict of interest.

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Chapter 7

Warming-Up for Resistance Training and Muscular Performance: A Narrative Review

Pedro P. Neves, Ana R. Alves, Daniel A. Marinho and Henrique P. Neiva

Abstract

Warming-up is an indispensable component of any type of training, aiming to prepare the body for the intensity required by the following exercises. The use of different types of warm-up seems to produce different results, mainly because of the effects on force production. However, the research is not clear and further research is needed. The present study aimed to analyze and discuss the main results of the literature regarding the effects of warm-up on force production, as well as to analyze those responses during resistance training and maximal strength assessments. Additionally, based on the outcomes, we intended to suggest some practical recommendations for sports-related professionals and researchers, providing essential knowledge for their intervention near the athletes, and also to contribute to the performance optimization during training and in the competition. For this, a search on four databases (Web of Science, Scopus, PubMed, and ScienceDirect) for original research published until November 2020 was performed, and then the outcomes were critically analyzed. The literature revealed that there is still little agreement on what should be the best warm-up to be used for strength performance and training. We, therefore, concluded that more research must be carried out and new approaches must be taken to clarify this issue.

Keywords: strength, performance, pre-exercise, warm-up, training control

1. Introduction

The warm-up is widely understood as a preparation practice to perform before any physical exercise. It is usually used by athletes, coaches, and general physical activity participants, to obtain an optimal physical and psychological state and to get kinetic and coordinative preparation in the prevention of injuries during the practice [1–4].

Based on previous studies, the main benefits of the warm-up were increased body temperature, decreased muscle and joint stiffness, [5] increased efficiency in the transmission of nerve impulses, [6] and, simultaneously, the increase in metabolic reactions, leading to the improvement of muscle power [7]. It may also lead to an increase in the dissociation of oxygen, hemoglobin, and myoglobin, causing vasodilation and, consequently, an increase in muscle blood flow [8].

These changes could be promoted by two basic types of warm-up, specifically, the active and passive warm-up [3, 9]. Hot water bags, short waves, hot baths, sauna, are some of the means used to complete a passive warm-up [3, 9]. This type of warm-up provides an increase in muscle and central temperature without energy expenditure, with the use of external heating [3, 9]. On the other hand, the active warm-up can be performed through the use of physical activity, for instance, walking, running, swimming, cycling, or any other specific exercises [3, 9, 10]. One of the main advantages of the active warm-up is its specificity, as it prepares the muscles that will be used during the activity and could benefit from the movement itself [3, 9].

Despite the positive influence of warm-up on sports performance, [9] there is still a lack of specific investigations about the variables that compose it, the optimal warm-up design as well as its effects on the force production and strength training performance [11, 12]. Any movement performed during physical activity requires the use of specific muscles to produce movement. The movement depends on muscle performance and therefore force production, either in maximal or submaximal efforts so that the exercise could be carried out successfully. The role of muscle strength performance is widely recognized in the scientific and sports context [9, 13]. Maximizing the strength and optimizing force production should be a priority to any person participating or willing to participate in sports performance or physical exercise. For this performance improvement, in physical activity and sport context, resistance training (strength training exercises where muscles exert a force against an external load) assumes an important role to develop individual capacities. Moreover, to improve the efficiency of resistance training and force production, the warm-up could be essential. It is important to understand the way that warm-ups can influence strength training and performance, to analyze the effects, and then to provide a useful strategy to apply in the real context. With this knowledge, professionals are able to design a warm-up that will optimize resistance training and thus, maximizing strength gains, force production, and resulting in improvements in physical exercise performance.

It is then important to understand the effect of warm-up in strength performance and this may be through the assessment of maximum dynamic strength (load at 1 repetition maximum: 1RM), isometric strength, or even through the rate of production of muscle strength [3, 10–12, 14]. Previous findings suggested that the warm-up procedure (for example, aerobic exercise, specific activity, and stretching) seems to influence the results of the 1RM assessment, as well as to improve the strength produced during the assessments [3, 12, 15]. Generally, it is recommended that the warm-up routine prior to a 1RM test includes general (aerobic) and specific (imitating target activity) exercises [16–18]. The general warm-up is usually completed using an aerobic activity of low to moderate intensity with the main purpose to increase the muscle temperature, which can be performed with different types of aerobic activity (for example, running or cycling) [3, 10, 12]. Stretching exercises can also be performed as part of a typical warm-up routine. Regarding the specific warm-up, it is recommended to perform it by including exercises that use the same or similar movements as the main activity at progressively higher intensities in an attempt to increase neuromuscular activation [2, 12]. In fact, there is suitable scientific evidence in the literature to support the implementation of only specific warm-ups before exercise, [19, 20] however, the effects of general warm-up on strength measurements are not clear yet.

In order to design an effective warm-up, several parameters and variables are associated with it, which seems to be extremely difficult to select an ideal type of warm-up for all sports. Then, it is necessary to understand what type of warm-up is more appropriate to the variable that influences performance in all exercises, i.e. force production. Thus, our narrative review aimed to analyze and discuss the main results of the literature on the effects of warm-up on force production and strength, by analyzing responses during resistance training and assessments of maximum strength. The results determined in this study, aimed to elucidate sport-related professionals about the effects of warm-up and help them to design their training.

2. Methods

The current study intended to summarize the findings and evidence reported in the literature about the effect of warm-up protocols in force production, strength evaluation and resistance training. In order to identify relevant articles on this topic, an extensive bibliographic search was carried out. Of all the articles identified, only nine were chosen, which corresponded to the theme addressed here.

2.1 Search strategy

A search in the literature that studied different types of warm-up was conducted, where the focus was to understand the effects of warm-up in strength performance. Considering that active warm-up is the most commonly used by people engaged in sports and physical exercise and that is the most investigated, it was only included original articles that focused on the effects of active warm-up. Original research articles published between 2010 and 2020 were selected to identify studies in which warm-up and strength performance were reported. The search for scientific articles was performed in 4 databases (Web of Science, Scopus, PubMed and ScienceDirect) in which the keywords "warming-up", "resistance training" and "strength" with multiple combinations were used and with no restrictions of language.

2.2 Inclusion and exclusion procedures

To carry out this research, the studies had to respect inclusion criteria such as, being focused on active warm-up, being cross-sectional studies, focusing on measures of strength, being carried out by healthy individuals, aged 18 years or over. As exclusion criteria, all types of review (qualitative review, systematic review and meta-analysis) were excluded, the non-use of at least one active warm-up and studies with young participants (<18 years old). Articles that were not written in English were also excluded.

3. Results

The literature search found 163 relevant articles, of which 152 did not meet the defined inclusion criteria. These studies were excluded based on the focus on other physical activities rather than strength-related ones, such as running performance, anthropometric characteristics, or strength evaluation performed in participants of other chronological ages including children. Consequently, a total of 11 studies were considered for further analysis. These studies were published between 2009 and 2020. The studies focus on the results that different types of warm-ups may cause in resistance training (**Table 1**).

Authors	Objective	Sample	Warm-ups	Main outcomes
Ribeiro et al. [21]	Verify the effects of three specific warm-ups on squat and bench press resistance training.	14 males	3 protocols: • 40% of training load • 80% of training load • 40% and 80% of training load	The results showed that the strength outputs were optimized mainly by warm-up with 80% of the training load in the squat training and by the warm-up that brought the two loads together (40% and 80%) in the bench press training.
Krzysztofik and Wilk [22]	Determine the effects of plyometric push-ups as a conditioning activity on high-loaded bench press performance.	24 males	2 protocols: • conditioning activity • aerobic warm-up	The results demonstrated that plyometric push-ups lead to performance enhancement of the bench press exercise at 70%1RM.
Rodrigues et al. [23]	Investigate the acute effect of three different warm-up protocols on a maximal isokinetic strength test.	22 males	3 protocols: • general warm-up • stretching warm-up • specific warm-up	None of warm-ups were able to change the total work of maximal isokinetic strength.
Mina et al. [24]	Examine the influence of another form of variable resistance during a warm-up on subsequent free-weight 1RM back squat performance compared to free-weight resistance alone.	16 males	2 protocols: • free-weight resistance • chain-loaded resistance	The results are indicative of a potentiating effect of chain-loaded resistance in a warm-up.
Ribeiro and Romanzini [25]	Investigate the acute effect of different warm-up procedures on the repetition performance of a fatiguing resistance training protocol designed to induce metabolic stress.	15 males	4 protocols: • control • specific • aerobic • combined	No significant difference for the sum of repetitions or for fatigue index among conditions for the 3 exercises.
Abad et al. [26]	Investigate whether the combination of a general with a specific warm-up protocol would improve leg press 1RM values compared with a specific warm- up protocol.	13 males	2 protocols: • combination of a general with a specific warm-up • specific warm-up	These results suggest that a general with a specific warm-up protocol induced temperature-dependent neuromuscular adjustments that increased muscle force production capacity.

Authors	Objective	Sample	Warm-ups	Main outcomes
Chattong et al. [27]	Investigate the potentiating effects of different levels of external resistance during box jumps on vertical jump performance.	12 males	5 protocols: • Control • 5, 10, 15, or 20% of their body weight	Performing an active dynamic warm-up with or without a weighted vest produced significantly greater posttest vertical jump performance.
Sotiropoulos et al. [28]	Determine the effects of a specific warm-up using half-squats at low and moderate intensity on vertical jump performance and electromyographic activity of the thigh muscles.	26 males	2 protocols: • low intensity • moderate intensity	The use of a specific warm-up that includes half-squats performed explosively with low to moderate intensity, improves countermovement jump performance.
Barroso et al. [29]	Investigate the effect of different intensities and durations of general warm-up on 1RM performance.	16 males	5 protocols: • control • short duration and low intensity • long duration and low intensity • short duration and moderate-intensity • long duration and moderate-intensity	Long-duration low-intensity general warm-up seems to be appropriate to improve 1RM performance in strength-trained individuals
Resende et al. [30]	Analyze different types of warm-up on the physical performance of Paralympic powerlifting athletes.	12 males	3 protocols: • without warm-up • traditional warm-up • stretching warm-up	The different types of warm-up methods did not seem to provide significant differences in the force indicators in elite Paralympic powerlifting athletes.
Girard et al. [31]	Investigate the influence of two warm-up protocols on neural and contractile parameters of knee extensors	10 males	2 protocols: • running-based warm-up • strength-based warm-up	Running and strength-based warm-ups induce a similar increase in knee extensors force-generating capacity by improving muscle activation.

Table 1.
Main characteristics of studies.

4. Discussion

It has been evidenced that the warm-up brings positive effects to the subsequent physical exercise, so it is very important to study it and understand how it can be manipulated according to the specificity of exercise training and performance. The purpose of this investigation aimed to analyze and discuss the main results of the literature regarding the effects of warm-up on force production, as well as to analyze those responses during resistance training and maximal strength assessments. The scarcity of research on warm-up protocols in resistance training and strength performance is notorious. Nevertheless, it is possible to verify that the results obtained in most studies are positive. The use of warm-up causes enhancement of performance when external loads are used, especially when the intensity is high. However, more research should be carried out on this topic.

The selected articles of this review tend to focus on the effects that warm-up produces on resistance training, namely the effects on strength performance. Due to the scarcity of articles about the addressed issue, it was difficult to compare the different types and approaches of warm-ups. Moreover, it was also noticed that exercises were not the same in different studies, which also difficult outcomes analysis.

In the study of Rodrigues and collaborators, [23] three different types of warm-up were compared: a general warm-up, a specific warm-up, and a warm-up through stretching, to understand whether it would influence maximal isokinetic training. The results reported that the three types of warm-up had no adverse effect or any type of improvement in acute muscle strength. However, it is important to highlight that the peak of concentric torque reported a lower value in the specific warm-up protocol when compared to the control group, which may mean that the use of a specific warm-up tends to reveal positive results when compared to the control group, which did not perform any type of warm-up.

The study by Ribeiro and Romanzini [25] aimed to compare the effects of three types of warm-ups on the performance of resistance training: a specific warm-up, an aerobic warm-up, and a combined warm-up of both, also using a control group. This study had the particularity of evaluating the performance using repetitions until failure, thus observing whether the conditions would affect resistance training. As in the abovementioned study, none of these conditions showed significant differences in resistance training, although no negative effects were observed after applying a warm-up. This study seems to suggest that the warm-up protocols used do not contribute to the development of strength.

Although the previous two studies have not found a significantly positive response in the strength assessment, the literature reported several benefits on the human body when considering the implementation of warm-up before resistance training [12]. In the study by Abad and his collaborators, [26] the aim was to understand if the implementation of a general warm-up before a specific warm-up would be beneficial when compared with a specific warm-up only. The tests were measured in the leg-press exercise, being evaluated by its 1RM. Two protocols were used in order to determine the effects of warm-up on training: combined warm-up (general with specific) and specific warm-up. The results of the combined warm-up were higher values in the force production, in comparison with the specific warm-up. Considering the positive results of the tests, a combined warm-up would have more benefits than a specific warm-up.

Barroso and his collaborators, [29] purposed to understand the best intensity to use in the general warm-up before the specific warm-up. Thus, four combined warm-up protocols were performed, with different intensities and durations, which were compared with each other and with a control group, which performed only a specific warm-up, with no general warm-up. These researchers found that a general warm-up followed by a specific warm-up would be more beneficial to increase the strength when compared to a specific warm-up that reported lower results. The authors also suggested that when performing the aerobic component of general warm-up, it should be long lasting with low intensity for better results.

On the other hand, the results of Krzysztofik and Wilk [22] did not corroborate with the studies of Abad and his collaborators [26] and Barroso and his collaborators [29]. This study aimed to compare a specific warm-up (named conditioning activity) with a general warm-up, performed before a bench press exercise. In this study, the specific warm-up was performed with a different exercise (plyometric push-ups) from the training exercise (in this case, bench press). The researchers concluded that the use of a specific warm-up had significant results in the strength assessment compared to the general warm-up. The outcomes showed improvement in the bench press exercise performance, being incongruent with the previously mentioned results.

Otherwise, Ribeiro and colleagues, [21] aimed to understand the best intensity to use when only a specific warm-up was performed. This study verified if three types of warm-ups would have an effect on strength training, and its protocols would use three types of external loads in the warm-up exercise: 40% of the training load, 80% of the training load, and the combination of the 40% and 80% of the training load. Positive effects in force production were found when warming-up with higher loads (80% of the training load) before the squat exercise training. The same authors also reported that, when performing a warm-up with low loads and repetitions, there was no effect on strength training performance.

Similar to Ribeiro and colleagues, [21] Minas and collaborators [24] evaluated a specific warm-up in their study. These authors, although also used the squat exercise in their study, used two different warm-ups. A protocol with a chain-loaded (as external weight) and another where it would be used only with the weight of the body, without any help from external loads. The aim of this study was to perceive the effect of another form of variable resistance in a warm-up compared to a warm-up with only bodyweight. After applied the two defined protocols, it was concluded that using a chain-loaded weight as the body's external weight can enhance our results in the field of strength. Then, it is possible to notice that this study is in agreement with the previous one, although it cannot be directly compared. Both concluded that when using a warm-up with external loads to our body, the results tend to be better.

Sotiropoulos and his collaborators [28] carried out a study to determine the effects of a specific warm-up using low and moderate-intensity squats in the vertical jump. In his study, two warm-up protocols were performed using two different external loads (low and moderate), before performing the countermovement jump. Both protocols demonstrated to be effective when performed before the vertical jump, reporting significant results in the acute force production and the electromyographic activity, showing to be quite beneficial for the countermovement jump.

In the study of Chattong and his companions, [27] which aimed to investigate the potentiating effects of different levels of external resistance (weight vest) during box jumps in the vertical jump, five different warm-ups were assessed. The control condition was performed without any external load and then, the experimental warm-ups were performed with additional weight from 5% to 20% of bodyweight. In this study, the researchers concluded that no improvements in force production were found when increasing the load in the different warm-ups, not even any between using a vest or without it.

The study by Resende and his collaborators [30] aimed to analyze three different types of protocols, to understand their effect on the physical performance of paralympic powerlifting athletes. The protocols applied were: without warm-up, traditional warm-up and stretching warm-up. The results indicated by the researchers revealed that there were no significant differences when applying any of the protocols studied. Although the results did not show significant results, it is important to note that the participants were highly trained athletes and this might have triggered these results.

Gerard and his colleagues, [31] performed the following protocols: running-based warm-up and strength-based warm-up to investigate the influence of two warm-up protocols on the neural and contractile parameters of the knee extensors. It was revealed a significant shortening of time to contract, while the other twitch parameters did not change significantly. Thus, they concluded that both protocols can influence strength training and muscle contraction during training.

After analyzing these studies, there is still controversy around the issue of warming. All studies included in this narrative review are relatively recent, but a consensus has not yet been reached, neither what is the best type of warming up that will have the best results on force production and strength performance. Further investigations should be developed to provide a consensus and clarify the subject. For future studies, it would be interesting to explore this topic a little more. We suggest to study the effect of warm-up on strength training, exploring different types of intensities, in order to achieve more robust and concrete results. The same studies should not be based on a single exercise, but rather deepen the study on several exercises performed in a sequence. It is true that, in a real training context, no single exercise is performed. For example, most resistance training includes more than one exercise and for different muscular groups. It would also be interesting to verify if it will be necessary to warm-up before each exercise and specifically for each exercise, or if the first warm-up before training is enough to guaranty better results during the entire training.

5. Conclusion

With this narrative review, we could verify that there is a great lack of studies on the subject of warm-up for strength performance, resistance training performance, and force production. It was also possible to show that some authors did not report benefits after warm-up, however, others found quite significant results in their studies. These positive results were either after using only a specific warm-up or using a general warm-up followed by a specific warm-up. So, it is possible to determine that special attention on this topic is needed. Nevertheless, most of the studies tended to suggest that a warm-up should be performed before resistance training is performed. The increased strength outcomes seemed to be better when a higher load is used during warm-up, with few repetitions. Moreover, the use of a general warm-up showed to be beneficial in some specific assessments. Therefore it can also be a strategy to be applied and combined with the specific warm-up. Further investigations should be developed to better understand and determine the effects of warm-up, or even other studies using another type of exercise, so we can provide a more in-depth conclusion.

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Chapter 8

Concussion and Balance in Sports

Lilian Felipe

Abstract

Balance, spatial orientation and stable vision are imperative factors for sports or any other physical activity. It is achieved and maintained by a complex integration set of sensorimotor control systems that include sensory input from vision, proprioception or somatosensory and the vestibular system. A Sport-Related Concussion (SRC) is an individualized injury that presents a range of clinical signs and symptoms (cognitive, physical, emotional, somatic, and sleep-related). For this reason, SPR is a meaningful public health issue that involves a multidisciplinary team to properly manage it. In the sports medicine filed, Sports-Related Concussion assessment and management has become an argumentative issue. Presently, the consensus includes a combination of subjective examination, combined by multifactorial evaluation batteries that allowed to verify several components of brain function. Athletes frequently complain of dizziness and imbalance subsequent a concussion, and these symptoms can expect increased period to recover and return to play. Balance assessment is an important component of the concussion evaluation, as it can contribute with an awareness about the function of the sensorimotor systems.

Keywords: Assessment, Balance, Concussion, Sports, Vestibular

1. Introduction

Concussion is one of the most common sports-related injuries [1]. Lately, concussion has converted an import subject for injury prevention in sport due to the increasing concern surrounding its medium- and long-term consequences. The assessment should be conducted preferably in a systematic approach. The evaluation should contain clinical history and specific details about the injury, followed by assessing neurocognitive function and balance [1, 2].

Balance performances a fundamental role in the maintenance of fluid, dynamic movement common in sport. And complains related to it are commonly reported symptoms following a sport-related concussion [3]. This chapter provide an overview of the systems involved in balance, the importance of assessing motor function following a concussion, and concussion management and treatment of vestibular and balance impairments in athletes.

Replace the entirety of this text with the introduction to your chapter. The introduction section should provide a context for your manuscript and should be numbered as first heading. When preparing the introduction, please bear in mind that some readers will not be experts in your field of research.

2. Balance

Balance, spatial orientation and stable vision are important components of physical activity and athletic participation [2].

Balance is the capability to keep the body's center of mass over its base of support. It is managed and maintained by a sophisticate combination of sensorimotor systems that include (1) vision, (2) proprioception/somatosensory and (3) vestibular systems [2, 4].

The accurate function of balance is essential to daily activities as allows to see clearly while walking and/or moving, to determine direction and speed of movements, to recognize orientation according to gravity, and to accomplish automatic postural modifications to sustain posture and stability in several circumstances and events [4]. The integration of these three components are used to maintain one's postural balance (**Figure 1**).

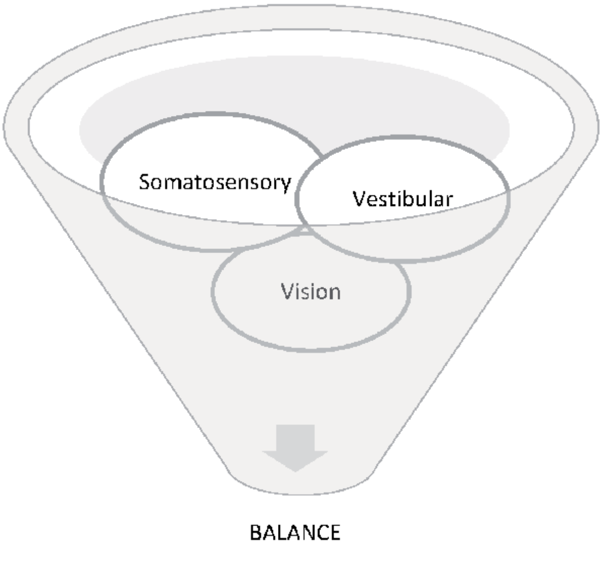

Figure 1.
The integration of three systems (vestibular, somatosensory and vision) are crucial to maintain one's postural balance.

3. Vestibular system

The vestibular system is a complex network that includes small sensory organs of the inner ear (utricle, saccule, and semicircular canals) and connections to the brainstem, cerebellum, cerebral cortex, ocular system, and postural muscles [4, 5].

The vestibular system is distinctive from other systems because it becomes immediately multisensory and multimodal [4]. For example, the vestibular system intercorrelates with the somatosensory system through the vestibulospinal reflex that is responsible for postural control and with the visual system controlling the vestibulo-ocular reflex (VOR), that maintains visual stability during head movements.

These linked group of systems allows the brain to differentiate active from passive head movements and provide information regarding head movements and positions to maintain visual and balance control. Furthermore, visual and somatosensory systems interact with the vestibular system throughout the central vestibular pathways and are essential for gaze and postural control. This interaction of multisensory and multimodal pathways is important for higher level of function such as self-motion perception and spatial orientation [2, 4–6].

Usually, individuals who present impairments related to the vestibulo-ocular reflex complain about dizziness and visual instability, this is due the organization and neurophysiology of the vestibular system [4].

Inversely, vestibulo-spinal dysfunction (correlated to the vestibulo-spinal reflex - VSR) normally present as consequences imbalance. Since these reflexes do not share the same neuronal circuitry, it is possible to have damages one without affecting the other [4, 6].

4. Sport-related concussion

Traumatic Brain Injury (TBI) occurs in subjects of all age groups and is a significant public health issue [7].

The Post-Concussive Syndrome (PCS) defines the set of symptoms and signs present frequently in a persistent mild TBI [8]. The Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) presents the clinical criteria for PCS [9]. The symptoms include headache, fatigue, vision changes, disturbances in balance, confusion, dizziness, insomnia, neuropsychiatric symptoms, and difficulty with concentration [7–9].

Disturbances in balance and dizziness are described in literature by 23–81% [8, 10–13] of concussed athletes [and is correlated with a 6.4-times higher risk to have another concussion if not treated, comparing to any other on-field symptom [11, 14]. Currently, several studies have presented that imbalance and dizziness are usual after a TBI have a correlation with the time to recovery (protracted recovery superior to 21 days), causing a delay comparing to the ones who did not present those symptoms [10–14].

Cohort studies and analysis had shown that women are at greater risk for persistent PCS. Besides, they are more likely to present headache, irritability, fatigue, and concentration problems post-concussion. Increases in age are also associated with a higher risk of PCS [15].

5. Assessment

The assessment of an injured player is facilitated by the presence of a certified athletic trainer, team physician, or other health care provider at the location where the injury occurred. It is important to mention that balance symptoms may not become apparent for several hours after injury bringing an additional obstacle to identification. Thus, the follow up for SRC is crucial to assess any balance dysfunction and treatment during the patient's recovery. Hence, vestibular and balance evaluations must be included in the concussion assessment battery and when available, objective tests may be used [16].

The assessments strategies present in this chapter were noted in scientific literature to be used as part of the concussion evaluation as well as a preseason baseline. The same tools for assessment are applied and can benefit other individuals with vestibular and ocular/oculomotor disorders as well [16–18].

Among the recommended assessments are physical examinations, clinical interviews, symptom reports, and neurocognitive and balance tests. For that reason, is recommended to use the Symptom Checklist. It is a self-report graded symptom checklist validated for concussion assessment. One example is the Sport Concussion Assessment Tool 5 (SCAT-5). The SCAT-5 contain 22 items and corresponding 0 to 6 points where higher numbers indicate greater symptom severity [19].

Below, it is described some assessments that can be applied in case of vestibular impairments after concussions:

Balance Error Scoring System (BESS)
Sensory Organization Test (SOT)
Head Shake-Sensory Organization Test (HS-SOT)
Concussion Balance Test (COBALT)
Vestibulo-Ocular Reflex and Vestibular/Ocular Motor Screen (VOMS)
Dynamic Visual Acuity Test (DVAT)
Head Impulse Test (HIT)
Post-Concussion Symptom Scale (PCSS)
Dizziness Handicap Inventory (DHI)
Dix-Hallpike Maneuver

5.1 Balance error scoring system (BESS)

The Balance Error Scoring System (BESS) is an objective measure of assessing static postural stability. It is an assessment that verifies three positions in different surfaces (firm and foam). The individual sustains the posture (feet together, tandem stance, or single leg stance) with the hands on their hips and without vision (eyes closed). During 20 seconds in each position, an examiner counts errors that include: to open the eyes, to remove hands from the hips, to lower the raised foot during single leg stance, to lift the heel or forefoot, or to remain out of the test position for more than five seconds. The advantages of the assessment are good reliability, low cost effective and easy to administer [20].

Figure 2.
Equipment for computerized Posturography. Courtesy: Interacoustics and Bertec.

5.2 Sensory organization test (SOT)

The Sensory organization test (SOT) is used to evaluate postural instability. It is a clinical tool used to that allows to manipulate the sensory systems that contribute to balance [21]. The SOT is completed via Computerized Dynamic Posturography (CDP), which provides objective measures of balance through implementation of software and protocols in combination with force plates (**Figure 2**). Through six unique conditions, the SOT examines sensory reweighting by challenging the somatosensory, visual, and vestibular systems. One of the benefits of the SOT identified in the literature is the assessment's potential to provide information about the specific sensory system affected by the injury that may assist in directing treatment for patients with a concussion (**Figure 3**). Studies suggested that the use of additional evaluation tools could increase the sensitivity of the SOT and improve the identification of balance issues after a concussion [22].

5.3 Head shake-sensory organization test (HS-SOT)

The Head Shake Sensory Organization Test (HS-SOT) is an expansion of the sensory organization test (SOT). HS-SOT has been proposed to increase the sensitivity of SOT incorporating head movements into the assessment for the two eyes closed conditions. The addition of the head shake provides an added challenge to the vestibular system, through stressing the Vestibulo-Ocular Reflex (VOR) [23].

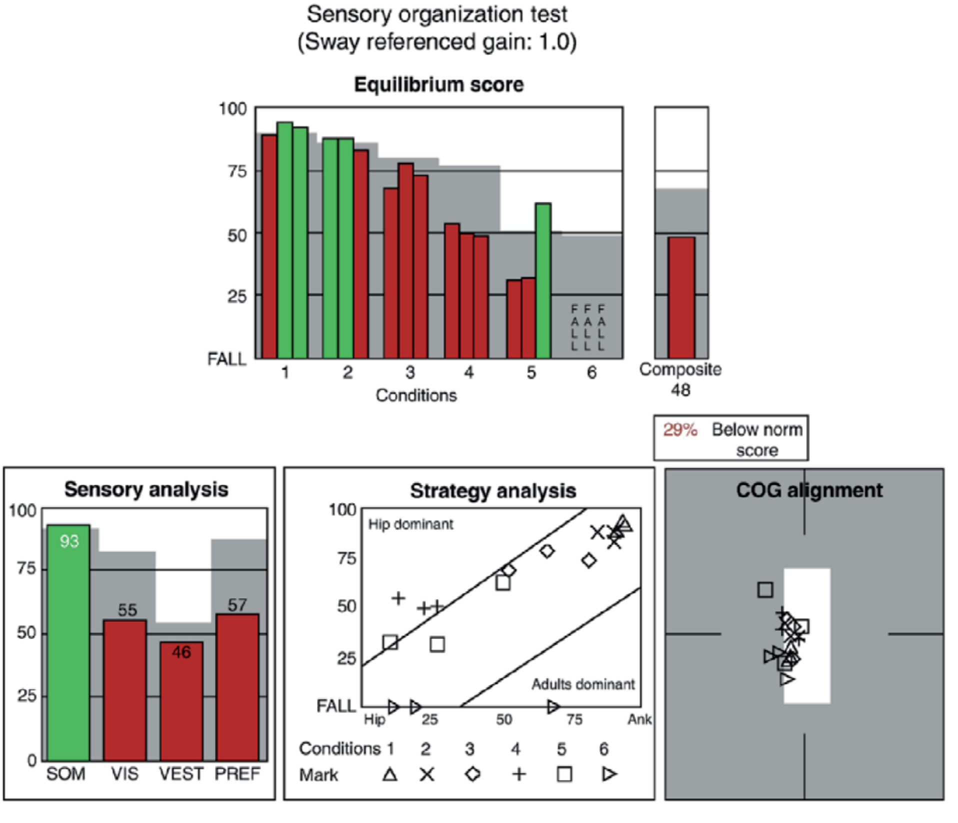

Figure 3.
Sensory organization test report. The green bars represent the patient's normal results, the red bars indicate that the patient had an abnormal result in the tested condition and the area with dark gray bars indicates the normative limit. Courtesy: Interacoustics and Bertec.

Researches indicated a deficit relative to evidence to the psychometric aspects of the HS-SOT, and appliance and value of this assessment in PCS and other clinical populations. Consequently, to evaluate the effectiveness of this tool, more studies must be done to evaluate the tool, prior to suggesting its use in clinical practice [22–24].

5.4 Concussion balance test (COBALT)

The Concussion Balance Test (COBALT), is an eight-condition test that assesses postural control with active vestibular stimulation using force plate technology (**Figure 4**). The test verifies the posture in a dynamic situation analogous to the one experienced during the sport. The goal is to try to reproduce the same or similar level of balance required to the activity. It is considered particular from other tools due the capability to identify subtle balance deficits. COBALT tasks the vestibular system by incorporating a head shake with an eyes-closed (visual suppression) [25].

5.5 Vestibulo-ocular reflex and vestibular/ocular motor screen (VOMS)

The evaluation of the Vestibulo-Ocular Reflex (VOR) and the oculomotor movements have been suggested as part of the clinical neurological examination for concussion. During the assessment, it evaluates aspects related to the interaction of both systems (vestibular and ocular) and other cranial nerves through functions that utilize both components. The VOMS (**Figure 5**) is a screening assessment that includes: (1) smooth pursuits, (2) horizontal and vertical saccades, (3) near-point of convergence (NPC) distance, (4) horizontal and vertical VOR, and (5) visual motion sensitivity (VMS). Initial studies including VOMS as a post-concussion assessment identified measurement properties that propose efficacy of this evaluation for SRC [26, 27].

5.6 Dynamic visual acuity test (DVAT)

The Dynamic Visual Acuity Test (DVAT) provides an instrumented, objective, behavioral assessment of vestibulo-ocular reflex (VOR) function in response to rotational or functional head movement stimuli by determining the smallest optotype an individual can identify during both dynamic and static conditions. One option to perform the DVAT is applying the Snellen Chart (**Figure 6**) combined with a metronome or other systems [28].

Figure 4.
COBALT courtesy: Bertec.

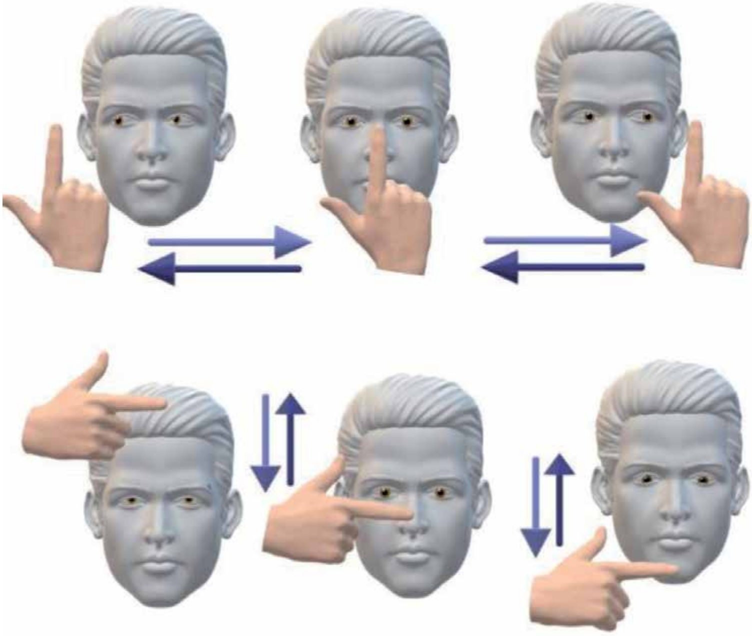

Figure 5.
Vestibular/ocular motor screen.

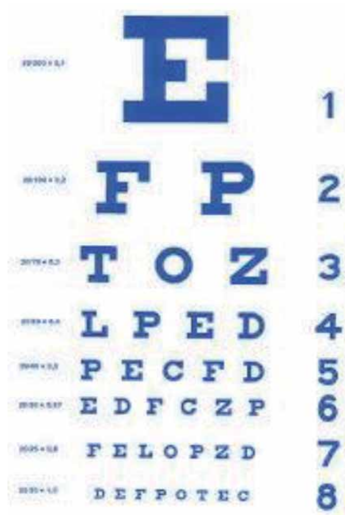

Figure 6.
Snellen chart.

It is also available in computerized systems. In this case, the patient is solicited to recognize the direction of the middle arm of the optotype while continuing either an active or passive head movement at a fixed velocity. According to the modification (increase or decrease) in the target size or optotype, established on the successes or failures on each trial until a final acuity is defined [29].

The test has been reported to have good reliability in healthy athletes however has not consistently demonstrated the ability to discern between those with and without a concussion. Further research is necessary to consider the clinical utility for SRC [28–30].

5.7 Head impulse test (HIT)

The HIT is a bedside technique used to diagnose reduction in vestibular function in one vestibular system versus the other. It allows the evaluation of VOR function in high head velocities (delivered by a clinician) in the direction of each pair of semicircular canals (**Figure 7**). During the head movement, the subject is asked to keep the eyes in a target or fixed object. The test can detect semicircular canal paresis or abnormal eye movements (as "catch up" saccade), which indicate peripheral vestibular disorder [31].

5.8 Post-concussion symptom scale (PCSS)

The inventory corresponds to 22-items (common concussion symptoms) and the athletes are asked to rate each symptom on a 7-point scale (**Figure 8**). The subjective measure is valuable in the clinical assessment for balance issues; however, studies

Figure 7.
Head impulse test (HIT).

SEVERITY RATING
Please use this scale to rate each symptom.
None 0 | Mild 1 2 | Moderate 3 4 | Severe 5 6

PATIENT'S NAME: ______________________

POST-CONCUSSION SYMPTOM SCALE

Symptoms	Date:	Date:	Date:	Date:	Date:	Date:	Date:
Headache							
Nausea							
Vomiting							
Balance Problems							
Dizziness (spinning or movement sensation)							
Lightheadedness							
Fatigue							
Trouble falling asleep							
Sleeping more than usual							
Sleeping less than usual							
Drowsiness							
Sensitivity to light							
Sensitivity to noise							
Irritability							
Sadness							
Nervous/Anxious							
Feeling more emotional							
Numbness or tingling							
Feeling slowed down							
Feeling like "in a fog"							
Difficulty concentrating							
Difficulty remembering							
Visual problems							
Other							
Total							

Figure 8.
Post-concussion symptom scale (PCSS).

frequently do not report comorbid circumstances or complains, such as cervical abnormalities that could affect in these symptoms associated with a lengthy recovery. More recently, the symptoms have been organized into clusters based on the etiology or concussion domain [32, 33].

5.9 Dizziness handicap inventory (DHI)

The inventory consists in 25-item questionnaire that assesses possible causes of balance issues and evaluate the impact of it in the quality of life (**Figure 9**). The possibly responses are "yes", "no" or "maybe". The DHI is distributed into three areas; emotional, functional, and physical to better identify the root cause of the dizziness The answers are graded and summed (varying in 100 to 0 total points), considering a higher score an indication of higher perceived handicap [34].

5.10 Dix-Hallpike maneuver

The Dix-Hallpike Maneuver evaluate the presence of Benign Paroxysmal Positional Vertigo (BPPV). It is important first to evaluate if no concern related

	Questions	Always	Sometimes	No
P1	Does looking up increase your problem?	☐	☐	☐
E2	Because of your problem, do you feel frustrated?	☐	☐	☐
F3	Because of your problem, do you restrict your travel for business or pleasure?	☐	☐	☐
P4	Does walking down the aisle of a supermarket increase your problem?	☐	☐	☐
F5	Because of your problem, do you have difficulty getting into or out of bed?	☐	☐	☐
F6	Does your problem significantly restrict your participation in social activities, such as going out to dinner, going to movies, dancing or to parties?	☐	☐	☐
F7	Because of your problem, do you have difficulty reading?	☐	☐	☐
F8	Does performing more ambitio dancing, and household chore putting dishes away; increase	☐	☐	☐
E9	Because of your problem, are home without having someone accompany you	☐	☐	☐
E10	Because of your problem, have you been embarrassed in front of others?	☐	☐	☐
P11	Do quick movements of your head increase your problem?	☐	☐	☐
F12	Because of your problem, do you avoid heights?	☐	☐	☐
P13	Does turning over in bed increase your problem?	☐	☐	☐
F14	Because of your problem, is it difficult for you to do strenuous housework or yard work?	☐	☐	☐
E15	Because of your problem, are you afraid people may think that you are intoxicated?	☐	☐	☐
F16	Because of your problem, is it difficult for you to go for a walk by yourself?	☐	☐	☐
P17	Does walking down a sidewalk increase your problem?	☐	☐	☐
E18	Because of your problem, is it difficult for you to concentrate?	☐	☐	☐
F19	Because of your problem, is it difficult for you to walk around your house in the dark?	☐	☐	☐
E20	Because of your problem, are you afraid to stay home alone?	☐	☐	☐
E21	Because of your problem, do you feel handicapped?	☐	☐	☐
E22	Has your problem placed stress on your relationship with members of your family or friends?	☐	☐	☐
E23	Because of your problem, are you depressed?	☐	☐	☐
F24	Does your problem interfere with your job or household responsibilities?	☐	☐	☐
P25	Does bending over increase your problem?	☐	☐	☐

Figure 9.
Dizziness handicap inventory (DHI).

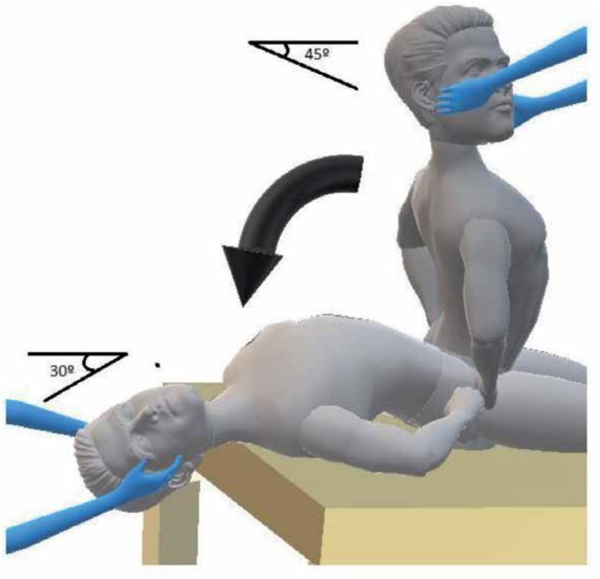

Figure 10.
Dix-Hallpike maneuver.

to cervical spine is present, before the administration. It is also termed the "head-hanging positioning maneuver" [35].

During the maneuver, the individual is positioned seated and the head is turned 45° toward the tested side. The individual is moved (lying down) into the supine position with the head extending (**Figure 10**). The patient's head is held in this position and the clinician verify the eyes to detect or not the presence of nystagmus. To complete the maneuver, the patient is returned to the seated position and they eyes are observed to detect presence of reversal nystagmus [35, 36].

6. Treatment

Vestibular Rehabilitation Therapy (VRT) is an exercise-based treatment program created to promote vestibular adaptation and substitution [37].

The objectives are: (1) to enhance gaze stability, (2) to enhance postural stability, (3) to improve vertigo, and (4) to improve activities of daily living. After SRC, different vestibular rehabilitation techniques may be used based on the symptoms and impairments present. Vestibular rehabilitation may help reduce dizziness and improve balance after SRC [38]. Studies combining individualized vestibular therapeutic rehabilitation techniques to an established physical therapy program has been seen to benefit individuals returning to play by decreasing recovery times and strengthening athlete's compensatory strategies to prevent reinjury [37–39]. Current evidence for optimal prescription and efficacy of VRT in patients with concussion is limited. Available evidence, although weak, shows promise in this population [37–40].

7. Conclusion

Poor balance has been associated with increased injury risk among athletes. The literature shows that over 6,000 athletes experienced a sport-related injury and over 25% of these injuries result in a loss of more than seven days of participation. Consequently, it is urgent to recognize instruments that prevent injuries and could improve balance.

A combination of tools for assessment, as: physical evaluation combined with other tests/exams/inventories provide a better comprehension for vestibular disorders in sport concussions. It is important to understand that the questionnaires and outcomes may have clinical utility in the evaluation of vestibular pathologies post-SRC but should not be used as a distinguishing point for vestibular diagnosis alone.

Knowledge of a patient's diagnosis is a critical foundation for planning comprehensive treatment programs with the goal to reduce impairment and symptoms and expedite the return to daily activities, sports, or work. Although vestibular rehabilitative therapy is beneficial among most populations post-concussion, further research should be conducted using individualized treatment protocol. Limitations of this review include the lack of available randomized controlled trials or cross-sectional studies; therefore, further research is determining the effectiveness of vestibular rehabilitative therapy is warranted. Additionally, normative data based on athletes should be included.

Conflict of interest

The author declares no conflict of interest.

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Chapter 9

Peculiarities of Muscle-Tendon Mechanics and Energetics in Elite Athletes in Various Sports

Mikhail Shestakov and Anna Zubkova

Abstract

The article presents results of the research on jumping strategies applied by elite athletes in various sport disciplines. Research hypothesis: to perform the same motor task athletes employ different ways of organizing the movement and different features of MTU functioning. The choice of a mechanism to enhance muscle contraction depends on sport discipline, in particular specific features of the sport movement. The study involved members of the Russian national teams in alpine skiing, bobsleighing, mogul skiing and ski jumping. The athletes performed drop jumps from the heights of 0.1, 0.3, and 0.5 m with no arm swing. Experimental data were obtained online from 24 cameras using the Qualisys motion capture system (400 frames per second) and the two force plates AMTI 6000. Data was processed using the OpenSim package. The authors calculated the amount of accumulation and utilization of elastic strain energy and assessed metabolic energy expenditures in MTU. The authors concluded that employment of different strategies of movement organization in drop jumps could be explained by the transfer of motor skills specific to the athlete's sport discipline. The results of the study may help coaches develop individual training plans for athletes, in particular strength training exercises targeting specific muscle groups.

Keywords: muscle-tendon unit, drop-jump, OpenSim, elite athlete, elastic energy

1. Introduction

Elastic strain energy is stored in tendons and is used in various motor tasks. It permits to minimize energy costs of muscle contraction and increase power output of muscle-tendon units (MTU). Therefore, specific mechanical properties of different tendons can influence MTU behavior and, ultimately, mechanical power and muscle efficiency of movements [1].

It was suggested that there was a relationship between the structure of various mammalian tendons and their role in effective transmission of force or energy conservation during elastic deformation [2]. The relevance of this idea lies in the context of improving results in various sport movements due to conformity of MTU functioning with requirements and specific features of a sport discipline.

This article presents research data on various strategies used for power production by MTU of the lower extremities in drop jumps. According to the hypothesis [3], to perform a motor task, a muscle develops power that should be adequate to mechanical requirements of the task in order to produce a movement. Any movement is determined by timing, sequence and amplitude of muscle activation. Two elastic mechanisms contribute to the efficiency of power production in multi-joint movements of the lower extremities during a take-off: pre-stretch of skeletal muscles and mechanical energy transfer via biarticular muscles. It is assumed that the extent to which each of the mechanisms is used exerts effect on the strategy of organization of multi-joint movements.

Preliminary stretching of skeletal muscles is the first mechanism to increase power of a take-off. It is known that pre-stretch of the muscle-tendon complex (MTU) amplifies strength of its subsequent contraction [4, 5]. This mechanism manifests itself in various movements, including vertical jumps [6–8].

The second mechanism of increasing power of a take-off (mechanical energy transfer) was described in a few works related to running, hopping and vertical jumping [3–5, 9–12]. The mechanism of mechanical energy transfer via barticular muscles is also associated with the effects occurring in the MTU [13, 14].

Enhancement of MTU contraction can be reached with the help of three mechanisms: accumulation and release of elastic deformation energy, activation of spinal reflexes, and muscle potentiation. Many studies related to this topic were carried out in both animals and humans. They showed that several mechanisms could be activated simultaneously in the stretch-contraction cycle in order to enhance the MTU contraction. Those mechanisms could vary depending on external conditions and motor tasks [15–23]. For example, in running and hopping it is necessary to maintain muscle strength that is achieved by the use of MTU elastic strain energy; in accelerations, starts and jumps the catapult mechanism is used; and in landing energy is absorbed due to muscle compliance [24]. Such variability in performance of different motor tasks is achieved by modulating the muscles' intrinsic mechanical properties due to spinal reflexes, which can increase or decrease muscle stiffness [25–27]. So, it is possible to use the elastic deformation mechanism in muscles or, conversely, the muscles can act as a damper in landing. It is assumed that the choice of this or that mechanism depends on the character and requirements of the sport exercise, and athletes from different sports may demonstrate difference in organization of MTU control.

We hypothesized that to perform the same motor task athletes could employ different ways of movement organization. An athlete's preference when choosing this or that mechanism for enhancing power of muscle contraction depended on specific features of sport discipline, notably, requirements to the main sport exercise.

From a practical perspective, our research was aimed at obtaining data that could be used in training of top athletes. Strength training is an integral part of athletic training in sport of top results, and it is effective only when it is based on individual characteristics of elite athletes. The results of this study will help coaches develop individual training plans for athletes, in particular strength training exercises targeting specific muscle groups.

2. Methods

The study involved male members of the Russian national teams in alpine skiing n = 4, bobsleigh n = 5, mogul skiing n = 5 and ski jumping n = 5 (**Table 1**). All athletes took part in the World Cups and World Championships. The experiment was carried out within the framework of regular testing of national team members according to established protocols in the course of preparation for international competitions [28].

	Alpine skiing	Mogul skiing	Bobsleighing	Ski jumping
Weight (kg)	82,4 ± 4,3	73,5 ± 2,3	108,9 ± 6,5	69,1 ± 1,7
Height (m)	1,79 ± 3,1	1,66 ± 2,4	1,89 ± 2,5	1,78 ± 2,1
Body mass index (m/kg°)	25,7 ± 6,5	26,6 ± 5,4	30,4 ± 7,8	20,3 ± 2,8
% of muscles in the body (%)	53,4 ± 7,5	34,1 ± 6,7	49,1 ± 8,1	51,6 ± 2,4
Experience (y)	10,1 ± 3,1	7,8 ± 1,8	11,4 ± 2,8	8,9 ± 2,2

Table 1.
Characteristics of the subjects. Mean ± SD.

Testing procedure. After a warm-up subjects performed drop jumps (vertical jumps after jumping down) from the height of 10 cm, 30 cm, and 50 cm with no arms swing. The subjects were advised to wear their preferred athletic shoes and to keep hands on the hips during the jumps. The best of three trials, regarding jumping height (CoM elevation), was considered for further analysis. Rest interval between the trials was about 2–3 min depending on the individual need of the athlete.

Data Processing Approach. The software complex received input data of real movement from by the Qualisys Motion Capture System (24 cameras Oqus 5 Qualisys, Sweden). Jumping exercises were performed on two force plates AMTI 6000 (AMTI, USA). Recording was done at frame rate 400 fps and synchronized with force plate's signals. The data were processed with the help of the software package OpenSim [29]. The software package permitted to create an individual musculoskeletal model of every athlete and identify specific features of his movement technique.

Kinematic and dynamic calculations were performed using simulation of a full-body model proposed by the Hamner and Delp paper [30]. We used a three-dimensional musculoskeletal model with 29 degrees of freedom, 92 muscles of the torso and lower extremities driven by torque actuators. This model was previously used to study how each muscle contributes to accelerating the body's center of mass during a jump [30, 31]. The model included 35 lower limb muscles, 5 of which were examined in this study. To analyze metabolic costs during the jump experiment, we selected a group of key muscles involved in the take-off phase of a vertical jump: Gl (gluteus maximus, gluteus medius, gluteus minimus muscles), RF (rectus femoris), VAS (vast medial muscle), GAS (lateral sections of the gastrocnemius muscle), SOL (soleus muscle).

An individual muscle and tendon complex was described by a three-piece MTU model, based on Thelen's work in 2003 [32], modified by few other authors [33, 34] and implemented in the OpenSim application. The model calculated the change in length and strength of muscles and tendons over a wide range of body positions. The model also permitted to study in detail functioning of the MTUs of the ankle, knee and hip joints when generating force and its derivatives for each subject. We simulated each jump with the help of the methods described by Hamner and Delp [30].

Our simulation workflow began with scaling the geometry of the generic musculoskeletal model to match the anthropometry of each of our subjects, using the OpenSim Scale Tool. In addition, we scaled the maximum isometric forces of the muscles according to a regression equation based on each subject's mass and height [31]. Then we generated muscle driven motions of the recorded experiments with OpenSim's Computed Muscle Control (CMC) Tool [32], using the individual models and the adjusted kinematics. CMC calculated muscle excitations that could produce the observed jumping motion while minimizing the sum of squared muscle activations at regular intervals in the motion.

Elastic Strain Energy (ESE) Calculation. During the analysis we attempted to calculate the possible amount of stored and utilized elastic strain energy (ESE) using methods suggested by [4, 35]. According to the authors mechanical energy expenditures (MEEs) of two human lower extremity models are associated with two different sources of mechanical energy - (1) muscles and (2) joint moments. The source of mechanical energy in the Model 1 was a group of eight muscles, three of them being two-joint muscles. The source of mechanical energy in the Model 2 was a set of net moments in its joints.

It was shown that the model with two-joint muscles spent less mechanical energy than the model with no two-joint muscles in the same movement. Saving of mechanical energy by two-joint muscles was possible on condition that: (i) muscle powers produced by the two-joint muscle at both joints were of opposite signs, (ii) moments produced by that muscle at each of the two joints were codirectional with the net joint moments at those joints, and (iii) biarticular antagonist muscles did not produce force.

Metabolic Costs Calculation. To estimate metabolic energy consumption, we used a metabolics model developed by [36, 37] with few modifications by [36]. To employ this metabolic model, we used the Umberger2010MuscleMetabolicsProbe in OpenSim v4.

In accordance with the calculation method, we summed the rate of energy expendutures of all muscles, added a basal rate (1.2 W/kg – [38]).

Leg Stiffness Calculation. We estimated leg stiffness:

$$K_{leg} = F_{max} / \left(\left(l_o - l_{min} \right) / l_o \right), \qquad (1)$$

where K_{leg} – the leg stiffness normalized to body weight as the ratio of the peak vertical ground reaction force (F_{max}) to the difference between the leg length when standing and the leg length when the center of mass is at its lowest point lmin. The leg length l0 was the distance from the center-of-pressure [39] to the center of the pelvis in a model derived from the musculoskeletal model described by [40].

To process the results of our research we used a software package STATISTICA ver.10. As we had small sample sizes, we used non parametrical statistical methods: Kruskal-Wallis test and Wilcoxon test.

Ethical Approval. The study was approved by the Local Human Research Ethics Committee, and all participants gave their written informed consent prior to testing. All human testing procedures conformed with the principles of the Declaration of Helsinki.

3. Results

Figure 1 demonstrates multidirectional changes in the maximum peak power in drop jumps from different heights performed by the subjects. Mogul skiers showed negative dynamics of the maximum peak power as the height of the drop jump increased: the maximum peak power in drop jumps from the height of 0.1 m and 0.3 m differed by 2.67 ± 0.05 W/kg (($T = 0{,}0$, $p = 0{,}043$), the difference of the maximum peak power in drop jumps from the height of 0.3 m and 0.5 m was 2.89 ± 0.07 W/kg ($T = 0{,}0$ $p = 0{,}041$). All the other subjects (alpine skiers, bobsledders, and ski jumpers) showed positive dynamics of maximum peak power. The greatest maximum peak power was reached in the group of ski

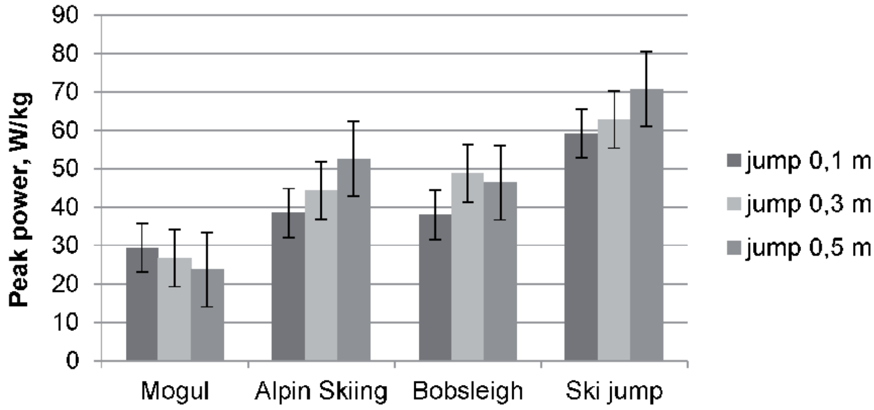

Figure 1.
The maximum peak power in the take-off phase.

jumpers (0.1 m – 59.2 ± 0.23 W/kg; 0.3 m – 62.8 ± 0.30; 0.5 m – 79.8 ± 0.56 W/kg), while the lowest – in the group of mogul skiers (0.1 m – 59.2 ± 0.27 W/kg; 0.3 м – 62.8 ± 0.23 W/kg; 0.5 м – 79.8 ± 0.46 W/kg) . Mogul skiers demonstrated significant difference in maximum peak power in comparison with the other athletes (H = 8,22003 p < 0,01).

Time of the take-off phase (**Figure 2**) significantly differs in ski jumpers (0,1 м - 0,18 ± 0,06 s; 0,3 м - 0,215 ± 0,05 s; T = 8,32117, p > 0,01; 0,5 м - 0,23 ± 0,07 s; T = 8,32117, p > 0,01) and in athletes from the other groups. The average time of the take-off in the groups of bobsledders, alpine skiers and mogul skiers was 0.11–0.13 ± 0.02 s in all jumps, while in ski jumpers it was 0.18–0.23 ± 0.05 s (H = 8,32117, p < 0,01).

If we compare **Figures 1** and **3**, we will note that the athletes achieved different power of movement on the background of different leg stiffness. The maximum leg stiffness was registered in alpine skiers in drop jumps from 0.1 m – 23659.6 ± 1182 N/m, bobsledders in drop jumps from 0.3 m – 24384,9 ± 987 N/m, and mogul skiers in drop jumps from 0.5 m - 23608,8 ± 1243 N/m; the minimal leg stiffness was registered in ski jumpers (0.1 m - 14463,4 ± 723 N/m; 0.3 m - 9206,8 ± 803 N/m and 0.5 m - 7115,1 ± 654 N/m). The difference between the groups was significant (H = 8.75356, p < 0.01), the dynamics of data within each group was different. Mogul skiers demonstrated the maximum values in leg stiffness in drop jumps from 0.5 m. In alpine skiers

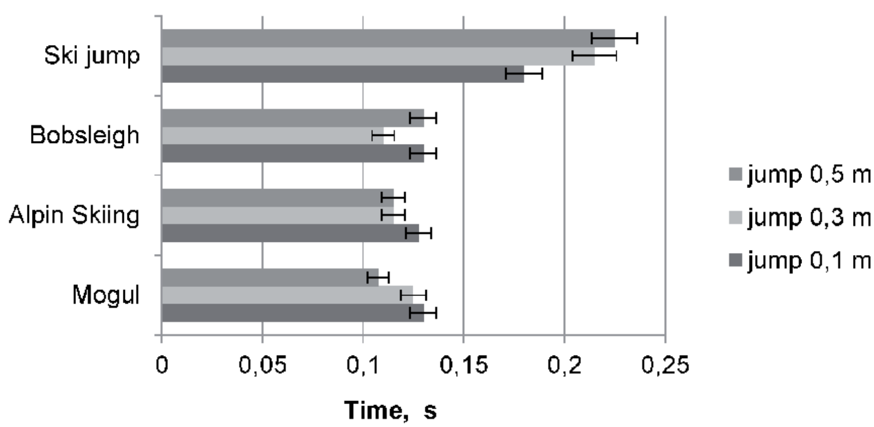

Figure 2.
Time of the take-off phase.

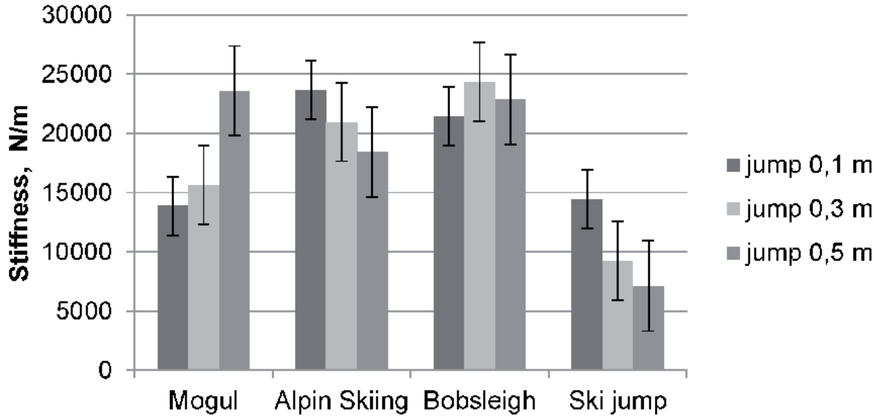

Figure 3.
Peak value of the stiffness of the muscles of the lower extremities in drop jumps.

and ski jumpers the maximal leg stiffness was found in drop jumps from 0.1 m. The small height may permit these athletes to perform preliminary muscle stimulation before landing that makes it possible to counteract external inertial forces acting on the body. When the height is greater, athletes try to compensate loads on the musculoskeletal system in shock absorption phase by increasing the amplitude of movement in the knee joints, thereby reducing the stiffness of the legs. In bobsledders leg stiffness in the jump from 0.5 m was 6.5% lower than that in the jump from 0.3 m. It might be that the bobsledders tried to keep high leg stiffness, but as they were heavy, their muscles could not resist the load in the eccentric phase.

Energy transfer between the muscle groups of the lower extremities during the concentric contraction phase of the take-off was calculated using the method described in [4, 35] (**Figure 4**). We found that the mechanism of energy transfer was almost not used by ski jumpers (Hip-Knee: 3–6%, Knee-Ankle: less than 3%, H = 8,564 p < 0,01). The highest percentage of energy transfer was found in bobsledders (Knee-Ankle: 28 ± 0.8% in a drop jump from 0.3 m, 25 ± 0.7% in a drop jump from 0.5 м) and alpine skiers (Hip-Knee: 23 ± 0.4% from 0.3 м), but the segments

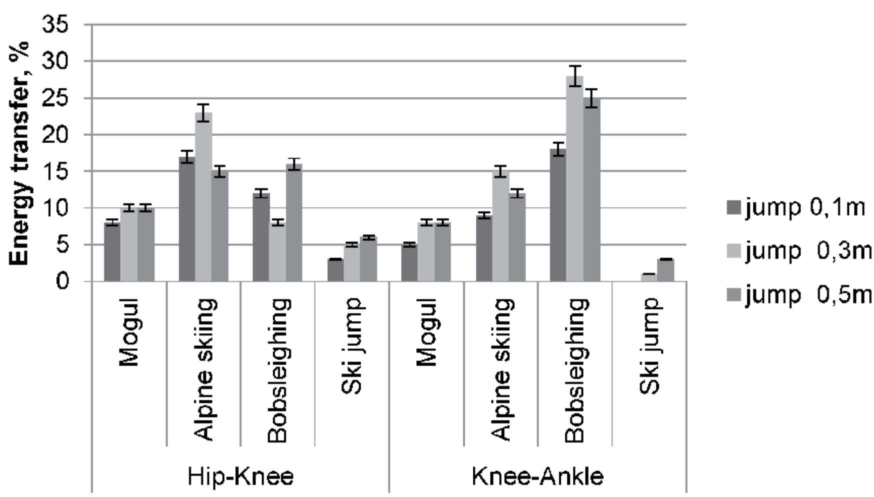

Figure 4.
Transfer of energy between muscle groups of the lower limbs in the take-off phase (concentric muscle contraction).

of the lower limbs mostly involved in the energy transfer were different in those two groups. In bobsledders the highest energy transfer occurred from the thigh muscles to the lower leg muscles via the knee joint, while in alpine skiers energy transfer between the hip extensors and the thigh muscles was the highest. Mogul skiers showed a very low energy transfer from the hip extensors to the thigh muscles and almost no energy transfer from the thigh muscles to the lower leg muscles via the knee joint.

Gl - gluteus maximus, gluteus medius, gluteus minimus muscles, RF - rectus femoris, VAS - vastus medialis, GAS - lateral sections of the gastrocnemius muscle, SOL - soleus muscle.

The highest peak metabolic costs of all lower extremities muscles were found in mogul skiers (**Figure 5**). In all athletes peak metabolic costs of the hip extensor (Gl) tended to decrease, as the height of drop jumps increased, because athletes tried to maintain more upright posture for stability. All athletes had the lowest peak metabolic costs in GAS. In mogul skiers the maximum metabolic costs in GAS were registered in drop jumps from the height of 0.1 m (40.9 ± 2.5 W); in ski jumpers the minimum metabolic costs in GAS were registered in drop jumps from the height of 0.5 m (7.2 ± 1.2 W). High peak metabolic costs in RF and VAS were found in all athletes (87.2–73.1 and 105.1–74.6 W, correspondingly). As the height of drop jumps increased, the metabolic costs in RF and VAS_L increased in mogul skiers and decreased in alpine skiers. The total metabolic costs increased in mogul skiers and ski jumpers, were stable in alpine skiers, and decreased in bobsledders, when the height of drop jumps increased.

Gl - gluteus maximus, gluteus medius, gluteus minimus muscles, RF - rectus femoris, VAS - vastus medialis, GAS - lateral sections of the gastrocnemius muscle, SOL - soleus muscle.

The peak force in the tendon of the MTU model involved in the take-off is shown in **Figure 6**. Ski jumpers had the lowest peak force in the tendon in comparison with the other subjects for all muscles and in all drop jumps. Alpine skiers, bobsledders and mogul skiers demonstrated active work in the tendons of the GAS and SOL muscles, as well as positive dynamics, as the height of drop jumps increased. Tendon activity of VAS in mogul skiers and alpine skiers revealed similarity in magnitude and positive dynamics. The greatest peak activity of the Gl tendons during the take-off was observed in alpine skiers when drop jumping from a height of 0.5 m (108.3 ± 6.7 N).

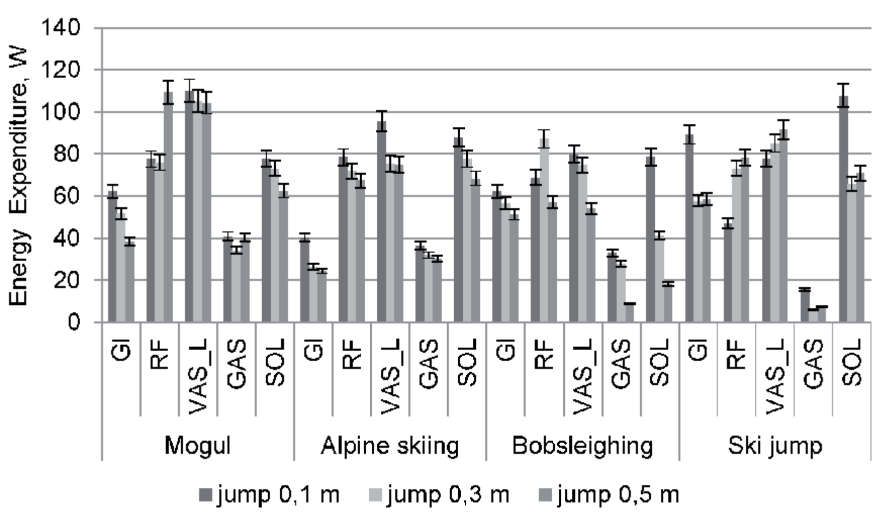

Figure 5.
Metabolic expenditures in simulated muscles.

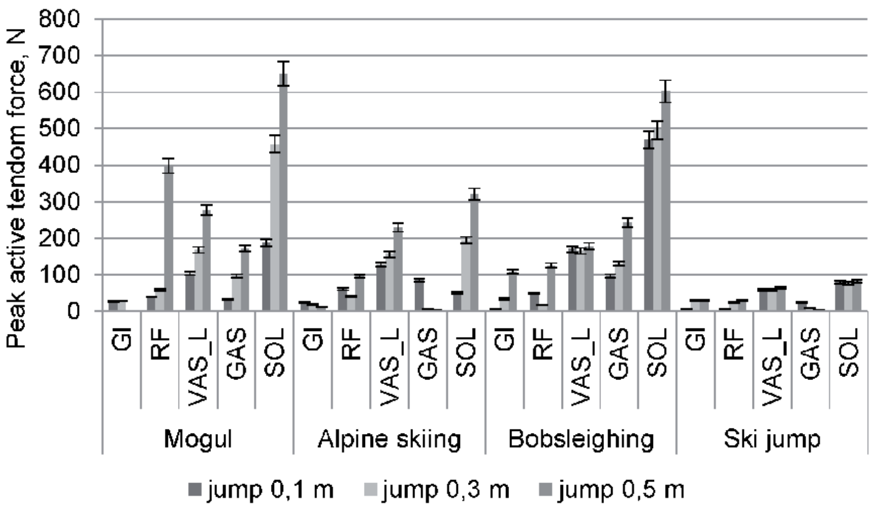

Figure 6.
Peak active tendon force.

4. Discussion

To understand the peculiarities of the MTU work in athletes of four different sport specializations, it is necessary to briefly present specific features of those sport disciplines.

4.1 Alpine skiing

Alpine skiing includes four disciplines, which are divided into technical disciplines (slalom SL, giant slalom GS) and speed disciplines (super giant SG, downhill DH). In slalom (SL) the peak ground reaction force (GRF) being a measure of the external load on the skier and equipment, can reach five times the body weight of an athlete [41]. In three other alpine skiing disciplines the highest GRF values are observed in giant slalom [42]. The main muscles involved in alpine skiing are the thigh muscles, hamstrings, quads, calves, and foot muscles [43]. Most of the muscles involved in alpine skiing contract eccentrically during the race. This means that the muscle lengthens as it contracts. The contraction rate during downhill skiing is relatively slow compared to running or jumping. This is due to the fact that, for example, the angle of the hip does not change significantly during a ski turn, so the rate of contraction is relatively low. Alpine skiing requires fast movements with multiple maximum contractions. Compared to other athletes, alpine skiers have high isometric leg strength [44] and isokinetic leg strength, measured as maximum torque during knee extension [45]. In technical disciplines, a "quasi-static" component of skiing has already been proposed because of the evidence for coactivation during contraction of the thigh muscles [46]. Evidence from elite Swiss riders confirms that eccentric muscular work prevailed over concentric work in the SL, GS and SG disciplines [47]. Authors [47] claimed that alpine skiing is "the only sport in which eccentric muscular activity predominates" [47]. Higher levels of force allow the skier to work with less relative strength, which can lead to more control in turns (less energy dissipation) and less fatigue when racing.

4.2 Mogul skiing

Mogul skiers have to overcome irregularities in the form of bumps and pits when descending from the mountain. On a mogul course, the turns to the left and right of the downhill line are always made cyclically, without any separate transition phase between individual turns. An athlete goes around the hillocks on the descent. He/she makes a turn at each bump that forms the so-called "swinging rhythm". Mogul skiing is characterized by clearly identifiable ski loading and unloading phases, and alteration of ski bending and unbending. The load, being almost evenly distributed between both skis, reaches the maximum value of about 150% of the skier's body weight on each ski. The technique obliges athletes to move along the track with an angle at the knee joints close to 90° to ensure the minimum deviation of the CoM trajectory. This stance allows a skier to cushion the height differences of bumps and pits, while maintaining and controlling the speed. According to the data of [48, 49], it was shown that in mogul skiers, in contrast to alpine skiers, the ratio of eccentric/concentric patterns is close to those in running.

4.3 Bobsleighing

A standard bobsled race may be divided into three phases: start, race and finish [50]. Acceleration and high speed at the end of the start phase are crucial for high bob speed during a race and a better overall result [50, 51]. At the start phase, athletes must start the race by pushing the bob within 60 seconds after the start signal and run at full speed about 55 m. The start and push phases last for only 6 seconds, but they are the most important for the final result [52]. To perform a push-start, leg extensors must generate high mechanical power in the hip, knee and ankle joints to create significant horizontal propulsive force that propels the athlete's body and bob forward. Previous studies reporting the electromyographic (EMG) activity in sprinters in the acceleration phase have shown that biceps femoris (RF) is one of the most important muscles for developing maximum speed [53]. Similar as at the start of a sprint run, the longer running distance increased workload of the plantar ankle flexors [52].

4.4 Ski jumping

Take-off in ski jumping is a very important phase [54, 55], since it affects the initial flight phase. Three parameters indicating a change in body position during a take-off are important for the overall performance: (1) generation of angular momentum during a take-off [54, 56, 57]; (2) high speed of leg extension [54, 56, 57]; and (3) direction of a take-off [58–60]. Athletes perform a take-off in a quasi-static crouch position [57]. This position is necessary to maintain an effective aerodynamic posture and to resist the pressing external force acting on the body at a speed of about 90 km/h. According to [61], time from the start of the lower extremities extension and the rise of the athlete's center of gravity (COG) is about 0.22 ± 0.03 sec. The data presented in [62] indicate the time range of 0.25–0.30 sec. The study [59] examined the activity of the vastus lateralis muscle, vastus medialis, gastrocnemius, tibialis anterior and gluteus maximus. During acceleration on the jumping ramp the activity of all those muscles is very low. When an athlete enters the inner curve of the jumping ramp, the activity of the vastus lateralis, tibialis anterior and the gastrocnemius muscles grows that stabilizes the knee and ankle joints. Stable knees resist additional stress caused by the centrifugal force. The gluteus maximus remains inactive. During the take-off activity of the vastus lateral and the gastrocnemius muscles significantly increase. The tibialis anterior and gastrocnemius muscles are active to stabilize the ankle, but their activity is not greater than that registered at the curve of the jumping ramp. Greater activity of Gl at the end of the take-off results in an increase of moments in hip joints. Involvement of GA in the final phase of the take-off is considerably lower than in vertical jumps, in which plantar flexion plays very important role. A ski jumper rises skis quickly that does not allow him/her to use the gastrocnemius effectively, and knee extensors are the main muscles involved in the take-off. On the other hand, the design of ski jumping boots limit efficient plantar flexion during the take-off [62].

The data presented in the results section show that all groups of athletes chose different strategies for producing muscle power in order to achieve the maximum jump height in drop jumps. We will try to explain the mechanisms of work of lower extremities' muscles in athletes, who demonstrate different organization of movement and interaction of muscles and tendons in drop jumps. Let us examine ways of enhancing MTU contraction, which employ elastic properties of muscles, in particular, their resilient elements, that results in muscle potentiation. Besides that, enhancement of muscle contraction occurs due to stretch reflex, which manifests itself when the muscle is stretched for 20–50 ms [63] and even up to 60 ms [64]. There is no disagreement in the literature that the preliminary stretching of the MTU enhances its subsequent contraction, and this fact is described by many authors. However, with regard to the mechanisms underlying this phenomenon, many authors express doubts about the unambiguity of conclusions in favor of each of them, in particular, regarding the use of the energy of elastic deformation [65]. At the same time the use of the energy of elastic deformation in running and hopping is beyond any doubt. All doubts arise from the difficulty to examine human MTU behavior in vivo, in particular in complex multi-joint movements. Without inquiring into the mechanisms of MTU pre-stretching, let us discuss if the athletes participating in our study use the positive effect of MTU pre-stretch.

In the groups of alpine skiers and mogul skiers, duration of the take-off went far beyond the time limits where it was possible to use the positive effect of the stretch reflex. However, the subjects of these two groups could enhance voluntary contraction of their leg muscles due to elastic strain energy, even though the shock absorption phase was very long. Although an increase in the MTU stretching time reduced efficiency of elastic strain energy use, this mechanism was preserved [66]. We might be confused by the fact that the optimal ratio of muscle length and speed of their stretching is disturbed in alpine and mogul skiers because of large angular amplitudes of movements in leg joints. However, the use of elastic energy is still possible for any muscle length [67]. The question arises with regard to the use of the positive effect of shock absorption in drop jumps performed by alpine and mogul skiers. Question: Did the MTU work differ in these groups of athletes, since the technique of sport exercise was different? The answer is obvious - yes, it differed. This is confirmed by the data related to the transfer of elastic deformation energy between the lower extremities links. First of all, let us examine results of the drop jump from the height of 0.3 m, in which the load on the leg muscles is optimal for achieving the maximum jump height [68]. In the drop jump from 0.3 m the possible use of elastic energy in the take-off phase was: 23 ± 1.6% (Hip-Knee) and 15 ± 1.1% (Knee-Ankle) in alpine skiers, and 12 ± 0.6% (for Hip-Knee) and 8 ± 0.5% (for Knee-Ankle) in mogul skiers. Alpine skiers used energy transformation more effective than mogul skiers that was due to the higher stiffness of their leg muscles. The difference in the utilization of stored elastic energy between the subjects was visible when comparing metabolic costs in RF and VAS and tendon strength in these muscles, which were significantly higher in mogul skiers. In a drop jump from the height of 0.5 m the external load on the leg muscles was almost critically high. Mogul skiers showed a drop in mechanical power as well as an increase in RF metabolic costs and RF and VAS_L tendon strength. In both groups we found a decrease of elastic energy use. Referring to the difference in the requirements of a sport exercise, we may assume that there are no mandatory requirements for mogul skiers to generate maximum power during a mogul race, unlike for alpine skiers.

In alpine skiers, the decrease in efficiency of energy transfer might be associated with the decrease in stiffness in order to increase the role of muscle activity.

Bobsledders demonstrated the highest percentage of mechanical energy transfer. As the height of a drop jump increased, the metabolic costs of activation of the GA and SOL muscles decreased and the peak strength of tendons increased. These results indicate the use of the mechanism of transfer of mechanical energy generated during muscles pre-stretch. This mechanism can only be activated if the extension starts in the hip joint, which generates the greatest power. The energy transfer cannot occur instantaneously, because the bicarticular muscles need time to stretch and gain stiffness in order to reduce energy loss caused by dissipation [69]. When the hip joint extended due to Gl contraction, the energy was transferred to the shin via the RF, then it took time for the GA to be activated after the start of the knee extension. Elastic energy was stored in the tendons of the ankle extensors and then it was released quickly. The MTUs of the muscles acted as an adjustable spring, and the contractile component modulated the energy required for fast limbs extension. Thus, leg extension occurred with successive achievement of peak power values in each of the joints and peak values of the linear velocity of the leg links in the direction from the proximal joint to the distal one. In fact, energy transfer in squat jump and counter movement jump occurs exactly this way [3, 70–72]. As a result, the ankle joint being controlled by the weakest muscle group, can develop greater power due to the energy received from the proximal joint [3]. Thus, to achieve maximum muscle power, bobsledders used conjoint work of both muscles and tendons that permitted them to make use of the mechanism of energy transfer based on the pre-stretch effect. The group of bobsledders included former track-and-field athletes. To push the bob, they extended the lower extremities using similar range of articular angles as in drop jumps. According to our data, it can be assumed that ski jumpers have no technical skills to increase muscle power in a take-off using additional mechanisms besides muscle activity. The ski jumpers showed the longest take-off time in drop jumps, and it corresponded to the take-off time from the take-off table in their sport exercise. In accordance with the temporal characteristics of the take-off, we may assume that ski jumpers do not use the effect of stretch reflex. High metabolic costs of muscle work and small forces in the tendons indicated that the ski jumpers used only muscle strength to perform drop jumps from different height and did not employ any additional mechanisms to increase the power of the movement. Pre-stretch in the MTU in the shock absorption phase in drop jumps led to utilization of energy stored in tendons and muscles into heat in the take-off phase. Athletes performed the take-off in drop jumps using the technique they are accustomed to, i.e. the technique of their sport exercise. This was confirmed by a decrease in legs stiffness and an increase in mechanical power as the drop jump height increased.

5. Conclusions

The results demonstrated the strong effect of sport specialization on the motor control in elite athletes. Drop jump performed from different heights revealed peculiarities of MTU functioning which were similar to those used by athletes in competitive exercises. Thus, our data provided an important insight into the contribution of various mechanisms to generating power of a movement in top athletes from different sport disciplines. It has been determined that to achieve the maximum mechanical power in any motor action, athletes used their previous sport experience. Apparently, athletes chose a motor program that maximized the MTU potential, but they used the energy of elastic deformation stored in muscles and tendons in different ways: (1) the energy of elastic deformation permitted to obtain the maximum power due to conjoint work of muscles and tendons; (2) the energy of elastic deformation was accumulated in the tendons for its further recuperation into the muscles and their additional stretching; (3) the energy of elastic deformation dissipated with heat and the movement was performed due to muscle activation. This study confirmed the presence of two mechanisms for transferring elastic deformation energy in the lower extremities: the MTU pre-stretch mechanism and the mechanism of energy transfer via biarticular muscles. These results helped us understand how athletes of different sport specializations employed different mechanisms to increase efficiency of generation of mechanical power taking into account requirements to performance of their main sport exercise.

There were certain limitations in our work. As there were not so many elite athletes to form the experimental groups, the number of subjects in the samples was quite small. Thus, it was not possible to carry out a sufficient statistical analysis. Nevertheless, the results allowed us to define the general trend. Besides that, the work lacks experimental data related to sport exercises. Availability of such data and development of appropriate models would make it possible to expand the comparative analysis of the data. To continue this work in future, it seems important to use an individualized approach to assessing the effectiveness of each elite athlete, taking into account peculiarities of his/her sport technique. A very interesting lead for further research is modeling of conscious control of skeletal muscles and the whole body, taking into account regularities related to the use of various mechanisms of generation power of movements and behavior of MTU presented in this article.

The results of the study are useful for interpretation of differences in test jumps performed by top athletes in the course of regular control. The results of our study may help coaches choose appropriate means and methods of strength training in different sport disciplines, develop special exercises and training regimens for them.

Conflict of interest

The authors declare no conflict of interest.

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Chapter 10

Basic Tools and Techniques for Assessing Strength and General Endurance

Alexander L. Yurchenko and Maria O. Zamulina

Abstract

The desire of more and more segments of the population for self-improvement and self-expression through amateur sports has acquired a global scale. The evaluation and analysis of the amateur athletes' achievements in the chosen physical activity become of practical importance for most amateur athletes and open up the possibility of developing innovative interventions to stimulate the engagement in physical activity of as much population as possible. For this purpose, we have developed an elementary methodology for monitoring the achieved level of strength and overall endurance of students, designed to monitor and motivate amateur athletes of various types of physical activity. The purpose of this research project was to conduct the targeted analysis of the array of physiological indicators of those engaged in physical activity, and also to justify and test technologies for collecting and interpreting objective indicators of performing elementary physical test exercises and calculating their dependence on objective indicators of the cardiovascular system. Subsequently, we planned to develop a simple methodology for collecting, evaluating, and interpreting test information. We suggest using this technique in the daily training sessions of amateur athletes of various qualifications.

Keywords: motor activity, physical activity, age-related changes, heart diseases, cardiovascular and respiratory systems, lifestyle, physical exercises, health promotion, physical training, physical fitness, functional state, working capacity, adaptive capabilities, cardiovascular system, regular physical activity, mobile services, endurance development, fitness level, healthy lifestyle

1. Introduction

This project began as an analytical review of the applied technologies used for periodically monitoring of the physical fitness levels of amateur athletes and then evaluate their practical results. Thereafter it was followed by methodological justification and technological development of methods for selecting and applying test exercises, methods for calculating functional indicators and methods for obtaining objective data. Then 6 months of testing for students who regularly engage in physical activity as part of the educational process [1]. Using the tools of this methodology, the initial (at the beginning of the semester), current (mid-semester) and final (end of the semester) types of monitoring of the strength levels and overall endurance of students were conducted. In total, 112 students and teachers of the Financial

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University took part in the study. Analytical methods and a polystructural approach provided the collection and processing of reliable indicators of the physical fitness level of the examined individuals and indicators of their cardiovascular system.

1.1 Results

4 reliable ($p > 0.5$) test parameters characterizing features of male and female representatives were determined, as well as 4 objective indicators of the cardiovascular system and 1 integral indicator – the endurance coefficient, which shows the level of fitness of the individuals. The age range varied from 17 to 49 years. The methods of data collection used in the study and the point scales of indicators of strength development and general endurance allowed the individuals to form stable skills of control and self-control of indicators of physical fitness and indicators of the individual functional state. The body mass index ranged from 18.5 to 38.98, while 8 subjects were related to the "obese" category. During the training, 8 students were expelled due to poor progress in the development of the main curriculum. More than 80% of the subjects had previous experience of collecting blood pressure and heart rate indicators. More than 90% of the participants acquired the skills of organizing and controlling test physical exercises, which they did not have before. Only 72.2% of the subjects expressed complete satisfaction with the study of objective indicators of physical fitness and cardiovascular system and ways to assess them. The average score was 4.31 points out of 5.0. The presented indicators were obtained according to expert estimates [2, 3].

2. Elementary methodology for monitoring the achieved level of strength and overall endurance of students

Based on objective and subjective methods of assessing physical activity indicators, a method for monitoring the level of strength and overall endurance was developed and tested. The results and opinions obtained during the pedagogical experiment suggest that the proposed technology is suitable for periodic use, and user satisfaction is significantly high. It is proved that the application of the methodology is possible both for expanding the practical skills of university students, and for objective assessment of the physical activity of amateur athletes [4, 5].

The underwritten section discusses the patterns of aging of the human body, the decrease in the amount of physical activity due to the specifics of modern labor activity, and the mechanisms of its negative impact on the body. The correlation between physical activity and the risks of developing cardiovascular diseases is substantiated and shown. The methods of preventing the processes of age-related changes by elementary means of physical activity are given [6].

Modern European and Russian society has changed a large number of life priorities, which were symbols of the outgoing XX century. Over the past 20–25 years, many countries have experienced significant changes in many areas of life: politics, economy, education, medicine, etc. The worldview and world perception of both an individual and entire social groups of the population have changed. Both moral guidelines and life values have changed. In the most developed European countries, the emphasis in mass sports was placed in such a way as to involve the general population in regular classes in sports clubs and sections, and to fight hypodynamia and hypokinesia everywhere [7, 8].

As a universal and most common means of combating the above-mentioned risks, modern humanity recognizes such types of physical activity as running, Nordic walking and cycling. And although the number of participants in the most popular running events in Europe in 2019 decreased by 13% and amounted to 7.9 million people compared to 2016 (then-9.1 million), they still remain the largest community of physical activity enthusiasts [9]. At the same time, in the countries of the Asian region and in Russia, the number of runners continues to grow to this day. There are more fans of running, but they have become slower to run their distances. To a greater extent, this applies to men. In 1986, the average finishing time for the marathon distance was 3:52:35. For today, this result is 4:32:49. The difference in the average finishing time increased by 40 minutes and 14 seconds. At the same time, the age of modern runners has also changed significantly. In 1986, their average age was 35.2 years, and in 2018–2039.3 years. The peculiarities of some running disciplines are that the amateur runners from Spain overcome marathon distance faster than other Europeans, and the Russians are the best at running half marathon distance. The Swiss and the Ukrainians are the leaders in the distances of 10 and 5 km, respectively. For the first time in history, the number of female runners exceeded the number of men. In 2018, the share of women accounted for 50.24% of all participants. In the last 5 years, there has been a steady growth trend in sports tourism. The motivation to participate in competitions has also changed. Now people are more concerned about physical, social, or psychological motivations rather than sporting achievements. This partly explains why people began to travel more, began to run more slowly. This is the answer to the question why the number of people who want to celebrate the achievement of a certain age milestone (30, 40, 50 years) participating in the marathon is less today than it was 15 and 30 years ago [10].

Consider as an example the Russian student population, as a quite significant social group, which in Soviet times, and today, is the object of close attention of specialists in various fields including doctors, psychologists, specialists in physical culture.

Over the past 25–30 years, an alarming pattern of deterioration in the health of young people and their overall physical development has been confirmed. This is due not only to the changes that have occurred in the economy, ecology, working conditions and everyday life of the Russian population, but also to the devaluation of the health and educational functions of physical culture in the society, which was reflected by the lack of harmonious personal development of many young men and women. The health of the nation still raises concerns due to the significant amounts of tobacco, alcohol, and drug use, as well as the lack of motor activity of young people. Positive changes are observed, but still not cardinal [1, 5, 11–13].

In 2018, students consumed 14.7% less alcohol than in 2019. According to the average data of official statistics and selective public opinion polls, 60.2% of young men and 21.7% of girls smoked about 10 cigarettes a day in 2018. In comparison with the beginning of the 2000s, the percentage of smokers among young students decreased from 62% to 60.5%, but in girls, on the contrary, an increase was recorded from 20% to 21.7%. A sociological survey conducted by RPORC (Russian public opinion research center) in August 2018 showed that 35% of the surveyed students living in megacities smoke in general. Surveys of the period 2013–2018 showed a stable share of smokers about 41% of the total number of students [3, 14].

If in 2016 only 39% of the surveyed students stated that they regularly play sports, then by the end of 2019, this figure reaches more than 52%. But at the same time, only 22% of them are engaged in physical culture every day.

As expected, the most active in this regard is the student youth living in megacities. More than 45% of the young people surveyed said that they regularly play sports. While only 26% of middle-aged people living in large cities turned out to be "regular" physical education students.

The most popular type of daily physical activity in Russia is fitness. 43% of respondents said that they do it, 15% of respondents said that they prefer athletics, 14% - swimming.

The main reason why residents of large cities do not engage in physical culture or sports is the lack of time. This was the response of 37% of respondents, 28% said that they do not need to exercise, and 22% said that they simply do not have the willpower to force themselves to exercise regularly.

Thus, over the past 8–10 years, the number of residents actively engaged in sports in Russia has significantly increased. And it is also important that only 30% of respondents believe that mass sports are poorly developed in Russia.

In modern society, the problems of forming the needs of university students in a healthy lifestyle occupy key positions, since students are the main reserve and a significant part of the labor resources of the national economy, and the state of health of students today is public health, the health of the nation in 10, 20, 30 years, as noted by a number of researchers, for example, by N. A. Aghajanyan, M. Ya. Vilensky, A. G. Shchedrina, etc. [1, 15].

These facts are extremely important for people to understand the most productive period of a person's life – a representative of middle age. Sociological research has shown that only 9% of respondents regularly engage in physical culture and sports, 17% of them do it on an occasional basis, and 18% - very rarely.

Physical activity is a multi-faceted and capacious concept. And one of the sharp edges of its implementation is the problem of building an optimal, individualized mode of physical activity, taking into account not the calendar, but the biological age. Otherwise, there is a great possibility of obtaining a negative effect and simply discrediting the principle itself.

With an overdose of physical activity in age-related individuals, overload manifests itself in an exacerbation of coronary insufficiency, blood pressure becomes unstable, and arrhythmia manifests itself. That is why medical, pedagogical and self-control should determine the individual dose of physical activity [6].

In countries with developed economies, the mortality rate from circulatory diseases by a large margin occupies a leading position among other causes of death and is 52%. Over the past half-century, this number has undergone a 5–6-fold increase.

As a result of large-scale studies conducted under the auspices of the World Health Organization (WHO) on large populations in different countries of the world, scientists have identified the main causes (risk factors) of the rapid growth of cardiovascular diseases and mortality from them. The factors were conditionally divided into two groups: primary, exogenous, depending on the lifestyle and environmental conditions; secondary, endogenous – pathological changes in the body that develop under the influence of external factors.

The leaders of the first group include: insufficient physical activity (inactivity) and excessive calorie intake (overeating). In the second: smoking, neuropsychiatric overexertion (stress) and alcohol abuse.

The predominant role of inactivity and overeating in the development of atherosclerosis and coronary heart disease (CHD) is confirmed by numerous studies conducted in different countries on different continents. It was found that in the countries of Africa and South-East Asia, where the population lacks food and the rhythm of life is characterized by relatively high physical activity, these diseases are almost not found [16]. For example, Ugandans, even in old age, are more likely to die from infectious diseases, but not from diseases of the respiratory system and blood circulation. A survey of representatives of the Maoban tribe in South Sudan showed that they do not have CHD at all, the blood pressure level is the same at 15 and 75 years old and is on average 115/70, the cholesterol content in the blood is low and averages about 3.47 mmol/l.

Mortality per 1000 people	A sedentary lifestyle	Moderate activity	High activity
General	20,6	10,6	—
From CHD	7,5	4,0	—

Source: compiled by the author on the basis of materials from international scientific research.

Table 1.
The relationship between physical activity during non-working hours and mortality per 1000 people, in %.

The role of lifestyle in the development of atherosclerosis confirms the following fact. As a result of emigration to economically prosperous countries, experiencing changes in the regime and structure of nutrition, changes in the mode of motor activity, representatives of the African continent are equally affected by diseases of the cardiovascular system, as well as the indigenous population. Moreover, for example, in the United States, the black population has the highest percentage of CHD among the rest of the American population.

A strong relation between physical activity during non-working hours and mortality is shown in the **Table 1**.

The table shows that among people with moderate physical activity, the mortality rate is 2 times lower than in people who lead a predominantly sedentary lifestyle, and in the group with high physical activity, there is no such relationship at all.

The 16-year follow-up of Harvard University graduates revealed that the mortality rate from CHD was 2 times lower in those graduates who were among those who regularly engaged in physical exercise and led an active lifestyle than in those whose life was characterized by a hypodynamic regime.

Dr. Ralph Paffenbarger, as a result of many years of research, has established an interesting fact: the preventive effect against CHD is most effectively provided by physical activity during non-working hours (intensity-7.5 kcal/min, energy consumption per week-at least 2000 kcal) [6].

When observing 36,000 people for 10 years, an American scientist found that only physical activity with an intensity higher than 7.5 kcal/min (long-distance running) had a protective effect, and the usual professional activity in modern production does not have such a protective anti-coronary effect. This fact allows us to conclude that only special wellness programs performed in their spare time are an effective preventive tool to combat atherosclerosis and coronary heart disease. The nature of the loads performed is also of great importance. These should be loads associated with the manifestation of general endurance and sufficiently long in time, the criterion of which is the value of the maximum oxygen consumption.

Thus, individually established modes of physical activity performed in their spare time (in the form of cyclic aerobic exercises aimed at developing overall endurance and increasing the level of maximum oxygen consumption) compensate for the lack of energy expenditure in most representatives of modern society. This avoids the negative effects of inactivity and is a natural, widely available means of promoting and maintaining health, as well as preventing cardiovascular diseases.

Mandatory elements of determining the regime of physical activity is the passage of medical and pedagogical control.

3. Basic assessment of the impact of aerobic exercise on the body ingaged in physical activity

This section substantiates and offers indicators and methods for assessing the level of endurance, functional state, adaptive capabilities and performance of the body, allowing you to quickly and objectively assess the impact of physical activity on the body of people who regularly engage in physical culture [8].

The main indicators by which the effectiveness of the content and methods of physical training performed by modern students, as well as other amateurs of physical activity is judged are the level of endurance development, the functional state of the body, the adaptive capabilities and performance. Periodic evaluation of these indicators allows you to determine on the one hand – the degree of influence of physical training, on the other – to clarify the effectiveness of the tools and methods used.

The proposed method of monitoring the level of strength and general endurance of students is recommended to be carried out independently or in a group with a frequency of approximately once every 1 or 3 months using the following tests:

- pull-ups on the crossbar (for men);
- flexion and extension of the arms at the stop on a bench with a height of 0.4 m (for women);
- lifting the legs to the crossbar (for men);
- lifting the torso from the “lying on your back” position (for women);
- walking on a step with a height of 0.4 m (ascent and descent) for 3 minutes;
- running 1 km (for women);
- running 3 km (for men).

Walking on a step with a height of 0.4 m is estimated by the number of ascents in 3 minutes – the more ascents, the higher the level of physical endurance. At the same time, you should strictly observe the conditions for performing the test – completely straighten the torso and legs.

Indicators of the functional state are the characteristics of the cardiovascular system, the respiratory system, and the motor system.

The state of the cardiovascular system is assessed by the indicators of heart rate, systolic (SP), diastolic (DP), pulse pressure (PP), endurance coefficient (EC). Registration is carried out by generally accepted methods with metered physical activity of the step-test sample. The data obtained during the examination in the state of muscle rest, as a rule, do not allow us to fully assess the functional state of the body, in particular, the cardiovascular system and its reserve capabilities. Various load tests are used for this purpose.

The “step test” is a three-minute physical activity in the form of walking on a step with a height of 0.4 m at a pace of 30 steps per minute. In this case, the registration of indicators is carried out before the load (sitting at rest), at the 2nd, 3rd and 4th minutes of the recovery period.

Based on the obtained data, the endurance coefficient (EC) and the step test index (I) are determined.

The endurance coefficient is used to assess the fitness level of the cardiovascular system.

$$EC = \frac{CCR}{PP} \text{x} 10, \quad (1)$$

where.

CCR – cardiac contractions rate;

PP – pulse pressure.

An increase in the endurance coefficient associated with a decrease of PP indicates a detrained cardiovascular system.

The cardiovascular system has several levels of regulation. It is a functional system, the end result of which is to ensure the necessary level of functioning of the body. These facts give reason to consider the circulatory system as a universal indicator of the adaptive and accommodative activity of the entire organism. The state of the respiratory system allows you to evaluate breath-holding tests on the inhale (Shtange's test) and on the exhale (Gencha's test). The results of the tests are evaluated by the time of holding the breath.

The state of the motor system can be judged by the indicators of students' physical fitness. The study of the students' psychological state is carried out by observation, survey and using the questionnaire HAM (health – activity – mood) demonstrated in the **Table 2**. The HAM questionnaire is designed to characterize the emotional state of military personnel due to the influence of physical training. The task of the subject is to correlate subject's state with a number of polar assessments presented to one. There is a short version of the questionnaire below with seven gradations of states, which are evaluated by points from 3 to 0:

+3 – strong increase (decrease – 3);

+2 – distinct increase (decrease – 2);

+1 – small increase (decrease – 1).

Zero denotes unchanged from the original state.

On the questionnaire form, the subject writes his last name, initials, date and time of filling in. Then, against each of the seven points of the questionnaire, a circle is drawn around the score that, in his opinion, corresponds to his condition.

The points obtained for each of the seven indicators are summed up according to the **Table 3**, and the maximum possible test result is 49 points [16].

The adaptive capabilities of the body are judged by the results of physical tests. At the same time, for these purposes, we propose an integral indicator of the functional capabilities of the body.

For this purpose, two types of physical activity are used:

1. dosed, high-power with recording of heart rate and blood pressure parameters (BP);

2. activity with the maximum possible work capacity, such as running for 1 km or 3 km.

A three-minute step test is used as a metered activity. At the same time, the use of only this load does not allow us to fully identify the physiological reserves of body adaptation – for this it is necessary to make higher demands on the body.

So, K. Cooper, on the basis of experimental studies, showed that the distance that a person can overcome in 12 minutes is proportional to the value of one's maximum of oxygen consumption.

Similar results were obtained by WD McArdle and co-authors when evaluating the dynamics of human cardiorespiratory adaptation during exercise on a treadmill and cycling [17, 18].

Comparing the results of laboratory tests and running tests, it was found that the latter are as accurate in assessing functional capabilities as the results of complex laboratory experiments.

1.	Vigorous	+3	+2	+1	0	−1	−2	−3	Tired
2.	Interest in work	+3	+2	+1	0	−1	−2	−3	Indifference
3.	Attentive	+3	+2	+1	0	−1	−2	−3	Distracted
4.	Good mood	+3	+2	+1	0	−1	−2	−3	Bad mood
5.	Overall health is good	+3	+2	+1	0	−1	−2	−3	General health is poor
6.	Calm, balanced	+3	+2	+1	0	−1	−2	−3	Excited, tense
7.	Confident	+3	+2	+1	0	−1	−2	−3	Uncertain

Source: compiled by the author based on the results of his own research.

Table 2.
Self-assessment questionnaire

Rating on the scale	+3	+2	+1	0	−1	−2	−3
Rating in points	7	6	5	4	3	2	1

Source: compiled by the author based on the results of his own research.

Table 3.
Processing of completed questionnaires on a scale in points

The performance indicators of the two considered loads are combined in a single formula for assessing adaptive capabilities:

$$FI = \frac{I}{\mathrm{T}3km} \mathrm{x}10. \quad (2)$$

where.

FI-functional indicator of adaptive capabilities in relative units;

I – the index of the step test in relative units;

T3km – running time for 3 km, min.

The physiological meaning of the above formula is that it reflects, on the one hand, the cardiac cost of metered work, and on the other – the ability to maximize the mobilization of the body's reserves.

The step test index is determined by the generally accepted formula:

$$\mathrm{I} = \frac{180x100}{\mathrm{P2} + \mathrm{P3} + \mathrm{P4}.} \quad (3)$$

where

I – is the index of the step test;

P_2, P_3, P_4 – heart rate at the 2nd, 3rd, 4th minute of the recovery period after exercise.

The performance can be judged by many of the considered indicators, including tests for assessing physical fitness, adaptive capabilities of the body. The main indicator of human performance is considered to be the maximum oxygen consumption. The value of the maximum oxygen consumption (MOC) reflects the level of person's physical performance.

To determine the MOC, the step-test is convenient to use. The power of the work performed in this case, the heart rate and the nomogram to get the value of the MOC [16].

The most important information about the impact of physical training is the dynamics of the main body state indicators during the training process. Therefore, it is necessary to keep a strict record of the body state indicators obtained during monitoring and self-control.

For rapid assessment of the functional state, a step-test can be used, where after a three-minute load, the heart rate should be determined immediately after the work phase (CCR_w), at the 2nd, 3rd and 4th minutes of the recovery period. At the 4th minute, the blood pressure is measured: systolic (SP) and diastolic (DP).

The functional state of the body can be judged:

CCRw – the heart cost of work (HCW), the lower the indicator, the higher the functional capabilities of the body;

CE – the coefficient of endurance, its increase indicates the detrainment of the cardiovascular system;

I – the index of the step test, the higher the indicator, the higher the functional capabilities of the body.

CE and I are calculated using the above formulas.

An additional survey on the HAM questionnaire will allow to assess the well-being, activity, and mood of the students.

For a more complete assessment of the functionality, it is necessary to conduct races for 1 km or 3 km. The results obtained provide important information, since it is a high-power load and its performance is largely determined by the functional capabilities of the cardiovascular and respiratory systems.

Methods and scale scoring indicators of power and overall endurance development allow to quickly and objectively assess the functional state of students or amateurs of physical culture in the process of their physical perfection, and to determine the effectiveness of their tools and techniques of training, to ensure harmless and motivating process of physical activity, to minimize or eliminate the adverse impact of exercise on the body [19].

Nowadays, the issue of maintaining a healthy lifestyle in a consumer society and maintaining the public health of the population is relevant. According to Federal State Statistic Service, in 2019 only 12% of the Russian population considers themselves fully adhering to the principles of healthy lifestyle. This indicator is calculated based on several criteria. This includes smoking cessation, daily consumption of vegetables and fruits in an amount of at least 400 g, adequate physical activity (at least 150 minutes of moderate or 75 minutes of intense physical activity per week), etc.. To increase the attractiveness of the elements of healthy lifestyle for young people, incentives have been introduced for admission to higher educational institutions for passing the standards of the Civil Defense Squads (CDS) complex and other sports achievements. The article considers the XRF indicators of young people aged 18–24 years, substantiates the claims that the use of mobile services helps to achieve the desired physical fitness indicators.

For the purpose of the study, data from 50 Strava users of both sexes, who were randomly selected, systematically used the program's services and regularly, at least 3 times a week, shared the total results of all their physical activities – walking, running, cycling. The data obtained after mathematical processing are presented in **Table 4**, in which the average annual total indicators of 25 men and 25 women are calculated [12].

According to **Table 4**, the average speed of a man's regular physical activity is 2.33634 km/h lower than the target average speed in the "5 km run race" test. This indicates an insufficient level of men's endurance development of this sample. The actual average speed does not allow them to pass the CDS standard for the Golden Badge of Distinction, shown in the **Table 5**, without special direct training. To give a more complete degree assessment of physical fitness of the selected group of men, let us compare their performance with the standards necessary for passing the CDS for the Golden Badge. As an example, consider cross-country running, because this type of physical activity is most similar to running on the street, which the subjects are engaged in.

When comparing the indicators, it is clear that the average mobile service user does not fit into the standard of the CDS, since its "endurance coefficient" (the ratio of time to distance) and the average speed are lower than the calculated ones. Thus, it should be concluded that the level of overall endurance of the examined men is insufficient. However, if we pay attention to the more individual data of each participant, we can note a different picture. The results of 7 out of 25 men are close to the coefficient required for successful completion of the CDS complex, which is 28% of the total number of subjects.

A similar situation is observed among women. According to the **Table 6**, it can be concluded that the average speed of women using the mobile service is lower than the estimated speed (**Table 7**). This fact shows an insufficient level of overall endurance in the category of women.

Comparing homogeneous indicators of "coefficient endurance" of the women, and the test of the CDS VI stage "3 km run race", it is clear that the rate in equal measure is not valid, as in the case with men.

When considering the individual indicators of the surveyed participants, it was found that 6 out of 25 women can pass cross-country running in accordance with the standard of the CDS, which corresponds to 24% of the total number of surveyed women.

Total time of physical activity (min)	Total distance (km)	Endurance coefficient (EC)	Actual average speed during physical activity (km/h)
7827,783	88454,10	0,088495	11,30002

Source: calculated by the authors in the course of the study.

Table 4.
Annual average total indicators of physical activity of the test subjects-users of the mobile service (men).

Age category (CDS stage)	Target indicators	Endurance coefficient(EC)		Actual average speed during race (km / h)	
		aim	fact	aim	fact
Men 18–24 y.o.	«Gold» Run race 5 km	0,073333	0,088495	13,63636	11,30002

Source: calculated by the authors in the course of the study.

Table 5.
Comparison of homogeneous numerical indicators (men).

Total time of physical activity (min)	Total distance (km)	Endurance coefficient (EC)	Actual average speed during physical activity (km / h)
6733,083333	62259,10	0,10814617	9,246744

Source: calculated by the authors in the course of the study.

Table 6.
Annual average total indicators of physical activity of the test subjects-users of the mobile service (women).

Age category (CDS stage)	Target indicators	Endurance coefficient (EC)		Actual average speed during race (km / h)	
		aim	fact	aim	fact
Women 18–24 y.o.	«Gold» 3 km run race	0,097222	0,10814617	10,28571	9,246744

Source: calculated by the authors in the course of the study.

Table 7.
Comparison of homogeneous numerical indicators (women).

Based on the performed analysis and data processing, it can be concluded that the level of overall endurance of mobile service users is not sufficient to pass the CDS test "from scratch", without specially directed training. Elementary calculations of the personal XRF and their comparison with the target indicators will help in planning the process of preparation for passing the standards of the CDS complex. The study showed that monitoring the personal results of the XRF has a motivating effect on users, contributes to the progress indicators, and makes this process interactive and interesting.

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Chapter 11

The Interaction between Dietary Components, Gut Microbiome, and Endurance Performance

Basista Rabina Sharma and Ravindra P. Veeranna

Abstract

Research so far indicates that gut microbiome and diet interactions influence obesity, diabetes, host immunity, and brain function. The ability of athletes to perform to optimum for a more extended time, as well as the ability to resist, withstand, recover from, and have immunity to fatigue, injury depends on the genetic factor, age, sex, training history, psychological factors, mode, intensity and frequency of training and their interactions with the external dietary components. However, recent evidence indicates that the gut microbiome may also potentially influence the development of endurance in response to the type and composition of the external diet, including several food supplements. Thus, the gut microbiome has become another target in the athlete's pursuit of optimal performance. This chapter discusses the effect of exercise on the gut microbiome, the interplay between dietary components and supplements on the gut microbiome, and its impact on endurance performance.

Keywords: Diet, Gut, Endurance

1. Introduction

Endurance exercises can be defined as prolonged exercises like running, cycling, cross-county skiing, aerobics and swimming, often involving resistance [1]. Endurance exercises require systemic and muscle-based physiological and biochemical responses to complete the endurance activity [2]. The athletes expose their bodies beyond their physiological circumstances, which affect the homeostasis, overwhelming normal tissue function [3]. Prolonged physical exercise will force body to defend against the events that will result in the synthesis of proteins, releasing of hormone, changes in body fluid as well as metabolic balance [4]. In order to adapt toward the endurance exercise, an individual should improve his mechanical, neuromuscular, metabolic and contractile functions in muscle, rebalance of electrolytes and decrease in glycogen storage [5]. Furthermore, endurance exercise will cause muscle damage, alterations in intestinal permeability, systematic inflammation, immune response and oxidative stress in the athletes [6]. Excessive exercise will effect the blood flow, resulting in loss of fluids and electrolytes. The body will start synthesizing glucocorticoids and adrenaline hormones to re-establish homeostasis [7].

Human gut microbiota act as an endocrine organ and plays a significant role in energy harvesting, nutrient uptake, vitamin synthesis, modulation of inflammatory, host immune response etc. Several intrinsic and extrinsic factor effect the gut microbiota, which will lead to dysbiosis. Some factors include diet, lifestyle, environment, antibiotic use, age and birth delivery route. Recent findings reported that exercise induced changes in gut microbiota, through mechanisms not well-understood results modifications in metabolism, physiology, immunity and behavior in host [8]. Dysbiosis depends on the intensity, types and timing of excessive exercise [9]. Human gut microbiota also influences muscle mass and aging of the body. Studies reported the reduction of microflora in gut microbiota having anti-inflammatory and proanabolic effects [10]. To adapt to the excessive physical load and increased energy consumptions, individuals performing excessive exercise e.g. athletes, should balance gut microbiota composition, which can only be done by adopting good dietary habits and using sports nutritional supplements. Gut microbiota plays significant role in the wellbeing, health and sports performance in athletes [11]. This chapter, discusses the effect of exercise on the gut microbiome, the interplay between dietary components and supplements on the gut microbiome, and its impact on endurance performance.

2. Gut Microbiota

Gut microbiota refers to specific microbial population in the gut that includes the bacterial and viral origin and is considered as non-pathogenic [12]. Gut microbiota coordinately works with the immune system of the host, to protect from pathogen colonization and invasion. Gut microbiota act as a good source of essential nutrients and vitamins, also help in the extraction of nutrients, including vitamins and SCFA from food. In the end, host depends on its intestinal microbiota, and intestinal microbiota contribute to the host's health [13]. The interplay between gut microbiota and host physiology influences the metabolic phenotype, stress response of the host. Further, the equilibrium between the microbial diversity is is essential maintain the host homeostasis including energy metabolism, oxidative stress, hydration status, immunity response, systematic inflammatory response and brain-gut axis [14]. The dysbiosis in the gut microbiota may contribute to the onset of chronic conditions including inflammatory and irritable bowel diseases, gastrointestinal symptoms linked to exercise, colorectal cancer, obesity, diabetes, metabolic syndrome, allergy, depression, anxiety [15]. The factors that influence host intestinal microbiota are genetic, lifestyle including physical activities, diet and environmental factor [9]. Physical activity is linked to specific markers of intestinal health [16–18]. Some of the evidence suggests that exercise positively influence the gut microbial community, which is beneficial to the host [19].

2.1 Effect of diet on gut microbiota

The human diet is very complex, where foods are not consumed separately, and nutrients are act synergistically. Hence, the dietary patterns are considered the key element of human health. Dietary habits includes the diet variety, nutrient adequacy, intake of healthy food, and considerable amount of less healthy foods [15, 20]. Changes in dietary habits leads to change in the GM. GM since diet has a significant role in determining the composition of GM [21, 22]. Alternative or mismanagement in dietary patterns may harm the population of healthy microorganisms in GM. Researchers have identified that prevailing dietary patterns in US, European and Asian populations, may have a risk of diabetes and obesity [23, 24]. *Bifidobacteria*, *Clostridium* and *Bacteroidetes* decreases due to low carbohydrate diet as carbohydrate is the source of energy for these microbes [25, 26] studies have found that intake of dietary fiber in the diet increases the short chain fatty acid (SCFA) producing bacteria in the GM. The western diet rich in animal protein and fat showed a significant reduction in gut microbiota diversity due to the low amount of dietary fibers [27]. The mediterranean diet includes intake of various polyphenol rich fruits, herbs and vegetables which lower down the risk of metabolic diseases especially diabetes and obesity [28]. Intake of a high protein diet leads to increased *Bacteroidetes*, *Lactobacillus*, *Bifidobacteria* which will benefit the host for metabolism, immune system and nervous system [29]. Keto diet will lead to Dysmicrobism because microbiota need carbohydrates as a source of energy [30]. Intake of high-fat diet will result in impairments in colonic epithelial integrity and barrier function due to the decrease in *Bacteroidetes* and *Firmicutes* [31].

2.2 Effect of endurance performance on gut microbiota

The effect of excessive exercise on human gut microbiota compositions depends on several factors like body fat, age, diet, timing, training status of the particular subjects. Effect of exercise start early in life. Physical activities promote increases in *Bacteroidetes* and decreases in the *Firmicutes* phylum in the gut of young than in adults, also increases in lean body mass through the adaptation of host metabolism [32, 33]. Several have reported that microbial population altered by exercise favour the development of the brain [9]. Several pieces of evidence reveal the present of diverse microflora in an athlete, with an abundance of *Bacteroidetes, Akkermansia, Veillonellaceae, Prevotella,* and *Methanobevibacter* [32]. A higher amount of *Prevotella* and *Methanobrevibacter smithii* were found in professional as compared to amateur cyclists. This microflora is known to involve in carbohydrate and energy metabolism in the human body [34, 35]. Overweight adults, following a fiber and whole-grain-rich diet for six weeks, the presence of *Prevotella* abundance predictive of weight loss, suggesting that enterotype should be considered in personalized nutritional strategies to counteract obesity [36, 37]. One of the studies shows the difference of microflora between active and sedentary Women. Active women have a higher amount of health-promoting bacterial species, including *Akkermansia muciniphila, Roseburia hominis, Faecalibacterium prausnitzii* and *Coprococcus* genus [38, 39]. *Akkermansia muciniphila* is a mucin degrading bacteria that protects the intestinal lumen, and its levels are, negatively associated with metabolic disorder in pateints with inflammatory bowel diseases [40, 41]. In addition, exercise has shown positive impact on the gut mucus layer, which is an essential substrate for the mucosa-associated bacteria e.g. *Akkermansia muciniphila. Roseburia hominis* and *Faecalibacterium prausnitzii* were known to produce butyrate, showing a positive impact on intestinal function and metabolism of lipid, thereby having anti-inflammatory properties [42]. Other studies have also reported the abundance of *Coprococcus* genus in active women [32]. One of the study conducted between lean and obese adults performing endurance exercise under proper dietary control reveal the abundance of butyrate producing taxa in lean adults as compared to the obese adults [43]. Similar studies reported by Galle, (2019), showed the abundant of *Faecalibacterium* sp. in lean adults compared to obese adults [44]. This study confirmed the influence of BMI in gut microbiota. Thereby normalizing the BMI, age and diet can have a beneficial effect on individuals, by increasing butyrate producing taxa.

Recently, it was reported that *Veillonella* is a performance enhancing microbe known to utilize lactate and produce propionate [45]. Similar studies reported that lactate can be converted into propionate by the *Veillonella* [46]. Thus the production of SCFA by gut microbiota will promote health benefits toward the host during exercise, thereby contributing to exercise-induced adaptation. The SCFA produce by the microbiota fermentation will later act as an energy source for the liver and muscle cells, thereby improving endurance performance. Moreover, it is needed to balance the gut microbiota composition over time.

3. Dysbiosis of gut microbiota during endurance performance

The dysbiosis in the GM is linked to various pathophysiological conditions such as intestinal disorders (inflammatory bowel disease, coeliac disease, irritable bowel disease) and extra-intestinal disorders (allergy, metabolic syndrome, asthma, cardiovascular disease, obesity, oxidative stress) [47]. The beneficial bacteria play an essential role in controlling the fermentation and absorption of dietary nutrients such as SCFAs [48]. The dysbiosis in the microbiota influences the development of disease which involved the pivotal mutualistic relationship between colonic microbiota, their metabolic product and the host immune system. Recent evidence has implicated the influence of excessive exercise on GM dysbiosis [49]. Studies in mice found that excessive exercise negatively impacts immunity, substance and energy metabolism, and gut microbial diversity [50].

Generally, it is believed that exercise is beneficial for the gut, but athletes with regular training and exercise have been reported to experience gastrointestinal disorders termed exercise-induced gastrointestinal syndrome. The frequency of developing the syndrome depends on numerous factors like sport type, the intensity of exercise, gender and syndrome often observed: loose stool, diarrhea, abdominal pain, intestinal bleeding in the lower digestive tract [51, 52]. There are two pathways suggested as causative for this disorder: Circulatory- gastrointestinal pathway and neuroendocrine-gastrointestinal pathway. In Circulatory-gastrointestinal pathway, high intensity exercise cause gut ischemia–reperfusion, which is a factor associated with site specific oxidative stress intestinal injury and in Neuroendocrine-gastrointestinal pathway, both physical and psychological stresses alter the gut motility and transit through enteric nervous activity which causes gut malabsorption of nutrients [53–55]. Studies found that intense endurance running (triathletes) lead to malabsorption of carbohydrates [27]. Evidence suggests that female endurance runners had a higher abundance of inflammation related bacteria and a higher concentration of succinate in the intestinal lumen due to dysbiosis, thus affecting the endurance performance [56].

3.1 Energy metabolism

During endurance exercise, energy availability is the essential limiting factor, and restoring the cellular energy homoeostasis is a must. There is a complex relationship between gut microbiota and host's energy metabolism. Gut microbiota increases the ability to harvest the energythe energy from digested food, thereby producing metabolites and microbial products (SCFA, secondary bile acids, and lipopolysaccharides). These microbial products will later modulate appetite, energy uptake and storage, gut motility and energy expenditure [57]. Healthy gut microbiota can exert positive effects in athletes. One of the studies reported that physical exercise and associated dietary adaptation are linked with changes in the gut microbial diversity [58]. Supplementation of probiotic bacteria *Lactobacillus plantarum* TWK10 improves energy metabolism. It transports the host fatty acid to the organ via bloodstream, further metabolized in the mitochondria to generate energy [59].

3.2 Immune response

During endurance exercise, immune response activation plays an important role. Some evidence suggests that, prolonged periods of intense exercise suppress the immune response, including monocyte, granulocyte, leukocyte count, and serum immunoglobulin levels among individuals [60]. Intense exercise training increased the number of pro-inflammatory cytokines, also anti-inflammatory modulator, intestinal lymphocytes. These will lead to the fluctuation of gut microbiota diversity and in their secreted metabolites, increase hyperthermia, gastrointestinal permeability, destruction of gut mucous membrane thickness and weakens the activity of antioxidant enzymes [61]. Studies found that strenuous exercise suppresses the lymphocytes proliferation, levels of secretory IgA in saliva and modulates the synthesis of inflammatory cytokines [62]. Studies suggest that monitoring the gut microbiota diversity and modulating it by the supplementation of probiotics and prebiotics will be more cost effective compared to the utilization of drugs [63].

3.3 Oxidative stress

During endurance exercise, oxygen consumption increases which will cause disturbance in intracellular pro-oxidant-antioxidant homeostasis [64]. Modulations of oxidative and nitrative stress can control tissue damage, bacterial translocation and intestinal permeability. Enzymatic and nonenzymatic antioxidant protect excessive oxidative damage, and therefore, consumption of antioxidant would be a beneficial to control the oxidative damage [65]. The relationship between gut microbiota and controlling GI redox is still not clear. Some data found that *Lactobacillus* and *Bifidobacterium* levels are negatively correlated with oxidative stress, while the *Escherichia coli* population is positively correlated with oxidative stress [66]. Study in mice, found that higher levels of *Bacteroidetes* protect against intestinal infection by supressing pro-inflammatory and pro-oxidant responses [67].

3.4 Dehydration status

During endurance exercise, an increased in fluid loss from sweating will lead to dehydration [68]. One of the main functions of mucosal epithelial cells is transportation of electrolyte. For proper functioning and protection of intestinal barrier, proper water transport and mucosal hydration are necessary [69]. During excessive exercise, studies found that healthy gut microbiota can maintain proper hydration and will prevent inflammatory response. Evidence suggest that activation of Cl- secretion alters the colonic inner mucus layer which lead to the increased in abundance of *Firmicutes* phylum and *Alistipes* genera [70]. In order to obtain a good hydration state and protect intestinal barrier in athletes, it became necessary to understand the role gut microbiota on water transport, diet and mucus intestinal layer.

4. Diet modulation of gut microbiota in athletes

Dietary changes are the most significant factor in altering gut microbiota both in infancy and in adulthood. Recently, it has been found that probiotics, polyphenols, prebiotics and antibiotics can modulate the gut microbiota community [71]. Many evidence have been reported, how probiotics, prebiotics alter the gut microbiota population which will benefit individuals suffering from metabolic disorder, gut permeability, inflammation, immune system and energy metabolism [14, 72].

Probiotics are food supplements that contained a live microorganism (Lactic acid bacteria), which confer a health benefits a health benefit for the host [73]. Many probiotics products are available in the markets like fermented milk and yogurt, etc. [74]. Consuming probiotics has a positive effect gut microbiota's population which will influences the immune function as well as intestinal epithelium cell proliferation, function and protection in the athletes. Various double-blind clinical trials, cross-over pilot studies show that supplementation of probiotic bacteria can modulate the gut microbiota and have a beneficial effect on the individual with regular exercise training (listed in **Table 1**).

The effect of probiotic bacteria in athletes has been reported and assists athletes with respiratory and gastrointestinal disorders during the specific training periods. However, the effects of prebiotics are not being studied in athletes. Many researchers reported the specific type of dietary components can do a measurable change in gut microbiota composition thereby increasing the levels of *Lactobacilli* and *Bifidobacteria* and many butyrate producing bacteria. The increase in *Lactobacilli* and *Bifidobacteria* can influence the immune functions, intestinal epithelium cell proliferation and protect individuals from oxidative stress induced due to the exercise [82]. Some of the studies reported that supplementation of polyphenol increased health promoting microbiota *Lactobacillus, Bifidobacterium,* and decreased pathogenic species *Clostridium* [83]. Roopchand [84] reported that polyphenols obtained from grape promote the growth of the gut bacterium *Akkermansia muciniphila* resulting in lower intestinal and systemic inflammation and improved metabolic system. These reported data can be a promised toward the various functional foods can regulate gut microbiome community, their structure and function

Exercise	Experimental design	Supplementation of Probiotic bacteria	Effect on GM	Remarks	References
Endurance trained men (triathletes, runners, cyclists)	Randomized, double-blinded, placebo controlled trial	*Bifidobacterium bifidum* W23, *Bifidobacterium lactis* W51, *Enterococcus faecium* W54, *Lactobacillus acidophilus* W22, *Lactobacillus brevis* W63, and *Lactococcus lactis* W58	—	Beneficially affected TNF-α and exercise induced protein oxidation	[75]
Athletes	Random trial	*L. rhamnosus* IMC 501® and *L. paracasei* IMC 502®	—	Increase antioxidant levels and neutralize the effects of reactive oxygen species.	[76]
Endurance Athletes	Randomized, double blind crossover study	*Lactobacillus Salivarius* (UCC118)	—	Attenuates exercise-induced intestinal hyperpermeability	[77]
Endurance Exercise (Swimming)	Random study	*Lactobacillus salivarius*	—	Improve muscle strength and endurance performance, increased hepatic and muscular glycogen storage, and decreased lactate, blood urea nitrogen (BUN), ammonia, and creatine kinase (CK) levels after exercise	[78]

Exercise	Experimental design	Supplementation of Probiotic bacteria	Effect on GM	Remarks	References
Treadmill exercise	Double-blind placebo-controlled clinical study.	*L. plantarum* TWK10	—	Physiological adaptation and health benefits for amateur runners	[59]
Treadmill exercise	Double-blind, placebo-controlled, crossover trial	*Lactobacillus fermentum* VRI-003	—	Enhance the mucosal immune system of elite athletes	[79]
Triathlon-high-intensity exercise	Double-blind experimental design	*Lactobacillus plantarum* PS128	**Decreases:** *Anaerotruncus*, *Caproiciproducens*, *Coprobacillus*, *Desulfovibrio*, *Dielma*, *Family_XIII*, *Holdemania*, and *Oxalobacter*) **Increases:** *Akkermansia*, *Bifidobacterium*, *Butyricimonas*, and *Lactobacillus*	Ameliorate inflammation and oxidative stress, with improved exercise performance	[80]
Endurance exercise	Cross-over pilot study	SymbioLactComp® (*Lactobacillus paracasei*, *Lactobacillus acidophilus*, *Lactococcus lactis* and *Bifidobacterium animalis* subsp. *lactis*)	**Increase:** *Akkermansia muciniphila, Faecalibacterium prausnitzii, Bifidobacterium* spp.	Prevent intestinal or immune disorders	[81]

Table 1.
Effect of probiotics in trained individuals.

which will directly or indirectly contribute toward the health and performance of athletes. Also, protein diet supplementation, increased *Akkermansia muciniphila,* thereby influence host immunity and host metabolism in athletes [51].

5. Conclusion

Endurance exercise requires a considerable amount of energy, and when this energy cannot maintain a stable supply, it will lead to fatigue and reduce exercise performance. Endurance exercise has a profound impact on oxidative stress, intestinal permeability, muscle damage, systemic inflammation and immune response, dehydration. Gut microbiota promotes digestion and absorption of food to produce energy in host, thereby playing a great role on athlete's energy consumption and exercise performance. There is a close interaction between exercise, microbiota and diet (**Figure 1**), the details warrant comprehensive investigations. Exercise, the proportion, timing and composition of the diet modulates the gut microbiota diversity. Better understanding, the impact of diet on gut microbiota and how gut microbiota respond to exercise, a nutritional strategy can be developed to modulate the gut microbiota diversity which can lead to enhanced the athlete's overall performance and health.

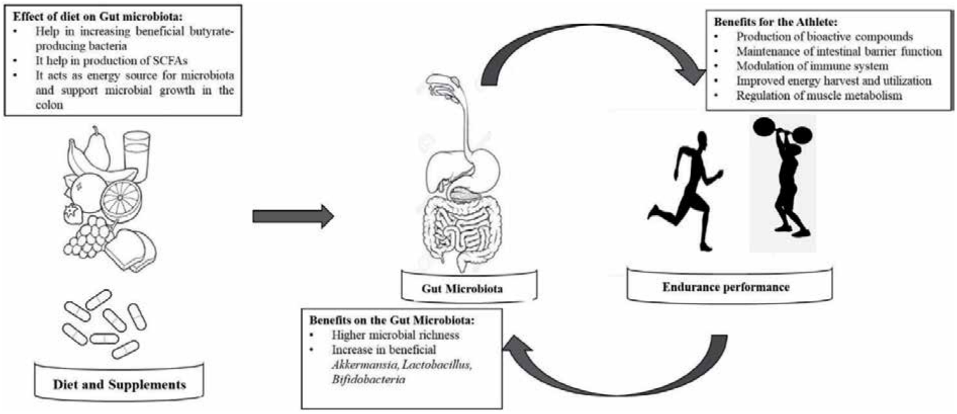

Figure 1.
Interaction between dietary components, gut microbiome, and endurance performance.

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Declaration of interests

We declare no competing interests.

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Chapter 12

Comparison of Anthropometric Profile and Cognitive Performance of Elite and Non-Elite Beach Volleyball Athletes

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Abstract

To compare the anthropometric profile and cognitive performance of elite and non-elite beach volleyball athletes. Comparative and descriptive study. The sample was composed by 8 athletes, divided in 2 groups: elite (n = 4) and non-elite (n = 4). They were evaluated in anthropometric parameters age, weight and height, and the variables of the cognitive performance evaluated by the battery of computerized tests CogState® (Brief Battery): Detection (Simple Reaction Time); Identification (Choice Reaction Time); One Back Speed (Working Memory); One Back Acuracy (Short Term Memory). Data were classified as non-parametric with the dispersion curve analysis performed by the Shapiro Wilk test. Anthropometric profile and cognitive performance variables were compared with the *Mann Whitney* U test between the groups. The procedures were performed with a significance level of $p < 0.05$ *using* the Statistical Package for the Social Science - SPSS®, Version 25.0. It was observed that there was significant difference in the anthropometric profile in the variable age (sig = 0.029) and in the cognitive performance significant differences occurred in the variables Detec (sig = 0.029) and Indent (sig = 0.029) of elite and not elite athletes of the beach volleyball modality. Elite and non-elite beach volleyball athletes present significant differences in the anthropometric variable (Age) and in the variables of cognitive performance (Detection and Identification) where elite athletes have a better cognitive performance than the non- elite athletes.

Keywords: cognitive performance, anthropometrics, CogState®, athletes elite and non-elite beach volleyball

1. Introduction

In the sportive competitions elite and not elite athletes have a demand for significant results. Therefore, the use of scientific methods is a current practice, in the sense of helping in the development of the sport performance and consequently in the sport results of these athletes. The characteristics that constitute the variables of the anthropometric profile of an athlete may be reflected in a way that he/she may play a determining role in his/her sporting potential within the chosen modality, which may lead to success [1]. Thus, the stature for athletes of the beach volleyball, can be important to contribute in the defensive and offensive actions of the modality, it is necessary, however a verification of the anthropometric profile to establish standards with relation to the modality [2]. We can affirm that the anthropometric profile of an athlete can influence in its more adequate sport performance for that modality [2]. However, anthropometric parameters are not the only determining variable in beach volleyball, as there are also cognitive factors in all its parameters, decision making, attention levels, working memory, which are fundamental in a sport with a great variability and impressibility [3–6]. The neurocognitive mechanisms in sport and the motor skills developed involve several neural processes, in addition to the learning of sport techniques. There are four elements that stand out with the development and neural adaptations of elite athletes [7]. (1) neural efficiency, which in turn is linked to a smaller amplitude in relation to the neuroelectric activity, causing a lower brain energy expenditure (2) referring to a larger cortical expansion, which is linked to motor and sensorial skills (3) specialized processing occurs in specific brain regions, which are developed through sports experiences lived by athletes, which induces the automation of neuroelectric connections (4) internal models, which cause the athlete to mentally simulate sports situations to which he/she will be submitted [7, 8]. These adaptations, for the most part, are considered to be motor areas, in brain regions that aid sport development, especially the cognitive engagement that is involved in sporting actions [9]. Cognitive processes trigger the so-called decision-making, being this decision-making composed of underlying elements such as attention, memory, perception and anticipation [6, 10] these cognitive factors are linked to sport. So the performance of the athlete to which he is dedicated will always depend on his physical and cognitive actions [11]. Elite athletes when compared to non-elite athletes, in several review studies demonstrate superior cognitive performance in specific situations of their sports [12]. Based on the perspective that these elements have repercussions on the performance of these individuals and on their sporting performance, the following objective of the study arises: to compare the variables of anthropometric profile and cognitive performance, between elite and non-elite athletes of the sport of beach volleyball?

2. Methods

This research had a descriptive characteristic [13] which verified the anthropometric profile and cognitive performance among elite and non-elite athletes of the beach volleyball modality. The universe of the study was constituted by athletes of the national circuit of beach volleyball/Banco do Brazil and the Cabo Branco Beach Volleyball Training Center/CT Cangaço. The sample was composed by 8 athletes, selected by non-probabilistic procedure, of the intentional type, with age bracket between 18 and 35 years old, being 04 elite athletes and 04 non-elite athletes. The participants received an informative document with all the procedures performed in the research. Afterwards, an informative document containing all the details regarding the date, time and place of research was delivered. Athletes who did not present the Free and Informed Consent Term - TCLE; did not agree with the terms of commitment, assumed with the researcher; were under medication treatment that influenced the execution of the tests; those who refused to participate in the study as volunteers, with no return or financial advantage, and those who did not show up on the day of data collection, were excluded from the process. The present study complied with the norms for research with human beings, resolution 466/12 of the National Health Council. CAAE: 26950119.0.0000.5176. One of the CogState® Computerized Cognitive Test Battery (Brief Battery) was used in the evaluation of cognitive performance, which is composed of four tests: Detection Test (cognitive domain measured: Psychomotor Function) **Figure 1**, Identification Test (cognitive domain measured: Attention) **Figure 2**, One Card Learning Test (cognitive domain measured: Visual Learning), One Back Speed Test (cognitive domain measured: Working Memory) in the study conducted used 4 tests from the (Brief Battery/ Brief Battery) being they Detection (Simple Reaction Time); Identification (Choice Reaction Time); One Back Speed (Working Memory); One Back Acuracy (Short Term Memory) which presented results in milliseconds (ms) and logarithmic values normalized to base 10, with validity from 0.76 to 0.89 [14, 15]. It was necessary to perform a demonstration of the protocol to facilitate the understanding and learning of the test. The analysis was done by the quantitative number of positive and negative answers divided by the total number of attempts executed.

Figure 1.
Detection test.

Figure 2.
Identification test.

Such results will be presented as percentage of correct answers. For weight evaluation a Tanita® Bc 601 bioimpedance scale was used, the individual barefoot with legs slightly apart with arms at the side of the body with the most erect body possible. For height assessment, a *Standard Sanny®* - ES 2030 stadiometer was used, with a range of use of 0.80 to 2.20 m, resolution in millimeters and a tolerance of +/− 2 mm at 2.20 m. The individual was barefoot, with heels together and arms relaxed. The data were classified as non-parametric with the analysis of the dispersion curve performed by the Shapiro Wilk test. The variables of anthropometric profile and cognitive performance were compared with the *Mann Whitney* U test between the two groups. The procedures were performed with a significance level of $p < 0.05$ *using* the Statistical Package for the Social Science - SPSS®, Version 25.0.

3. Results

In **Table 1** the anthropometric profile of elite and non-elite beach volleyball athletes were observed and it was verified that there was a significant difference in the variable age (sig = 0.029).

In **Table 2** the cognitive performance of elite and non-elite beach volleyball athletes was observed and it was verified that there were significant differences in

Profile	Veriables	Elite (n = 4)		Non-Elite (n = 4)		Comparison	
Anthropometric		Med	Min_Max	Med	Min_Max	Mann–Whitney U	Sig.
	Age	32,50	30,00_34,00	19,25	18,00_20,00		0.29
	Weight	94,46	85,00_102,85	88,50	78,00_110,00		0.114
	Height	1,98	1,85_2,10	1,89	1,79_1,93		0.200

Table 1.
Descriptive and comparative statistics of anthropometric data of elite and non-elite beach volleyball athletes - 2018 stage.

Performance	Variables	Elite (n = 4)		Non-Elite (n = 4)		Comparison	
Cognitive		**Med**	**Min_Max**	**Med**	**Min_Max**	**Mann–Whitney U**	**Sig.**
	DETEC	114,5	113,00_116,00	102,5	89,00_110,00		0.29
	IDENT	115,5	114,00_117,00	106,5	99,00_111,00		0.29
	OBS	107,25	96,00_113,00	101,5	93,00_112,00		0.200
	OBA	96,25	85,00_102,00	91,75	70,00_102,00		

DETEC. = Detection; IDENT. = Identification; OBS. = One Back Speed; OBA. = One Back Acuracy.

Table 2.
Descriptive and comparative statistics of Cognitive Performance (CogState®) of elite and non-elite beach volleyball athletes - 2018 Stage.

the variables: Detec (0.029); Ident (0.029); evaluated by the CogState® computerized test battery (Brief Battery).

4. Discussion

The results presented in this study showed significant difference in the variable of anthropometric profile age (sing = 0.029), in elite and non-elite athletes of beach volleyball (**Table 1**). According Guedes [16] states that the chronological age and age defined by the birth of an individual that is determined by the civil calendar, thus the difference between the two groups is simply chronological. With the data of the above presented variables, there is a need that during a process for a selection of athletes for the Beach Volleyball modality, especially in relation to one of the variables the height, it can be observed a certain evolution, where it demonstrates that the stature inside of the anthropometric profile and a main measure for a selection process of this modality [17]. According to Gabbett, Georgieff and Domrow the anthropometric profile characteristic of the variable height is of fundamental importance for the performance of attack and blocking that occur during a beach volleyball game. In the variable of the anthropometric profile with relation to the weight of the elite athletes and not elite of the beach volleyball, with the variations, it can have or not a negative association for accomplishment of some tasks to be accomplished in the beach volleyball modality [1, 2]. When analyzing the cognitive performance of elite and non-elite beach volleyball athletes (**Table 2**) in the overall score in the variables where these results are given through the speed in milliseconds (ms) that are logarithmic values normalized to base 10, with validity from 0.76 to 0.89: Detection (Simple Reaction Time); Identification (Choice Reaction Time); One Back Speed (Working Memory); One Back Acuracy (Short Term Memory); evaluated by the CogState® computerized test battery (Brief Battery). It was verified in (**Table 2**) that significant differences occurred in the analyzed variables: Detection (Simple Reaction Time); Identification (Choice Reaction Time); evaluated by the CogState® computerized test battery (Brief Battery). When analyzing the variables: detec (sing = 0.029), ident (sing = 0.029), we can observe that elite athletes, have a better cognitive performance, in relation to non- elite athletes in these two variables, once, in the test results of these two variables, they are classified in a lower score as better performance. Where the variable (Detec) has its cognitive domain the (attention) and the variable (Ident) has its cognitive domain the (psychomotor function) since we analyzed the cognition of the greatest athletes of beach volleyball in Brazil and the world, being these world and Olympic champions of this category. According to Santos [18]. The processes of perception and attention depend on some factors, among them, the conscious ability to select the most essential sources of information and the quantity of stimuli. For SCHMIDT (1993) the concept of attention is related to the "information processing capabilities that put limits on the skillful human performance". Baddeley and Hitch in [19]. postulated a theory that supports the main current on (Working Memory) from an assumption that (Working Memory) has a command center, which is the Central Executive System (CES), responsible for integrating new information with data stored in long-term memory [20]. Several studies show that the (Working Memory) is one of the last cognitions to consolidate, but also one of the first to suffer degeneration in brain structures, being the frontal lobe the most affected bringing cognitive losses [21, 22]. In view of these facts, it is necessary to research about the importance of these variables to improve the performance of these athletes.

5. Conclusions

Analyzing the anthropometric parameters and the cognitive variables, it was observed that there was significant difference, in the anthropometric profile in the variable age (sig = 0.029) and in the cognitive performance, significant differences occurred in the variables Detec (sig = 0.029) and Indent (sig = 0.029) where in these two variables the elite athletes have a better cognitive performance than the athletes no elite.

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Conflict of interest

There is no conflict of interest between the authors.

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Chapter 13

Design Thinking Applications in Physical Activity and Exercise Literacy

Emmanouil Georgiadis

Abstract

Various theoretical models of Health Literacy (HL) discuss its importance for behaviour change, supporting long-term health and disease prevention. During the 21st century Physical Activity (PA), Exercise and Sedentariness (SD) have received an increased priority over other health indices for quality of life purposes due to their central importance over metabolic conditions and their comorbidities. This review aims to conceptualise the main issues and challenges of Physical Inactivity (PI) and SD through the new proposals of Design Thinking (DT) which is considered one of the most promising pathways in health promotion. DT is prioritising empathy for service users, brings together collaborative multidisciplinary teams and provides the opportunity to assess various solutions via iterative practices. This chapter: A. provides a review over the efficacy of health promotion strategies during the current era and the urgency of behaviour change in PA and SD for various population segments. B. Explains how HL links self-care practices to PA and SD habits. And C. Presents DT as a new layout for supporting the exploration and feasibility of more active lifestyles for overall health and quality of life.

Keywords: Health Literacy, Design Thinking, Exercise, Physical Inactivity, Sedentariness

1. Introduction

Newer definitions of human health adopt notions of a balanced, holistic and dynamic decision-making process via an ever-needing adjustment to environmental demands [1]. Such adjustment needs to be dynamic, supportive of own abilities and autonomy driven to stimulate personal goals and long-term adherence [2]. When it comes to personal impactful choices of health actions, dimensions of personal empowerment like recognition of the meaningfulness of health promoting behaviours, own competence, belief in personal impact and self-determination have been suggested to enhance health status reverting any negative effects involved -also- in chronic diseases [3].

Such Chronic Inflammatory Diseases (CID) are currently recognized as the leading cause of death world widely with more than 50% of deaths being attributable to inflammation-related diseases [4]. Such diseases are cancer, stroke, ischemic heart diseases, diabetes mellitus, autoimmune and neurodegenerative conditions, chronic kidney disease and non-alcoholic fatty liver disease (NAFLD). Evidence is mounting that those inflammation related conditions start in early years of life, persisting throughout life and resulting in increased morbidity and mortality with health promotion behaviours being able to counteract those conditions [5].

2. Recent theories of physical activity and exercise

Within the top priority of behaviours able to counteract CID are regularly practiced physical activity and exercise. Even though exercise promotion has been at the focus of various organisations for more than thirty years [6], physical inactivity (PI) and sedentary behaviours (SB) are abundant in modern societies. It is estimated that they are the fourth contributing factor to global mortality [7, 8], causing -among other conditions- major modifiable cardiovascular diseases [9], diabetes [10], cancer [11], mental disorders [12], and specific illnesses such as Ischemic Heart Disease [13].

Further, PI and SB are currently considered among the most important modifiable factors for the prevention of cardiovascular conditions and other non-communicative conditions that contribute significantly to all-cause mortality in the global population [14]. It is estimated that 50 to 60% of selected cardiovascular conditions are currently attributed to PI [13], with the World Health Organisation (WHO) making the prevention of PI one of its key goals for reducing Noncommunicative diseases [15].

The current definition of PA is supportive of more than just the mere bodily movement that is produced by the contraction of skeletal muscles and the increases of energy expenditures resulting in significant health benefits. It is defined also by the psychological, social, political and situational phenomena related to the execution of physical movements and supporting a holistic definition of PA: "Physical activity involves people moving, acting and performing within culturally specific spaces and contexts, and influenced by a unique array of interests, emotions, ideas, instructions and relationships." (p. 5) [16]. It is important to note that when an individual is deciding to move, is far more than a travelling set of muscles, joints and energy expenditure repositioning in space, but rather a unique collection of emotions, interests, ideas, instructions, and relationships. Given the importance of regular engagement with PA for sustaining a good quality of life and maintenance of physical and mental health [17] such definition highlights novel suggestions and approaches for PA promotion and enhancement (see below).

Any PA that is planned, structured, repetitive and purposeful to increase physical fitness or its components is related to exercise behaviours [18]. Incorporating daily exercise programs in one's lifestyle is associated to reduced risks of morbidity and mortality across the lifespan [19]. Also, when exercise is part of therapeutic treatment of chronic conditions, contributes to better quality of life and prolonged duration of life [20].

Existing theoretical models are supporting a systematic approach towards the promotion of PA and exercise behaviours. In an attempt to create a better sense of those theories, their proposals and their applications, Rhodes [21] created the Multi-Process Action Control (M-PAC) Model with each theory placed at either, the reflective process (or else the intention formation phase), the regulation process (the adoption phase), or the reflexive process (the maintenance phase of exercise behaviour). Each of those phases is proposed to include separate stages of the exercise adoption, as social-cognitive theoretical applications are proposed to create an intention to become more physically active by enhancing the long-term utility of exercising, the expectation of positive emotional states during physical activity, the perception of physical and mental abilities to perform the requested exercise behaviours, and the environmental opportunity (i.e. time allocation) to perform physically active behaviours [21]. In the adoption phase, more behavioural methods are expected to create a change via techniques related to goal setting, positive feedback, relevant environmental cues, and self-talk. Finally, in the reflexive phase, associations, repetition and maintenance of environmental cues are expected to create long-lived habits contributing to a more active identity type [21, 22].

Two main validation pathways can link to the M-PAC Model. The first one, is its ability to confirm already proposed components of the Behavioural Change Techniques (BCT) taxonomy [23], which is considered a comprehensive, hierarchical, reliable and generalizable catalogue of methods [24]. Michie et al. [23] created a catalogue of 16 separate clusters precising behaviour change interventions helping to sort out for the first time their active intervention ingredients based on inter-rater agreement. This catalogue provided a clearly defined set of active intervention types, which is considered complete until recently [25].

A second validation of the Rhodes [21] model was offered by the authors of the Health Action Process Approach (HAPA) [26]. Based on the HAPA model three levels of self-efficacy (SE) are needed to support behavioural change of PA and exercise behaviour: Action SE, linked to the creation of intention and preparation to engage to more active behaviours through the anticipation of positive outcomes, Maintenance SE, associated to behavioural techniques enhancing behavioural persistence and motivation over the needed behaviour change, and Recovery SE, reflected by the ability to resume behaviour after relapse and interruption. Both M-PAC and HAPA models support same stages and constructs denoting similar processes and corresponding to needed actions for optimal behavioural change.

Another important set of theories holding an ability to promote increased levels of PA and exercise behaviours are the dual-process frameworks [22]. They are models consisting on the one hand reflective processes including social-cognitive approach variables (such as intentions, expectations and values), and on the other hand non-conscious processes including other not so well tested PA determinants such as habits, automatic thinking processes and personal effectiveness evaluations [27]. The most recent addition to this type of theories is including also the emotional valence and its importance for future intentions to participate in PA and exercise behaviours (Affective-Reflective Theory, ART) [28]. This occurs through reflective and non-conscious processes based on emotions individuals acquire during their PA and exercise participation. It is a theory that uses previously psychophysiology findings and related theories such as the Dual-Mode Theory (DMT) [29] to suggest a varying core affect as a product of different sets of intensities during PA and exercise participation based on innate psychophysiology mechanisms (see [28], for details). ART enhances the motivational importance of affect in relation to exercise behaviour, and most importantly how exercise and the affective experiences they produce are encoded in associative memory (i.e. physical pain vs. pleasure when exercising) and the way such associations are gradually integrated into cognitive processes that could support regular exercise participation [28]. According to Rhodes et al. [22], the case of conflict between non-conscious (affective) and reflective (cognitive) influences, lead individuals to experience affectively charged motivational states "such as craving, desire or dread" (p.104). Even though there are points of skepticism around measurement of non-conscious processes and how those can alter via educational processes, the dual-process models like the ART theory hold important potential for the future as they are the first to challenge the significance of attitudes and self-efficacy for the change of PA behaviours [22].

3. Shifting the educational approach

Promoting participation in PA and exercise entails acquired perceptions of the body and already created associations between the body and the mind in relation to personal attitudes, beliefs and appreciations from previous attempts to become physically active [30]. During this process, various implicit and explicit mechanisms are underway creating a unique response for the individual.

Using modern psychoanalytic views of unconscious processes representing wishful, fearful, and associated notions, Bendor [31] examined the main reasons behind exercise avoidance resulting in physical inactivity in modern society. Based on the views of practicing psychoanalysts, his results supported that exercise avoidance comes as a product of fear of identity change, learned disregard of own body, and repressed traumatic associations to exercise. Bendor's findings highlight the importance of unconscious processes over exercise adoption [29] in various populations in need and clearly call for the adaption of new exercise promotion and education methods [22, 28].

When it comes to exercise adoption, negative sentiments, fear and/or unconscious processes have been uncovered in coronary heart patients populations [32, 33], and community-dwelling osteoporotic older adults [34]. On the contrary, enjoyment and positive feelings are reported by young adult populations who actively participate in exercise behaviours [35] with positive feelings of valence and calmness supporting exercise participation in real life samples of healthy adults [36].

At the same time, very often messages calling for changing health behaviours (i.e. eating patterns, physical activity, smoking cessation) are based on appeals to personal responsibility, stigmatisation, controlling and inequality, that are ubiquitous around us [37]. This type of messages imply that illness or disable states are based on lack of responsibility, leading to blames of accusation to the sufferer (i.e. weak character) rather than social (lack of financial ability), environmental (i.e. relevant pollutants) or structural (i.e. disadvantaged working conditions) causes, contributing to the creation of stigma, fear and guilt [38]. The same type of messages are still making the most out of the exercise promotion campaigns aiming to change intentions and attitudes towards more active lifestyles based on cure and well-being rather than pleasures experienced during exercise [39].

Yet, it is not clear that those messages are capable of creating real change contributing to more active lifestyles [21]. Prioritising health over other behaviours by creating guilt and pointing out an inconsistency between personal standards and own behaviour having the goal of remorse and pointing out personal responsibility [40], seems to be successful in shifting health attitudes [41]. However, those changes are only related to initial stages of behavioural change, influencing attitudes and intentions to act towards more health-related behaviours, with their long-term effects still unexplored [40].

Criticism has been expressed in the past around the ways physical activity and exercise related concepts and resources have been conveyed to the general public in a non-understandable manner contributing to confusion as health related resources are not matching the recommended readability standards of the general public [42]. Same results were obtained from Thomas and Cardinal [43], showing that most of written PA educational resources are presented in a complicated and non-understandable format for the great majority of the American population. When it comes to PA and exercise literacy there seems to be an existing gap between what experts consider important to provide and the type of information required for the general public to change, becoming more physically active.

4. The importance of health literacy

Lack of knowledge of critical features that generate a health condition and low skills in obtaining, processing, understanding, and communicating health-related information are critical components for supporting health [44]. Hence, opportunities for health-related educational sessions are important for improving health status in various population segments.

Health Literacy (HL) is related to the capacities of people to appreciate, realise, and meet the complex demands of health in modern society and its requirements. In their seminal article, Sørensen, Van den Broucke, Fullam et al. [45] defined HL as "entailing people's knowledge, motivation and competences to access, understand, appraise, and apply health information in order to make judgments and take decisions in everyday life concerning healthcare, disease prevention and health promotion to maintain or improve quality of life during the life course" (p. 3). Health literate individuals are in position to contextualise and appreciate personal needs supporting their health, their close ones and their community, understanding the most influential factors for retaining wellbeing and taking steps towards meeting those. It is about taking control and responsibility of one's own health as well as the health of their loved ones and their community [46].

It can be easily confused with academic literacy and the notion of well-educated approach and familiarity with literature. However, during the second half of the 20th century the combination of literacy to health has been expanding denoting not just the potential of personal growth and individual transformation as a result of such procedure but also the contextual and social transformation with its capacity to influence economic growth, and social, political and cultural changes [47].

Four distinct abilities are being assigned to HL. These are, a. the ability to seeking, accessing and obtaining health information, b. the ability to comprehend health information that is accessed, c. the ability to interpret filter and evaluate health information and d. the ability to make a decision to maintain and improve health through conscious decision making [45]. These four types of ability highlight the importance of availability of needed resources, and the opportunity to appreciate connections among behavioural choices and health outcomes [48].

The need for HL supports recent models of health care reinforcing the importance of education and best practices starting from a micro level (self-care or else person-centred) which are based on 7 pillars of health promotion: 1. knowledge and health literacy, 2. mental well-being, self-awareness and agency, 3. physical activity, 4.healthy eating, 5. risk avoidance, 6. good hygiene, and 7. rational use of products and services [49]. One of these pillars having extended effects on quality of life, physical and mental health, reduction of premature mortality and avoidance of morbidity is regular participation in physical activity (PA) behaviours [50].

A perspective of the Rogerian proposal of HL is based on the view that a successful health education procedure needs to be mutli-dimensional, person-centred and based on a partnership between the eager professional to train and educate and the individual willing to act based on available resources while placing health as a priority [51]. An explanation of this standpoint defines that, "health education is a continuous, dynamic, complex and planned teaching-learning process throughout the lifespan and in different settings that is implemented through an equitable and negotiated client and health professional 'partnership' to facilitate and empower the person to promote/initiate lifestyle-related behavioural changes that promote positive health status outcomes" [51], (p. 133). This view suggests that boundaries and choices in each health promotion relationship are well-placed within each individual deciding the point the affiliation with the educator begins and ends, with related partnerships based on mutual responsibility, collaboration, freedom of choice, equity and autonomy [52]. When health education is lacking the above elements, is likely to fail to recognise and integrate the recipients' preferences and requests risking being ineffective in the short or long term [53].

5. Design thinking in physical activity and exercise

Bringing the previous notions together, it seems that physical literacy contributing to more active lifestyles is requiring a new approach able to solve more complicated problems in human decision making and actioning. New perspectives in education have the potential to provide novel methods of exercise promotion and literacy helping inactive populations to change perspectives and start their participation in exercise programs. Such a framework recently presented as a method of exploring, defining, and solving complicated problems claiming to utilise user-centred or human centred design processes [54]. Started with Brown's definitions [55, 56] Design Thinking (DT) comprises of iterative processes of three to five phases: 1. The phase of inspiration (or empathising) with an effort to explore and redefine the problem based on the clients, their perspectives and needs, 2. The phase of ideation (or definition and ideation) where the formulation of the problem and its solution is defined, and 3. The implementation (or prototyping and testing) phase where potential solutions are created and assessed [56].

DT has been proposed as one of the best approaches in health promotion as it is prioritising empathy for service users, brings together collaborative multidisciplinary teams and provides the opportunity to assess various solutions via iterative practices [57]. The potential of DT in multiple health care settings has been assessed in the past via diverse models of applications and demonstrated promising results in relation to traditional interventions [58]. Results on its potential for multiple health care domains and across diverse patient population and conditions were confirmed with authors urging for the use of DT in interventions of overlooked approaches and populations.

The application of DT in disciplines like PA and exercise literacy can be a product of related steps and procedures pertinent to the population in focus and caring for particular -amid unmet- needs. Relevant knowledge of applying DT is listed in multitude of resources highlighting the importance of the method and the application of its protocol [59]. Connecting with the requests of the real user and the population in need is the first step in the DT methodology. Claiming expertise and knowledge of the scrutinised behaviour/phenomenon when the user is not available, can possibly lead to unproperly clarified problems and quick fixes based on preconceived notions (see "empowerment model for health", [60]). Disciplines that have been scrutinising potential solutions effectively (i.e. medical treatments) supported by increased public attention and funding could generate a platform for creating diverse opinions on needs analysis [58]. The process of prototyping in a way that each potential solution is explored for its feasibility based on the elicitation of effective final results [56], is another step on the application of DT. The process of limiting solutions based on expressed ideas and their feasibility is another crucial area of DT [55]. Exchange of ideas is essential in DT and does not occur without trust, freedom of expression and undistracted collaboration among the team members [61]. Finally, having a basic appreciation of the protocol of DT and its needed steps can create a better engagement with team members ready to explore user needs, envision the ideal solution, realise its potential and endorse the answer that fits best to the initially proposed needs [55].

Testing DT protocol with the needs of the end user (i.e. unfit or obese individuals) in mind might hold the potential of more successful PA and exercise literacy helping to move way from proposals that have been shown limited success in the previous years with profound health and economic results [62]. Suggested tips that can enhance the implementation of DT for enhancing PA and exercise literacy are included in 12 tips presented by Wolcott, McLaughlin, Hubbard et al. [63]. These are separated based on the steps of DT protocol and relate to the preparation of DT (i.e. gathering resources and committing to its thinking patterns), engaging to the discovery of users' needs (i.e. connecting to the real user and being observant of the real issues), exploring expressed ideas with a variety of means (i.e. visualisation of ideal solutions, utilising a number of mediums to scrutinise the feasibility of ideas), and encourage optimism while testing chosen solutions (i.e. flexibility when it comes to the chosen time and setting to reach a conclusion, allow space for failure and iteration of solutions).

A model of DT dealing with PA and exercise literacy can take the following form based on the suggestions of Brown [55], and colleagues [56]:

Inspiration phase; realising the needs of the individual user when it comes to human movement requires their inclusion in the process. Observation of the user or the direct involvement of users targeting the improvement of the context and needed set of skills is foundational in DT [64]. There is a need to reframe the problem and exploring it while moving away from pre-existing assumptions that lead to unsuitably specified problems and unfeasible answers [65]. The example of wearable technology as means to support increased physical activity patterns is an assumption made and failing to incorporate more active lifestyles [66]. Contrary, the idea of Augmented Reality to support PA literacy/education and more active lifestyles remains viable and untested to a large extend [67].

Equally important is the realisation of the experience of PA and exercise through the eyes of the stakeholders. Experts in academia very often assume knowledge based on prior theoretical conceptions and what has shown potential in the past [22] whereas, unique ways of thinking, personal strivings, psychological responses and thinking patterns of stakeholders cannot be predicted let alone assumed in terms of realising change [68].

During the phase of ideation, solutions to the problem start to emerge. Such process is important to continue involving both positive and negative experiences of the user while clarifying the direction of solution [55]. Testing prototype ideas through iteration and experimentation is an essential part of this process with triggered rounds of problem definition and experimental solution creation with the goal to synthesise information into illustrative models [69]. Iteration refers to testing possible solutions through trial-error procedures, mock-ups, timelines and prototype appraisals with the support of end-users and representative stakeholders [70]. Scrutinising and visualising a solution (i.e. self-caring message before putting on walking shoes) [71], and utilising previous knowledge and experience of people representing different organisations [72], is a central notion of design thinking.

The implementation phase puts into final test the qualified prototype ideas through final series of iteration and experimentation aiming for synthesis [73]. Preparing a gestalt view on the proposed solution to the problem creates the opportunity for the users to be represented as a community testing assumptions and evaluating prototypes [74]. Through this process end-users have the opportunity to realise what each of the finalist proposals provides as a response to their recognised needs, offering feedback on the implementation of ideas [60]. This end result (i.e. new educational resources, holistic movement drills re-connecting mind–body) [75], provides the opportunity to move forward with new implementation of solutions and ideas around PA literacy that emanate from the users in need while implementing important theoretical positions produced via decades of systematic research and academic development [21, 22].

6. Conclusions

To overcome currently overwhelming degrees of worldwide physical inactivity [76], requires looking to new definitions of the problem emanating from the actual users and their needs [55], helping us to redefine physical inactivity and our solutions to reverse this global trend. Wide examination of "prototypes" of solutions towards literacy and increased engagement with PA and exercise practices remains unexplored and profoundly based on socio-cognitive approaches (for an example see, [76]). At the same time, feasibility exploration of recently proposed PA and exercise literacy programs remains largely unknown [77]. Ideas like the application of virtual and augmented reality in the promotion of exercise [67], the role of mind–body interventions in prolonged exercise participation [78, 79], and the potential of embodied creativity activities [80] are examples of such exploration requests. There is a clear need to explore user-friendly PA and exercise literacy solutions with an unknown capability for creating active lifestyle responses for populations in need. DT methodology provides new exploration affordances towards this remit [60].

In summary, HL is believed to be one of the most promising pathways to deal with CID in modern society [45]. Even though the existing theoretical models are supporting a systematic approach towards the promotion of PA and exercise behaviours, their educational applications are limited and still underdeveloped [21, 22]. The need to overcome resistance to exercise adoption due to negative sentiments, fear and/or unconscious processes necessitates the adoption of new approaches to PA literacy. DT has been proposed as an effective approach able to provide new proposals to health promotion as it is prioritising empathy for service users, brings together collaborative multidisciplinary teams and provides the opportunity to assess various solutions via iterative practices [55, 56]. Testing proposed solutions based on the needs of various populations (i.e. clinical, older adults) is the product of further scrutiny and exploration through the applications of DT.

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Conflict of interest

The author declares no conflict of interest.

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Chapter 14

Psychotherapeutic Approaches to Addressing Mental Health Problems Among Elite Athletes

Mark A. Stillman and Hudson Farmer

Abstract

Athletes suffer from clinical and subclinical mental health symptoms and disorders that affect their lives and their performance. The objective of this chapter is to describe methods of psychotherapy used in treating elite athletes and the unique challenges that clinicians may face when working with this population. Psychotherapy, either as the sole treatment or combined with other nonpharmacological and pharmacological strategies, is a vital component in the management of clinical and subclinical mental health symptoms and disorders in elite athletes. Effective psychotherapy takes the form of individual, couples/family or group therapy and should address athlete-specific issues while validated as normative by athletes and their core stakeholders. This chapter summarizes research on psychotherapy for elite athletes with clinical and subclinical mental health symptoms and disorders. Though psychotherapeutic interventions are similar to those with non-athletes, working with elite athletes can present unique challenges. These can include diagnostic ambiguity, barriers to help-seeking behaviors, and altered expectations about services. Other personality factors occasionally associated with elite athletes could create difficulties when engaging in psychotherapy. These challenges may prevent athletes from seeking or continuing treatment.

Keywords: elite athlete, psychotherapy, mental health, barriers, performance, treatment, challenges

1. Introduction

Just as with the general population, athletes can suffer from clinical and subclinical mental health symptoms and disorders that affect various areas of their functioning. A study conducted with elite athletes found that just under half of the respondents met criteria for at least one mental health "problem" including psychological distress, depression, general and social anxiety, panic disorder, and eating disorders [1]. Up to 60% of female athletes that participate in sports that require individuals to maintain a lean physique struggle with eating disorders [2]. College athletes display more binge drinking behavior than non-athlete college students [3], and 15% of student athletes have participated in pathological gambling behavior [4]. Athletes in the 30–50-year-old age have been shown to be at a 2–4 times higher risk of death by suicide than that of the general population in the same age range [5]. Within the athletic population, injured athletes experience more depression, anxiety, and lower self-esteem immediately after injury and during recovery than uninjured athletes [6]. In the case of elite athletes, these symptoms and disorders may have negative effects on performance, therefore potentially further impacting their well-being. The objective of this chapter is to discuss various forms of psychotherapy that are appropriate for the elite athlete population and to highlight several unique challenges that mental health professionals may face when working with this population.

2. Psychotherapy

In order to improve overall functioning, athletes dealing with mental health symptoms and disorders should seek psychotherapy. Psychotherapy, either as the sole treatment or combined with other nonpharmacological and pharmacological strategies, is a vital component in the management of clinical and subclinical mental health symptoms and disorders in elite athletes. For psychotherapy to be most effective with athletes, it must address athlete-specific issues while being validated as a “normal” or standard treatment for mental health difficulties by the athletes and their core stakeholders (partners, family, coaches, agents, etc.). As a means of decreasing the stigma often associated with mental health treatment, it may be helpful to reframe psychotherapy treatment as “performance help” as the goal is to improve functioning therefore improving athletic performance [7].

There are several different forms of psychotherapy that have been implemented and found to be successful in the treatment of athletes suffering from mental health symptoms and disorders. These are individual psychotherapy, marital/family psychotherapy, and group psychotherapy.

2.1 Individual psychotherapy

Individual psychotherapy involves a patient meeting with a trained mental health professional in a one-on-one setting. Oftentimes individual psychotherapy alone can be a sufficient treatment for less severe mental health issues such as mild depression, anxiety, and sports-related adjustment issues [8]. Individual psychotherapy provided by a sport psychiatrist or a psychologist or counsellor who specializes in the treatment of athletes can be useful in the treatment of psychiatric disorders as well as in improving adherence to medication.

The types of individual psychotherapies that are most commonly used in young adults, college students, and collegiate athletes are supportive therapy, cognitive behavioral therapy, motivational enhancement therapy, and psychodynamic therapy. These four therapies appear to have common healing factors including affective engagement, feeling understood by the therapist, offering a framework for understanding the problem/solution, therapist expertise, therapeutic structure/procedures, optimism regarding improvement, and experiences of success [9].

Of these therapies, cognitive behavioral therapy (CBT) has received the most empirical support [10]. CBT works to help patients understand how dysfunctional thoughts can lead to negative emotional activation and maladaptive actions or inactions [11]. This form of therapy is a very appropriate choice for athletes as it mirrors elements in physical training such as comfort with structure, direction, and practice [12]. As athletes are typically already comfortable with these elements, it can make this method of treatment one that makes practical sense to implement, especially athletes who participate in individual sports due to their familiarity with individual goal setting and self-reliance [8]. CBT appears to be most useful in cases of depression, anxiety, substance use disorders, anger/aggression, insomnia, somatization, chronic pain, and general stress [13].

An athlete's feelings and opinions on substance use, legal or illegal, can be strongly influenced by peers, family, coaches, trainers, and other individuals that they are in close contact with. For example, a coach who notices that a new prescription has caused a slight drop in performance may attempt to convince their athlete to take less than the prescribed amount or stop taking the medication altogether. Teammates that often engage in illicit drug use may pressure other athletes to try it or believe that it is permissible. Motivational enhancement therapy (MET) uses principles of motivational interviewing to help patients understand their ambivalent feelings and opinions towards substance use [8]. Accordingly, MET appears to be most useful in cases of risky drinking and adverse alcohol behaviors, cannabis use, tobacco cessation, and medication adherence issues [14, 15].

Psychotherapy, compared to psychopharmacological treatments, is considered the best primary treatment of adjustment disorder, one of the more common mental health disorders experienced by athletes [8]. An adjustment disorder is an excessive emotional or behavioral reaction to a stressful event or change in a person's life. Athletes often face many situations requiring them to cope with stressful changes, including being traded to a new team, moving to new cities, and adjusting to injury. Due to the relatively short duration of adjustment disorders, psychotherapies that are short-term and problem-solving focused appear to be the most efficacious modality, given the shorter timeframe of the disorder [16].

2.2 Couples/family psychotherapy

Involvement of family in psychotherapy can help athletes understand how personal and family stress can impact overall athletic performance [14]. Spouses or partners and other family members can play a significant role in the mental health of an athlete. Part of that role can involve assisting the athlete in caring for their mental health. If an athlete is willing to involve family members, a healthcare provider may gain a better understanding and more well-rounded view of the patient as family members can provide important supplemental information [7]. Family members are often crucial in ensuring treatment adherence, and it is a common belief that in certain circumstances, psychoeducation should be required for patients as well as their partner/family member(s) before being able to start psychotropic medications [7]. If an athlete is amenable, coaches, trainers, agents, and other close individuals can provide additional supplementary information about the athlete as well as work to facilitate their adherence to treatment during daily activities. These individuals and family members are often the people who encourage athletes to seek out help in the first place.

In addition to helping, family can also be a source of stress for athletes, or elements of the athlete's life may be sources of stress for their family. Many times, familial issues may either be the source of the presenting problem or the problem itself when an athlete seeks treatment [8]. Recent studies have shown that family problems in a collegiate athlete's life may predispose them to mental health distress and could be used as a good screening method to assist referrals [17]. Some issues that are not exclusive to the family setting of athletes alone but may present themselves with greater frequency include substance use, domestic violence, time spent away from home, jealousy, and extramarital affairs [14]. These types of issues can also be the underlying causes of psychiatric symptoms that lead athletes to present for psychotherapy. Because of this, clinicians must be able to appropriately implement marriage/couple psychotherapy which can sometimes be difficult if both parties are not committed to participating in treatment [8].

2.3 Group therapy

A third form of psychotherapy that may benefit athletes is group therapy. This form of therapy involves individuals coming together in a group setting with a mental health professional to receive psychoeducation and psychotherapy. In addition, the individuals are able hear and learn from the experiences of the other individuals in the group. Finding these shared experiences may lead to greater change than what can be provided by therapy and medication [18].

This form of psychotherapy is often used for athletes with substance abuse issues and can include groups such as Alcoholics Anonymous and Narcotics Anonymous. Group therapy is often used in combination with medication, particularly for substance use disorders, and can be led by qualified mental health clinicians [8]. Group psychotherapy may be particularly effective for team sport athletes as they are accustomed to performing as a member of a team (the group) and following the leadership of a coach (the mental health professional), and this format may provide an added level of comfort [7, 8].

A common issue with high profile athletes that may work as a deterrent to this form of psychotherapy is the issue of confidentiality and anonymity [8]. Athletes are more likely to agree to using this approach to therapy if they have had positive experiences with it in the past, confidentiality can be guaranteed, and it can be well integrated into their life [19].

3. Unique challenges

Due to differences in lifestyle and other factors, mental health clinicians must keep in mind several considerations when working with elite athletes compared to the general population. Although psychotherapeutic interventions are similar to those with non-athletes, elite athletes can present unique challenges including diagnostic ambiguity, barriers to help-seeking behaviors, and altered expectations about services.

3.1 Diagnostic ambiguity

When attempting to diagnose athletes, there are many considerations that a clinician must keep in mind. One is that many of the symptoms and behaviors that athletes may present with are shared between mental health disorders and typical/expected athlete behavior. Take over-training syndrome and clinical depression: shared symptoms are fatigue, appetite loss, weight change, cognitive deficits, and a general lack of energy and motivation [20]. These symptoms have two different causes and therefore require different treatments to resolve symptoms. Athletes may also perform ritualistic behavior in order to relieve anxiety during athletic performance [21]. This could include behaviors such as unique free-throw warm-ups in basketball, avoiding stepping on the foul line while taking the field in baseball, or eating Skittles™ before every football game. While this may lead a clinician to suspect a diagnosis of obsessive–compulsive disorder, these behaviors are limited only to competitive settings and result in no overall life impairment [22].

In addition to the presenting symptoms and behaviors themselves, the underlying cause of them may be different for athletes than for individuals in the general population. Due to their experiences and lifestyles, athletes have unique triggers that may cause their psychiatric symptoms. Depression can be brought on by overtraining, poor performance, or retirement from a sport [2, 22]. Athletes in contact and even non-contact sports are constantly exposed to the potential for severe injury which can bring about mood disturbance, tension, and anger [23]. There are also greater prevalence rates of performance anxiety and jetlag induced insomnia among elite athletes in comparison to the general population [24].

Even within the elite athlete population, athletes who perform in different sports may have varying risks for different mental health symptoms and disorders. Research shows that athletes who participate in individual sports, compared to those in team sports, may be at a greater risk for depressive symptoms [25, 26]. Because of these ambiguities and potential differences in symptoms and behaviors, mental health practitioners must carefully consider each case in order to choose correct diagnoses and methods of treatment.

3.2 Barriers to help-seeking behaviors

The most common barrier to athletes seeking treatment is stigma associated with mental health [27]. Some athletes may hold the belief that receiving mental healthcare is a sign of "weakness" and evidence of being "crazy" or untrustworthy [2]. In one study, student athletes in Australia reported poor understanding of mental health and past negative experiences in help seeking as other barriers to seeking out treatment [28]. Because of these misperceptions and misunderstandings of mental health, many athletes may refuse to seek help due to their own beliefs or the beliefs held by their peers, family, and coaches. Research has shown that perceived stigma, confidence in consolation, cultural preferences, and openness can be used to predict a coach's likelihood of referring their players to mental health services [8]. This means that coaches who view mental health as less stigmatizing, have greater confidence in positive outcomes from consolation, have receiving therapy as a cultural preference over other forms of treatment or no treatment, and have higher levels of openness are more likely to refer their athletes to therapy for issues regarding mental health.

Another barrier to seeking or continuing treatment is when a problematic behavior is viewed as positive or helpful to an athlete's sport performance. A wrestler or fighter may justify an eating disorder such as anorexia nervosa or bulimia nervosa because it helps them to maintain or cut weight before contests [20]. A football or baseball player may choose to struggle through mood disturbances and inter-personal difficulties while using anabolic steroids if they believe that the steroids are helping them to build muscle and perform at higher levels [4]. If an athlete is currently in treatment, beliefs such as these may cause strains in the patient-therapist relationship when the clinician points out the negative effects of these behaviors that are viewed as beneficial by the athlete [8].

As noted earlier, confidentiality can be difficult to ensure or maintain at times. Some athletes – especially those who are particularly well known in their area, state, or country – may fear being recognized while attending or traveling to and from treatment sessions. These athletes may prefer that mental health professionals come to them to provide services at team facilities or their home or hotel in order to avoid public exposure [27]. While this may be permissible, mental health professionals must consider to pros and cons of providing treatment outside of the clinical setting [8]. Some athletes may prefer not only confidentiality from the public but also confidentiality from individuals involved in their personal lives. Even though coaches, trainers, agents, and family may prefer to be involved and included in psychoeducation and psychotherapy as they are accustomed to being involved in the athlete's life, this can create complexities regarding confidentiality [2].

3.3 Altered expectations about services

Elite athletes are often accustomed to special treatment and accommodations that are not given to the general population. Many athletes have assistants or people within their organizations who create and organize schedules, arrange travel accommodations, and complete day to day tasks for them [27]. This can become a challenge for the mental health professional when it is preferable to speak with the athlete than with their assistant [14].

While some athletes prefer that mental health clinicians meet them where they are for confidentiality purposes, some athletes make this request because it is what is normal for them. Oftentimes athletes will have healthcare professionals and others meet them at team facilities or their home, so this is what is typical and expected. As stated earlier, mental health professionals must consider the advantages and disadvantages of providing psychotherapy outside of the clinical setting [8]. With their busy schedules and frequent traveling combined with repeated accommodations by others, athletes may expect that clinicians can provide services at any time if it is convenient for the athlete. This can make establishing and maintaining boundaries difficult for the clinician if they attempt to schedule and travel to meet the athlete's preferences [27].

Although many elite athletes may be well-off financially, they may not be accustomed to paying for certain services [2]. For example, agents may try to provide tickets, passes, or merchandise that are equal in value to the charge for treatment [2]. Accepting these in lieu of monetary payment is unethical and could lead to future boundary issues as the professional patient-therapist relationship could be viewed as a more personal one by both parties [2].

In all situations, the clinician's goal should be to balance "flexibility with appropriate boundaries" [2]. This is done by balancing the unique needs of the athlete with providing appropriate treatment based on the athlete's diagnosis, their specific circumstances, and the context in their sport [29].

3.4 Personality factors

Narcissism and aggression are personality traits that can be common among elite athletes [7]. These are traits that the clinician may encounter during mental health services with athletes, or they could be the presenting issue for a patient coming in for treatment.

Elite athletes may often achieve great fame and wealth. They are often held in high esteem by fans, family, teammates, coaches, and others. People admire them for what they are able to accomplish and follow not only their athletic performances but also their personal lives through the media. Because of social media, athletes' lives are more accessible to the public than they used to be, and they may receive praise and attention via this platform in addition to what they receive in person. All of this can lead to feelings of superiority or narcissism as they are often the center of attention and may be accustomed to being in the spotlight [8]. Because of this, an athlete may feel as though they are not in need of help since they receive so much adoration on a constant basis, or they may have unrealistic expectations about therapy [2]. For example, if they do not see immediate results from therapy or it does not come as naturally to them as their sport does, then they may decide that it is not beneficial to them and not worth their time or effort. In extreme cases, these athletes may develop grandiose beliefs, lose their ability to empathize, and respond with fury to real and imagined slights [8].

Recent research has found a positive relationship between anger, aggressiveness, general aggressive behavior, antisocial behavior toward opponents and teammates, and the experience of and expression of anger [30]. This supports previous findings that antisocial traits may often lead to outbursts of anger, especially within training, practices, and games [8]. Due to their pride being built upon the praise of others, many successful athletes are insecure or have fragile egos and may exhibit rage and aggression when confronted with real or imagined threats to their sense of self-worth [7, 31]. The loss of praise and increase of criticism due to a poor performance or decision by an athlete can "injure" the ego, which can lead to a response of "impulsive and explosive rage" as they deal with a cycle of praise and criticism that is uncommon in other populations [31].

4. Conclusion

Elite athletes are a unique population that can provide uncommon challenges, but they also have strengths and circumstances that make them good candidates for psychiatric treatment. The goal of treatment is to improve mental health in order to maintain peak athletic functioning. Psychotherapy is a common form of treatment for mental health issues and may be particularly effective for elite athletes in the form of individual psychotherapy, marital/family psychotherapy, or group psychotherapy. Due to the nature of the elite athlete population, mental health clinicians may face several unique challenges in providing services to these individuals. These include diagnostic ambiguity, barriers to help-seeking behaviors, altered expectations about services, and personality factors. Elite athletes face many pressures and stressors that are not common to the general population. Mental health professionals should keep these considerations in mind during treatment and work to normalize and reduce stigma towards receiving mental health services within the elite athlete population.

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Chapter 15

Biomechanical Aspects of the Static and Dynamic Patterns of the Feet of Runners with Plantar Fasciitis and Their Relationship with Sports Shoes

Ana Paula Ribeiro

Abstract

The purpose of this literature review was to evaluate studies that have investigated static and dynamic biomechanical patterns of the feet in runners with plantar fasciitis, as well as their relationship with sports shoes and insoles prescription. Original articles with different design on this theme were considered. In general, the increase plantar load rates in runners with plantar fasciitis may be directly related to changes in the plantar arch (elevated) and the rearfoot alignment in pronation, as well as the effect of shoes or insoles to reduce heel pain. In summary, the clinical support of the literature review was showed that a decrease in the medial longitudinal arch induces greater mobility of the foot, which promotes a greater angle of rearfoot pronation to maintain the stability of the subtalar joint during static and dynamic feet support in activities, such as running. This results in a greater overload on the medial region of the calcaneus, producing greater stress on the plantar fascia, contributing to the development and progression of plantar fasciitis in runners. In addition, treatment of acute plantar fasciitis was associate to insoles while chronic phase associated for shoes ultra-flexible intermediate midsole for heel pain reduction and improvement foot biomechanics in runners with plantar fasciitis.

Keywords: plantar fasciitis, foot, runner, plantar load, shoes, insoles

1. Introduction

Millions of people take part in sports activities that involve running as it is an activity available to all ages, and is low cost, versatile, and brings health benefits [1]. Currently, running is one of the most popular sports in the world, having experienced substantial growth over the past decades [1–3].

At the end of the 20th century, the considerable increase in running practice resulted in a higher prevalence of injuries in the lower limbs [2, 4, 5], with percentages of reported injuries of 5.7 to 39.3% over a period of one year in those who practice sports [1, 2]. Among the most frequent injuries, a retrospective study with 2002 runners revealed that plantar fasciitis is the third most common musculoskeletal injury in runners [6], reaching approximately 10% of them [3, 6, 7]. According to

Tauton et al., [7], of the 267 cases of plantar fasciitis analyzed in various sports, 160 of these cases involved only the running modality. In addition, it is the most common cause of acute and chronic calcaneus pain [8]. These facts have led to growing interest in research regarding the causal factors of plantar fasciitis in runners.

Plantar fasciitis is characterized by a musculoskeletal disorder of inflammatory and degenerative origin of the plantar fascia. The most common clinical symptom of plantar fasciitis is pain in the lower and medial region of the calcaneus, most typically close to its insertion in the medial tubercle of the calcaneus [9, 10].

There are several intrinsic and extrinsic factors related to the disease [11]. However, some specific intrinsic factors related to the development of plantar fasciitis have been further explored in the literature. Among them, obesity [12], decreased ankle dorsiflexion [12, 13], the type of medial plantar longitudinal arch [6, 7, 14–16], rearfoot pronation [11, 7], and increased plantar load stand out [17–20]. However, these factors still remain controversial, especially with regard to their involvement to a greater or lesser extent with the etiology of this injury [11].

The majority of studies report that the factors most strongly associated with the development of plantar fasciitis are biomechanical factors directed to the type of longitudinal plantar arch, excessive pronation of the rearfoot [6, 7, 14, 15], and increased pressure on the surface of the feet [17–20]. Thus, it is evident that changes in the plantar arch and in the rearfoot alignment can directly or indirectly influence the functionality of the plantar fascia and, consequently, in the redistribution of the plantar load.

Generally, the most accepted theoretical and scientific reasoning is that plantar overload, resulting from possible biomechanical imbalances in the structure of the feet, would result in greater pressure and increased force rates on the plantar fascia, inducing microtrauma and inflammation, characterizing the acute phase of the injury [21, 22]. Throughout the period of the disease, the repetitive support of the feet in contact with the ground would evolve to the fragmentation and degeneration of the plantar fascia, characterizing the chronic phase of plantar fasciitis associated with degeneration and fragmentation in the thickness of the plantar fascia [22, 23].

However, even though plantar fasciitis is the third most prevalent injury in runners [6, 7], the majority of studies that investigated calcaneus overload were directed to walking [17–19]. Another fact worth noting is that the presence or absence of the painful stimulus, common in the different phases - acute and chronic plantar fasciitis - has been the subject of studies on plantar loads in walking and running [16–19, 24, 25]. In addition, Ribeiro et al., [24] and Hong et al., [26] emphasize the importance of studying the distribution of plantar load during running in a training and competition environment, since running on a treadmill can influence the foot support pattern of runners affected by the disease.

According to the biomechanical studies carried out to date, it is likely that the plantar loads undergo changes during the acute (with pain) and chronic (without pain) phases of plantar fasciitis, especially in the running population [20, 24]. In addition, this possible increase in plantar load rates in runners with plantar fasciitis may be directly related to changes in the plantar arch, which remains elevated [6, 25, 27] and with the alignment of the rearfoot that maintains greater pronation of the feet [16, 25].

In this chapter, we aim to provide better understanding of scientific studies regarding the static and dynamic biomechanical patterns of the plantar support of the feet of runners with plantar fasciitis as well as their relationship with sports shoes and the prescription of orthoses and insoles, in order to assist in the clinical parameters of health professionals working in the conservative treatment of plantar fasciitis in runner athletes.

2. Static and dynamic biomechanical patterns of plantar support in runners with plantar fasciitis

2.1 Plantar load during foot support and plantar arch in runners with plantar fasciitis

Understanding of the plantar arch comes from pioneering [28, 29] and more recent studies [24, 25, 30, 31] that emphasize the importance of the plantar fascia for greater stabilization of the medial longitudinal arch, especially during mechanical support of the foot with the ground for better absorption and dissipation of forces received during walking and running sports activities [24, 25]. The plantar fascia associated with the medial longitudinal arch has the function of supporting up to 14% of the total impact forces of the foot in contact with the ground [29], thus allowing the best redistribution of plantar loads and, consequently, the appearance of plantar fasciitis.

Part of the clinical literature supports the theory that a decrease in the medial longitudinal arch induces greater mobility of the foot, which promotes a greater angle of rearfoot pronation to maintain the stability of the subtalar joint during static and dynamic support in activities such as running and walking [24, 25]. This results in a greater overload on the medial region of the calcaneus, producing greater stress on the plantar fascia [14–16, 20, 32, 33].

Another line of thought, consistent in most studies, is the theory that an elevated medial longitudinal arch induces greater rigidity and shortening of the plantar fascia [34], resulting in inefficiency in the ability to dissipate the impact forces of the foot in contact with the ground. Thus, the plantar fascia is placed under greater mechanical stress in the calcaneus region [15, 35]. In contrast, studies that evaluated the medial longitudinal arch [11, 36], rearfoot static alignment [11], and calcaneus pain in long distance runners, did not observe significant differences in these factors when compared to healthy runners.

Despite the lack of consensus in the literature on the question of the plantar arch in runners, studies have shown that in plantar fasciitis both types of plantar arch: increased and decreased can be causative factors of the condition [11, 16, 24, 25]. However, the majority of the literature is based on the reasoning of an increase in the plantar arch in runners with plantar fasciitis [7, 20, 24, 25].

Another risk factor of notable importance linked to the pathophysiological and etiological framework of plantar fasciitis, and which may be associated with changes in the conformation of the medial longitudinal arch or decreased ankle dorsiflexion, is excessive rearfoot pronation, usually caused by valgus alignment of the calcaneus [37]. This excessive pronation would result in decreased rearfoot stability, producing excessive stress on the lower-medial part of the calcaneus, related to plantar fasciitis [6]. This instability of the subtalar joint would hinder the transition from the medium support phase to the final support phase, which would promote greater plantar load in the medial region of the calcaneus, generating greater tension in the plantar fascia and, consequently, making it more vulnerable to repetitive microtrauma [14]. According to some authors [16, 24, 25] runners with plantar fasciitis present valgus alignment of the rearfoot. According to Lee et al., [38] the association between the maximum eversion angle of the rearfoot (pronation) and the height of the plantar arch can induce an indirect effect of tension in the plantar fascia that could result in overload on the plantar surface of the feet.

Thus, it is evident that changes in the plantar arch and in the rearfoot alignment can directly or indirectly infer the functionality of the plantar fascia and, consequently, in the redistribution of the plantar load. However, there are no studies in the literature that infer the direct relationship of these clinical variables of the feet with calcaneus overload, in injuries such as plantar fasciitis, especially in the population of runners where the prevalence of these injuries is high [3, 6].

The scientific relevance of this chapter is justified on the theme of runners with plantar fasciitis, since much of the literature, directed to runners without previous injury, observed that the elevated plantar arch is positively associated with the increase in vertical force load rates [35, 39, 40]. Thus, the increase in rates of force on the plantar fascia can induce microtrauma and inflammation, characterizing the acute phase of the injury [21, 22] and following the circle character of the condition, the repetitive support of the feet in contact with the ground, would evolve to fragmentation and degeneration of the plantar fascia, characterizing the chronic phase of plantar fasciitis without pain [22, 23]. Despite this understanding, and even though plantar fasciitis is the third most prevalent injury in runners [3, 6, 7], the majority of studies carried out on the increase in vertical force rates on the calcaneus were directed to walking [17–20].

The presence or absence of pain stimulus on the calcaneus during the period of plantar fasciitis (phases - acute and chronic) has been investigated by some authors [17–20, 24, 25]. When these plantar loads were investigated, specifically in the gait of individuals with plantar fasciitis, a confounding factor in the results was associated with the pain present in the acute inflammatory phase of the disease. The results observed were greater overloads in anterior regions of the plantar surface (midfoot, forefoot, and toes) and not in the calcaneous region, as expected by the pathophysiology of plantar fasciitis [17–19]. The authors justified these findings by a momentary mechanical adaptation during the rolling of the foot in gait to promote the reduction in rearfoot loads, due to the mechanism of protection against pain in the calcaneous region. However, as the pain factor was present in plantar fasciitis, it cannot be inferred whether these increases in plantar loads in the anterior regions of the feet are related to an analgesic mechanism present in the acute phase of the disease, or whether it can be considered an intrinsic factor of the etiology of plantar fasciitis that would promote stretching of the plantar fascia, stressing its insertion in the medial tuberosity of the calcaneus.

The effect of different phases of the disease (with and without pain) on the mechanical overload of individuals with plantar fasciitis was the focus of three studies during running [16, 20, 24, 25]. However, the results of both studies are still contradictory and remain inconclusive. The first study revealed that runners with a history of plantar fasciitis, without the presence of pain, have higher peak vertical strength and impact rates (0 to 100% and 20 to 80% of support) during running compared to control runners. The second study found that recreational runners with plantar fasciitis in the acute (with the presence of pain) and chronic phases (history of plantar fasciitis without pain) have similar distribution of plantar pressure in relation to control runners [20]. The third study, carried out by Ribeiro et al., [20], aimed to verify this effect of the presence and absence of pain according to the stages of plantar fasciitis in recreational runners. The authors concluded that the estimated impact rates and rearfoot plantar loads are higher in runners with plantar fasciitis compared to control runners. In addition, the authors found that the different clinical phases of plantar fasciitis promote runners in the acute phase of plantar fasciitis (with the presence of pain in the calcaneus) to have lower impact rates and plantar loads in the rearfoot compared to the chronic phase, likely due to the mechanism of pain protection in the calcaneous region. It is possible the contradiction in the results of these studies lies in the difference in the variable used to infer overload and in the environment in which the runners were evaluated. The first study inferred overload through the vertical force obtained by a force platform in a laboratory environment [16] and the third study using plantar pressures obtained by insoles when runners ran in natural training and competition environments [20].

The importance of studying plantar loads during running in training and competition environments, as performed by Ribeiro et al., [20] was recently highlighted by Hong et al., [26] who found that the distribution of loads during running on a treadmill is not the same as during running on fixed surfaces, like the ground. According to the authors, treadmill running can be used in rehabilitation programs to help reduce plantar load, however, for patients with injuries in the lower extremities, the change in the research paradigm from the treadmill to the fixed floor, and in an ecologically valid environment is of fundamental importance to better understand the causal factors involved in the daily life of the runner.

Understanding the pattern of these plantar loads during running in a natural environment would be of great therapeutic benefit for rehabilitation programs for lower limb injuries, such as plantar fasciitis. According to Giddings et al., [41] the running activity provides a load stress with a magnitude of approximately 3.7 to 4.8 times the body weight on the fascia and plantar ligament. Thus, considering running as a cyclical modality, with great magnitude impacts on the heel and plantar fascia, its continuous practice could be directly related to the appearance and progression of plantar fasciitis. Another point of understanding is in relation to the synchronization of the foot, ankle, and tibia, corroborated by the study of DeLeo et al., [42], where the foot eversion peak occurred between 39 and 54% of the support phase, and the knee flexion peak between 36 and 45%. Thus, the attenuating function of the foot resulting from this synchronization is evident.

The movement of pronation and supination of the rearfoot has been intensively investigated in the literature [43–46], due to the strong relationship of these movements with the generation of plantar overload and the appearance of some injuries, one of which is plantar fasciitis. A condition of hyperpronation is considered to be an important factor that predisposes to injury to the feet segment in runners. Viel et al., [33] suggests that rearfoot pronation may arise from the original position of the calcaneus, which is not projected vertically and the projection of the body weight medially in relation to the support point of the calcaneus. It is believed that the control of hyperpronation, through an adequate analysis of the distribution of loads on the plantar surface and the subsequent use of appropriate footwear, reduces this incidence of injuries [47].

Thus, plantar pressure, when properly distributed, must be symmetrical between the lower limbs, as well as between the anterior and posterior parts of the foot. When body weight support is normal, all foot is in contact with the ground and support 50% of the total load, while the heel is responsible for the remaining 50%. On the other study, Marsico et al., [48] report that the plantar load must be transmitted to the entire plantar surface, 40% of which is distributed on the anterior part of the foot and 60% on the posterior part.

In view of this context, it is clear that the possible increase in plantar load rates in runners with plantar fasciitis may be directly related to changes in the plantar arch [7, 20, 49], and with the alignment of the rearfoot that maintains a more pronated posture [16, 24, 25]. Better understanding of these dynamic patterns of plantar load in runners with plantar fasciitis and their relationship with the plantar arch and rearfoot alignment could be useful for prescriptions or interventions through insoles, orthoses, and footwear aimed at runners with plantar fasciitis, demonstrating the great clinical and scientific relevance of this study.

2.2 Intrinsic foot muscles dysfunction and risk of injuries for runners: relevance in rehabilitation process

Several authors suggesting that ineficient active support of the medial longitudinal arch (MLA) may contribute to injuries such as plantar fasciitis (recognized as a repetitive strain injury from excessive deformation of the arch) or medial tibial stress syndrome, through a reduced ability to control foot pronation [18, 19, 50]. Studies biomechanics, has revealed that dysfunction of the plantar intrinsic muscles of the foot leads to an increase in foot pronation in static stance, while walking or running [50, 51]. This may result in a less rigid foot as the midfoot remains "unlocked" and therefore, generates less torque leading to ineficient force transmission through the foot lever and insuficient foot stiffness adaptation in transverse plan. In addition, with excessive pronation, the angle of pull of the Achilles tendon and the plantar flexors would be less than ideal such that some of the force generated by the muscles would pull medially as well as upward [51–54].

Acoording to Fourchet and Gojanovic [51] In order to counteract or prevent these impairments, there are two ways for enhancing the foot core stability. Firstly in terms of volitional control of the intrinsic foot muscles, the "short foot exercise" must be practiced. Secondly strengthening sessions using neuromuscular electrical stimulation of these muscles seem to be a promising strategy in order to support the MLA and control the pronation during running. Practically, the foot core strengthening protocol may beneficiate not only the runners affected by excessive pronation related injuries but also those who sustained a long-term lower limb injury and may be affected by a detraining process. Dynamic foot control is of primary interest for runners' health and performance. The medial longitudinal arch actively controlled by the intrinsic foot muscles allows mechanical energy to be stored and subsequently released during each foot contact while running. Four weeks of short foot exercise training improve both local foot postural control and dynamic single-leg balance. Intrinsic foot muscles strengthening using neuromuscular electrical stimulation enhances foot postural control and plantar pressure proles during running. Foot core strengthening program me should be implemented in lower limbs rehabilitation plans and in strength and conditioning training sessions for runners.

In addition, recent study performed in 2020 [55], has showed the effect of body mass and ankle muscle strength on the dynamic foot-pressure distribution before and after running. Second the authors the body mass index and percentage fat mass were correlated positively to all components of foot-pressure distribution. Plantar flexor muscle strength significantly predicted plantar pressure and impulse underneath the midfoot area and the dynamic arch index. After running, plantar flexor and invertor muscle strength predicted from 30% (for metatarsal 2) to 58% (for metatarsal 1) of peak foot-pressure and impulse underneath the different foot zones. Thus, the obesity was associated with excessive plantar loading that is aggravated after running by fatigue-related reductions in plantar flexor and invertor muscle strength. To prevent foot pain and injuries related to excessive foot pressures, at the start of the weight control process non-weight bearing rather than weight-bearing exercise is advisable.

2.3 Biomechanical aspects of feet for treatment with insoles and shoes in runners with plantar fasciitis

In an attempt to prevent the progression of plantar fasciitis or even to eliminate the periods of recurrence of the disease, most therapeutic approaches directed to runners with this pathology occur through insoles, with the purpose of supporting the medial longitudinal arch and reducing overload in the rearfoot region, as well as footwear to minimize excessive rearfoot pronation [20]. However, few studies have aimed to understand the effect of these factors on plantar fasciitis [56, 57], especially in running [58, 59].

One explanation for the few studies on treatment with insoles or shoes in runners may be due to the treatment time for plantar fasciitis. According to Young *et al.*, [60] the treatment lasts around six to 18 months, a fact which can lead to frustration of the therapist and the patient [61]. Although conservative therapy (drugs, physiotherapy, and orthosis resources) is still the mainstay of treatment, there are several controversies about the effectiveness of the therapeutic program that best provides symptom relief [62]. Thus, when conservative treatment is unsuccessful, a percentage of 5 to 10% of those affected progress to surgical treatment for removal of the plantar fascia [63].

The purpose of most of the treatment strategies for plantar fasciitis described in the literature is to reduce pain symptoms and overloads imposed on the calcaneus. In this direction Landorf *et al.,* [57], evaluated 135 individuals with plantar fasciitis, non-athletes, in a longitudinal follow-up treatment with insoles. The objective was to evaluate the effectiveness of three types of insoles on the plantar surface, after three, six, and twelve months of treatment. The authors concluded that, in the long run, none of the insoles promoted a reduction in symptomatology and improved foot function. This may explain the cycles of relapse and remission of plantar fasciitis [64].

This study is important, since one of the most commonly used resources by runners in their running practice is the insole, as a corrective factor for a better mechanical performance of the feet, as it is low cost when compared to recognized brand footwear in the market. According to some authors [65–67], the support of the longitudinal plantar arch is one of the most common treatments used in the population of athletes with plantar fasciitis.

Another study aimed at conventional footwear in triathlete runners with plantar fasciitis found that many have manufacturing defects that possibly contributed to the development of plantar fasciitis. Evaluating the construction of sports shoes (in terms of flexibility and the sole) can prevent injuries from overuse of the lower extremities [58].

In another study, the authors aimed to verify the effect of traditional footwear in relation to footwear with an ultra-flexible intermediate midsole (Nike 5.0) for the treatment of chronic plantar fasciitis associated with diverse exercises for 12 weeks and a 6-month follow-up after intervention. The conclusion of this study revealed that the shoes with an ultra-flexible intermediate midsole (Nike 5.0) promoted pain reduction earlier than conventional shoes [59].

Given the biomechanical studies carried out to date, it is likely that the way the loads are distributed on the surface of the feet of individuals with plantar fasciitis is different depending on the type of insole and footwear used by runners, especially when considering the acute and chronic phase of the pathology. However, there is still a scarcity of studies that address the effects of footwear and insoles on heel pain in runners with plantar fasciitis and their relationship with the plantar arch and load imposed on the feet during running and static postures.

3. Conclusion

In conclusion, the clinical support of the literature review was showed that a decrease in the medial longitudinal arch induces greater mobility of the foot, which promotes a greater angle of rearfoot pronation to maintain the stability of the subtalar joint during static and dynamic support in activities such as running. This results in a greater overload on the medial region of the calcaneus, producing greater stress on the plantar fascia, contributing to the development and progression of plantar fasciitis in runners. In addition, treatment of acute plantar fasciitis was associate to insoles while chronic phase associated for shoes ultra-flexible intermediate midsole for heel pain reduction and improvement foot biomechanics in runners with plantar fasciitis.

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Conflict of interest

"The authors declare no conflict of interest."

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Chapter 16

Genotypic Variation and Talent Identification in Sports

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Abstract

Top performance of athletes is not limited to the demand of fame, public recognition, sponsorship, and prize money but genetic inheritance contributes a prime role to hold such traits. Recent years, we have witnessed the rise of sports specific tests that identify person's athletic talents, but human vary on genetic factors which silently work to achieve success in sports. Recent progress on the genetic determination in the sports sciences offer great perspective to analyze the genotype profile associated with the athletes. One of the most used advances in this field is the identification of variations in the DNA sequence, known as Single Nucleotide Polymorphisms (SNPs). Genetic evaluations should be combined with other tools to get an accurate identification of athletes and their respective fields to achieve optimum success.

Keywords: SNP, genetic testing, ACTN3, DTC, talent identification

1. Introduction

The common inheritance of approximately 22 000 genes defines folks as human. Heredity plays a crucial role in human performance. Researchers estimate that performance connected traits necessary to elite athletes have heritability values of regarding 50% for maximal oxygen uptake (V02 max), 42–46% for cardiac output, 40–50% for muscle fiber type properties and 67% for explosive muscle power. Indeed, elite athlete standing is partly heritable with twin studies suggestion that 30–80% of the variance during this attribute is explained by heritable factors [1]. Performance enhancing polymorphisms (PEPs) area unit genetic variants that, once inherited, will result in improved athletic performance. Over a decade past, Montgomery and colleagues identified for the first time a positive association between a genetic variation, the insertion/deletion (I/D) polymorphism of the angiotensin-converting catalyst factor (ACE), and endurance exercise performance. They found that the I allele and the II genotype were overrepresented in intimate British high-altitude mountaineers compared to their healthy, non-athletic referents. This pioneer analysis highlighted the requirement for a clear phenotype definition. The latest advances in genetic technology allow further exploration of the genetic basis of elite performance to identify single nucleotide polymorphisms (SNPs) and different genetic variants that may directly or indirectly affect athletic performance. For example, the SNP R577X (rs1815739) in ACTN3 has been proven to change the power and speed standing performance of elite athletes ([2], p. 3).

The latest "human genetic map for performance and health-related fitness phenotypes" identified more than 200 genetic variants with potential for physical performance phenotypes or coaching responsiveness-related potential, but only about 20 polymorphisms were particularly relevant for elite athletic standing.

We want to observe that genetic sequence which may help individuals to know their dominant side in sports and train themselves for future. By which we can predict in what kind of sports an individual should have to be associated with. Talent identification in sports with help of genetic basis will open the door to get more personalized effective exercise planning for athletes and boost performance.

2. Background

School playgrounds are the normal sites of basic talent identification systems wherever team captains choose, one by one, from the foremost to the smallest amount in a position and fascinating teammates. Nowadays, it seems, we should always instead ask our children for a cheek swab to genetically take a look at Possibility of their movement. Despite advances in science and technology, there are still questions about reliability and validity, so it is not clear if there is any advantage in effectiveness. We tend to critically discuss here the conceptual and moral questions that arise in leveraging a genetically based approach to athletic talent identification (TI). It is believed and acknowledged by scientific and sporting communities that genetic factors undoubtedly contribute to athletic performance. As of 2009, more than 200 genetic variants had been associated with physical performance, with more than 20 variants being associated with elite contestant status. Despite the lack of evidence, recent years have witnessed the rise of an emerging market of direct-to consumer marketing (DTC) tests that claim to be able to establish children's athletic skills. Targeted customers embrace principally coaches and parents [3]. Recent analysis has targeted on trying to know the influence of heredity on athletic performance. This has led to the identification of multiple candidate genes that can help distinguish elite athletes from non-elite athletes. One of the most promising genes in this regard is ACTN3, which has undoubtedly been labeled the "speed gene" [4]. One among the foremost used advances during this field is that identification of variations in the DNA sequence, known as Single Nucleotide Polymorphisms (SNPs). Genetic evaluations should be combined with other tools to get a correct identification of athletes and their respective fields to attain optimum success.

3. Epigenetic in sports

Since the human genome was decoded 10 years ago, the challenge is to form a complete map of the genome, which can be based primarily on linear DNA sequences to describe individual theoretical talents. Ideally, the map should include all polymorphic regions, including single nucleotide polymorphisms (SNPs), insertion deletions (indels), and copy number variations (CNV), as well as their potential effects. Phonological and physiological, such as genes and genes Interaction, gene–environment interaction and regulation of the epigenetic mechanism of genes. Therefore, the observation of exercise physiologists has turned to progress in molecular genetics that might provide answers to crucial queries in determination of individual limits of physical capability and skill. Considering the number of body systems (musculoskeletal, cardiovascular, respiratory, nerve, etc.) that must take action, athletic performance is one of the most advanced characteristics of humans. Perhaps the first obvious difference between different professional athletes is the body shape (that is, height and body composition). Certain body types will naturally adapt to certain sports. On the far side body morphology, endurance, strength, and power are primary factors underlying athletic performance. The primary evidence for study genetic influences on physical capability has derived from various twin studies, starting in the late 1970s and continuing through the 1990s [5, 6]. The study explains variance in performance, capacity for endurance trainability, maximal oxygen consumption VO2max, strength and other key traits (physiological and psychological), was estimated to be approximately 50% [6, 7]. Aerobic endurance is the ability to maintain aerobic effort over time, such as running or cycling. At the most basic level, aerobic endurance requires the ability of the cardiovascular system to deliver oxygen to functional muscles and therefore the ability of muscles to use this oxygen. The most common measure of endurance is the rate of maximal oxygen uptake (VO2max). However, VO2max does not perfectly correlate with endurance performance (e.g. running a marathon), as other factors such as economy and ventilation threshold also affect performance.

Muscle strength is the ability of a muscle to receive force. Muscle strength.

is usually quantified by a rep's maximum. Muscle strength is the interaction between strength and speed of muscle contraction (for example, an explosive movement such as a vertical jump). Strength and muscle strength are essential in sporting events such as sprinting, jumping, and weightlifting. Other side regulation of transcription by epigenetic modifications, non-coding RNAs (ncRNAs) and a variety of DNA-binding transcription factors has a strong impact on many physiological processes. These factors are known to be plagued by internal and external influences [8]. However, the ability to test these often specific tissues can help identify talented athletes; however, quantifying epigenetic changes can, in some cases, be difficult. Many epigenetic changes are often tissue specific and transient [9]. Increasing knowledge in the field of epigenetics during recent years has had crucial consequences for classical quantitative genetic concerns [10]. Because the epigenome may be a major regulator of gene activity, the question arises as to how and to what extent it contributes to phenotypic variance. Epigenetic processes are partially reversible and can occur during different developmental stages [11]. Histone modifications are in a constantly changing state, while DNA methylation is generally thought to be more stable, which can have a lifelong influence on gene expression. Within individuals, the epigenetic structure is specific to the cell type [12]. and is passed from cell to cell (generation) by mitosis [6]. To effectively classify the genetic determination of performance characteristics, it is necessary to recognize that the epigenome may be inseparable from physical performance characteristics. Although it is difficult to explore the direct impact of epigenetic modifications on physical performance, there are many phenotypic characteristics that are intrinsically linked to exercise and exercise physiology.

4. Identification of talent in sports

A plethora of talent identification problems can be found within the subdisciplines of exercise science including motor learning, sports psychology, and sociology. The purpose of talent identification (TI) is that the earliest possible selection of auspicious athletes with the goal of systematically maximizing their potential. Top performance of athletes is not limited to the demand of fame, public recognition, sponsorship, and prize money but genetic inheritance contributes a prime role to hold such traits. The current example of the soccer player Gareth Bale, for whom Real Madrid paid a fee of €100 million, reflects the prevailing economic pressure [13].

There are different organizations which select the talent and develop them into competitive athletes. Any eligible youth can apply to those organizations, who will be called for selection trials. The admission to the schemes will be subject to fulfillment of the eligibility criteria and battery of test as well as skill tests. Although the standards are subjected to multidisciplinary research and detailed discussion, the optimal test design for a reliable prediction of talent has not yet been found [14–16]. However, although talent identification and development plans have become more and more popular in recent decades, there is still a lack of consensus on how to define or identify talents, and there's no uniformly accepted theoretical framework to guide current practice. The success rate of talent identification and development plans is rarely evaluated, and the effectiveness of the application model is still very controversial.

Several authors dealing with any aspect of a 'talented person' note an inherent problem: the talent concept has been widely but indiscriminately observed and utilized [17]. Some models were based more on the hypothesis that talent is genetically transmitted or that success in a given domain is innately contributed ('innate' talent that is sometimes synonymously used with giftedness) [18, 19]. In this chapter, we unify the discoveries from these disciplines in a way to summarize and focus the traditional measurement methods of talent identification (TI) and emerging genetic testing (GT).

4.1 Conventional talent identification (TI)

The promotion of athletes basically follows two paths: talent identification (TI) (usually followed by selection) and talent development (providing the most suitable learning environment to reach this potential), which plays an important role in the pursuit of excellence. In many high-level organizations and teams, science-focused support systems (such as counseling, physical conditioning, and computer-based competition analysis) are now the foundation for cultivating elite athletes. However, due to the lack of scientific basis for most TID projects, many academics suggest that research work be transferred from IT and testing to TD and guidance. [20, 21]. Talent development programmes focus less on current abilities but more on providing athletes with appropriate practice conditions to promote their future potential in a given sport [22].

TI and TD models are associated with low predictive value and their validity and usefulness have been widely questioned [21, 23].

4.1.1 More about conventional talent identification (TI)

The recognition of talent includes the measurement and comparison of different characteristic values that determine the specific performance of sports. The test parameters come from a statistical path analysis, showing a single variable that largely describes complex performance. For example, sprinting performance depends primarily on body build, basic running speed, and technical or coordination skills [24]. Depend on these analysis TI tests assess atmospheric variables like weight, limb circumference, bone density, and physiological measures like maximum O2 uptake, aerobic, anaerobic endurance, strength, flexibility and sport specific skills such as running, jumping and diving performances. The analyst compares different age groups or performance levels in the cross-sectional design; if a top-down approach is adopted, the first-class athletes are compared with the poorer-performing athletes by evaluating certain differences. These differences that reveal the most significant differences between performance levels are identified as predictors. For example, among basketball players, vertical jump, arm width, and basketball pass a significant predictor [25]. However certain percentage of total variance of basketball performance could not be explained and observed to be an association of cognitive, psychological or sports specific factors such as decision making or game scene.

The cross-sectional designs of most talent studies hide other problems in terms of attribute assessment classification and transferability in into TI programmes. Further the classification into 'talented' 'elite' or 'successful' athletes versus 'les- or untalented' 'non- or sub-elite' or 'unsuccessful' [26, 27] differs between the studies and depends most evidently on the availability of athlete groups for the studies.

Many studies revealed only weak differences between high and lower performance levels that were insufficient for discrimination. Therefore, due to the dynamic and multidimensional nature of sport talent, traditional Talent Identification and Talent Development models are likely to exclude many, especially late maturing. This TI procedure focused on a limited range of parameters and select based on 'one-off' proficiency measures that fail to acknowledge that physical maturity and previous experience can influence performance.

4.2 Genetic identification of talent

Elite athlete ('elite athlete refers to one who has competed at a national or international level in a given sport') [28] status is a partially heritable trait, as are many of the underpinning physiological, anthropometrical, and psychological traits that contribute to elite performance. The phrase "genetic factors" refers to potential differences in DNA sequences between individuals. Although humans are considered to be 99.9% identical in genetic sequence, our human genome is composed of approximately 3 billion DNA "letters", and even small differences between two genomes mean that millions of letters will have The difference [29]. These letters provide a series of instructions for the development and maintenance of our body structure, including physical and mental attributes.

The main question is no longer if there is a genetic component associated with elite athletic status and endurance/power trainability, but rather, which genetic profiles contribute to elite performance [30]. Genetic information can be collected for a talent identification program by simply addressing family history of the aspiring athlete: do young athletes have talented parents or siblings or family members who have the physical or mental characteristics that match the needs of the target sport? But this genetic information is neither accurate nor perfect, like other aspects of talent identification. The addition of genetic profiling is being considered to make the prediction and selection process more precise and quantifiable and thus make the "art" of athlete selection more measurable [31]. Several companies are beginning to market genetic tests for sport performance prediction based on this assumption. Genetic testing could theoretically be applied regardless of time and place, with results independent of an athlete's age, training cycle, physical condition or daily health. From a governing body or club perspective, gene-based talent selection will help maximize economic resources. Around the world now a day, newborn screening is common practice for a variety of genetic disorders. In adults, genetic testing is used in many fields like diagnostic and predictive testing for any kind of disease condition and very promising carrier testing prior to pregnancy for both parents.

4.2.1 Can genetic testing identify talent for sport?

Recent years have witnessed the increase of an emerging market of direct-to consumer marketing (DTC) tests that claim to be ready to identify children's athletic talents. Since the 1960s, genetic tests have been provided to patients for health-related reasons within a clinical setting [32] usually following a medical referral, genetic counseling, and upon obtaining informed consent, but now many tests are offered by different organizations. A host of direct-to-consumer (DTC) genetic testing is available, where people submit DNA samples (usually cheek swabs) to the company, which then returns the genetic testing results directly to the consumer without the need for a healthcare provider. Keeping in mind of sports performance, genetic testing and profiling technologies are visualized as way to identify ones carrying particular combinations of gene sequence variants associated with particular physical or mental trait, or suited to success in particular sports. The genetic information would be paired with more typical analysis of talent selection in order to best select young athletes for early sport-specific training.

4.2.2 Examination for genetic trait analysis

Purpose: Among the non-athletic young man, first identify the effect of α-actinin-3 deficiency due to homozygosity for ACTN3 577X polymorphism on fast muscle fiber's contractile & morphological properties.

In human body, two genes are encoded for α-actinin of skeletal muscle, α-actinin - 2 protein for ACTN2 & α-actinin-3 for ACTN3. Generally, ACTN2 expressed in all skeletal muscle fibers but ACTN3 expression is on restricted to type-II fast fibers, predominantly involved in powerful explosive contraction. So, the aim of the study is to analyze skinned muscle fibers to get more insight into the contractile and morphological properties of α-actinin-3 deficient and α-actinin-3 expressing muscle fibers in non-athletic young males.

Method

Participants

Young non-athletic males (20. 9 ± 0. 7 years) were selected from the total number of participants based on their characteristics, including stature, weight, physical activity level and tissue- Maximum isostatic knee extension torque at 45° knee flexion. The level of physical activity was determined during an interview to determine the amount and type of activity of the participants. All participants volunteered and gave their written consent to participate in this study, a process approved by the Medical Ethics Committee.

Muscle Biopsies:

Using needle aspiration biopsy, we first collected a sample of Vastus lateralis from the participant's left leg. Prior to the biopsy, all participants were informed to abstain from strenuous physical activity. A small portion of muscle biopsies was inserted into TissueTek and frozen in nitrogen-cooled isopentane for immunohistochemical analysis. It was previously described that for myosin heavy chain isoforms, muscle infection was stained by immunohistochemistry. Samples used for the single-strand test were immediately placed at in cold stripping solution (0°C) and a bundle of filaments was cut lengthwise. At −20° C, packet skin peel solution was stored as a regular replacement for at least 5 days before the first experiment.

Single Muscle Fiber Experiments:

After counting, individual muscle fibers were tested for maximum trigger force normalized for fiber cross-sectional area (P0), maximum no-load velocity (V0), and force-velocity relationship. or passive tension properties on dynamic force profiles. Within 4 weeks after biopsy, all experiments were performed at 15°C. within four weeks after biopsy. Detailed protocols have been described previously. Briefly, after adjusting the length of the sarcomere to 2.5 m, the size of an optical fiber including the fiber length and the cross-section (CSA) was determined on the digital image of the optical fiber. When damaged fibers were removed prior to testing to exclude an effect on the contractile properties of the fibers, each fiber was visually examined for damage by shearing or processing of muscle biopsy results.. P0 was determined as the maximum stabilizing force developed by the fiber when immersed in the activator solution (pCa 4.5) corrected for the CSA fiber. By slack test, no-load shortening rate (VO) was measured; each fiber is maximally activated and then rapidly shortened, so that force drops to baseline and re-evolves after a period proportional to stride length. in the number of serial sarcomas between different fibers, the V0 fiber was determined as the slope of the fitted line and expressed as fiber length per second (FL/s) to account for the difference tested. The yarn was subjected to 5–6 times three consecutive isometric load clamps to determine the force-velocity relationship. Based on Hill's equation, the data obtained on an optical fiber are adjusted using an iterative nonlinear curve tuning procedure (Marquardt Levenberg algorithm). From the parameters of the adjusted force-velocity curve relationship, the fiber power (W/L) was determined. Passive tension was tested with a progressive stretch protocol while the fiber was still in pCa 9.0 solution. To evaluate the elastic properties of the fibers, Young's modulus (kN/m2) and hysteresis (kN/m2) were calculated & After mechanical testing was completed, the fiber fragment was dissolved in 25 μl sample buffer SDS and stored at −20°C until MHC isoform content analyzed by SDSPAGE.

Genotyping

In, using the manufacturer's procedure I Chemo magnetic Separation Module (PerkinElmer, Baesweiler, Germany), DNA was extracted from an EDTA blood sample at UZ Leuven. In this experiment, the TaqMan SNP genotyping assay, ACTN3 R577X polymorphism genotyping (rs. 1815739) was performed (ID C__590093_1, Applied Biosystems). Here, real-time qPCR was performed in 20 L of reaction mixture with 1 L of DNA, and other equipment required for the experiment was 8 L of RNase-free water, 1 L 20 × test mixture of TaqMan SNP genotyping and 10 μl of 2 × Taqman Universal PCR main combination (Applied Biosystems).

Statistical analysis

Using Student's t-test, participant characteristics and a muscle fiber composition were compared between ACTN3 577RR and 577XX individuals. An ANOVA analysis in SAS version 9.2 (SAS Institute, Cary, NC) measured single strands per fiber between the two groups of genotypes. A mixed process with a multilevel model is used to explain the dependence of multiple fibers in a single participant. For genotype differences, unbiased effect sizes and 95% confidence intervals are reported. Only Class I and Class IIa fibers are sufficiently abundant for a statistical analysis [33].

4.2.3 Genetic analysis: Genotype: Phenotype association studies using gene expression analysis

In deoxyribonucleic acid variation, the constitution is related to a technique for analyzing organic phenomenon victimization the "reverse" approach. During this approach, by suggests that of polymer expression studies, heterogeneousness in athletic performance was known by polymer expression studies, resulting in the confirmation and identification of deoxyribonucleic acid variants physiologically. Relevant and in theory to extend applied math power. Recent advances in biotechnology have enabled larger discovery of the genetic underpinnings of elite action, resulting in the identification of single ester polymorphisms (SNPs) and different genetic variants that have the potential to influence athletic performance, directly or indirectly. As an example, it's been shown that Associate in Nursing SNP in ACTN3, R577X (rs1815739) modifies the attainment of elite speed-power jock standing two three.

Here within the transformation, ends up in the substitution of the bottom C to T common from the essential amino acid base (R) to Associate in Nursing early stop sequence (X). by ACTN3, αactinin3, expressed solely in fast-twitch muscle fibers, homozygous for the X factor lacking the cryptography macromolecule. Speed power performance, these genotypes might not be underrepresented within the elite speed power cohort thirty eight. On this subject, the primary study was performed by principle and colleagues. Within the athlete's body, genetic polymorphisms will be studied extensively. The αactinin3 (ACTN3) Arg(R)577Ter(X) (rs1815739) polymorphism helps muscle macromolecule expression. Zdisc. α actinin3 stabilizes the contracted equipment, which might offer superior force absorption/transmission compared to kind I fibers. This macromolecule conjointly helps promote the formation of kind II fibers. Indeed, sarcomeric αactinins bind to calsarcins, interacting with calcineurin, a signal issue that plays a job within the specification of the kind of muscle fiber40. Over a billion individuals worldwide ar unable to precise to precise their muscle fibers (i.e., they are homozygous for the R577X nullallele). Exaggerated activity within the aerobic aerobic pathway forty two. Additionally, ACTN3-type mice conjointly exhibited higher resistance to fatigue, ablated muscle mass and muscle cell diameter, speedy contractions (IIB), and ablated fatigue. Muscle strength compared to wild kind mice [34]. In humans, it is shown that Olympic finalists in "strength" or "sprint" events (jump, throw, run a hundred meters) seldom specific the XX "null" genotype of the ACTN3 R577X polymorphism. With few exceptions, these results are duplicatable in some thus, though it's usually calculable that it explains concerning one to three of the variance of the thirty six forty five forty six speed result constitution, ACTN3 then known as "speed" forty seven forty one forty eight. During this our ambition was to explore the result of ACTN3 polymorphisms on response to muscle injury in athletes taking part in ultra-endurance races.

4.2.4 Technical aspects and shortcomings of genetic testing (GT)

"whole genome sequencing" procedure helps to identify the base sequence of genome. This procedure also concerns complete range of coding and non-coding variants of human genome and rare variants. The reference sequence data can come from various dbSNP databases, which contain most of the SNPs estimated to be present in the human genome [35]. The final result of whole genome sequencing shows a list of genotypes in which at least one allele differs from the reference sequence [36]. This seems to work well with SNPs but structural variants (SV) do not change the copy number of the affected chromosomal region so it remains difficult for SVs and their association with complex traits. They found only 0.5–1% of the genome, at least 20% of all genetic variants in human and this play a part in phenotypic diversity between individuals. In genetic research A genome-wide association study (GWAS) is an approach to associate specific genetic variations with particular diseases, identifying statistical associations between genomic intervals and common complex traits without assumptions about the genomic location of the causal variants [37, 38]. In the field of exercise, for showing some findings [39] 21 of the 324,611 SNPs were identified, which accounted for 49% of the response to maximal oxygen uptake. To aerobic training. Compared with subjects with 9 or fewer SNPs, individuals showing at least 19 SNPs had a three-fold increase in VO2max [34] identified three quantitative trait loci (QTL) for glucose and insulin metabolism phenotypes in response to endurance exercise training. Despite all the above aspects, "genetic performance tests", such as "GenEffect SPORT" (GenEffect, Falkendorf, Germany), are still for private use and seem to be widely used in the United States and Asia [40, 41]. These tests confirmed that they provided exercise-based genetic screening with real information about genetically determined susceptibility. The company called "GenEffect" claims that ACTN3 genetic screening indicates whether athletes are suitable for sprinting, strength and strength sports (RR genotype), endurance sports (XX) or mixed mode sports (RX), but it is clear that the classification has never been made public [42]. Recently published data from Russian endurance athletes primarily carry the RR or RX genotype, rather than the hypothetical XX genotype used for endurance performance. Think of companies like this that have chosen genes of uncertain scientific value [41, 43] Weak explanation of sum variance [41, 44, 45], and data collected from top adult athletes may not be transferred to children [40]. It is reasonable to call these tests "ridiculous".

4.2.5 DTC (direct-to-consumer) tests

Through the medical science community, Gene Science has evolved over the past decade at an unimaginable rate. Not only are genetic tests popular in clinical settings, they are also available to the general public. Over the days, the price will drop. Tests are also getting much cheaper. At first, whole genome sequencing cost around $ 2.7 billion, now it costs less than $ 1,000 and continues to drop by 61. Companies can offer genetic testing to the public on a commercial basis because it costs less to analyze specific variants of the genome. Any genetic test should be assessed against four key criteria: analytical validity, clinical validity, clinical utility, and ethical, legal and social implications.

Thirty companies (**Figure 1**) were identified as offering marketed DTP genetic tests related to sports or physical activities or injuries. Almost half of the companies identified are based in the United States. Not all companies engage in both DTC marketing and sales through their websites.

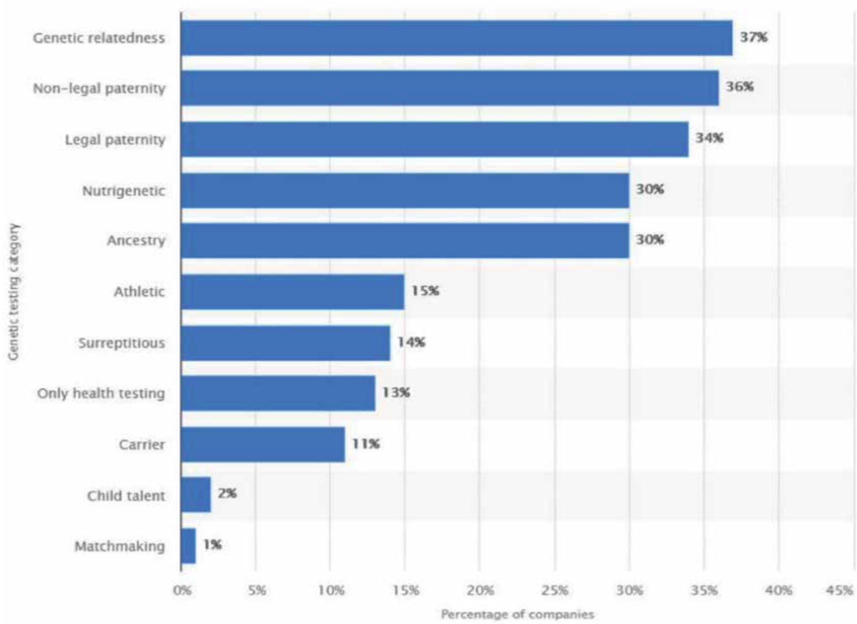

Figure 1.
Number of companies providing direct-to-consumer (DTC) genetic testing worldwide as of 2016, by category. Data has been obtained by using the search terms "genetic", "test", "exercise" and "sport" "DTC" in two popular search engines (Google and Bing) [46] © Statista 2021.

Despite the uncertainties in basic science, companies are beginning to commercialize genetic tests to predict athletic performance and athletes, parents, coaches and sports teams are starting to use them. Various companies and startups market genetic tests that claim to provide important information about future sports success (**Figure 2**).

In this test Genes included including. Some tests primarily focus on specific characteristics (soft tissue injuries), but most are often marketed as the result of "athletic performance" or some similar general performance characteristic. Alphaactinin3 (ACTN3) gene assay from Genetic Technologies Corp. patented in the United States (US 7,615,342 B2; issued November 10, 2009). The patent describes a specific genetic variation of the ACTN3 gene related to sports performance, and specifically describes that genetic information from this unique gene can be input into other performance tests when using talent selection programs. Consumers who purchase any of the testes shown in **Figure 3** receive individual results for all of the genes tested along with their descriptions and explanations of success in different types of sports, such as endurance or strength.

Consumers World Health Organization purchase any of the testicles delineated in **Figure 3** can receive personal results for all tested genes, yet as descriptions and explanations of their success in numerous sorts of exercise (such as endurance or strength). In some cases, firms additionally sell materials to live alternative physical or performance characteristics to be used in conjunction with genetic testing. The corporate has selected genes from the scientific literature as a part of the genetic testing kit, however as mentioned on top of, the lustiness of basic science is sometimes unsure. As an example, ACTN3 R577X tests for hollow polymorphism are obtained from completely different firms for many years66. Solely fourteen of the start known twenty two firms seem to still operate commercially, which implies that eight apparently have ceased operations, and twenty five new firms have emerged

Company	Website	Approx. Year Company Began	Location	Related Companies
23andMe, Inc.	www.23andme.com	2006	CA, USA	
Advanced Health Care Inc., India	http://www.advanceddna.in/sports.aspx	2008	India	
American International Biotechnology Services (AIBiotech)	http://www.sportsxfactor.com/Home.aspx	2010	VA, USA	Botswick Laboratories, Inc.
Asper Bio Tech	http://www.asperbio.com/athletic-gene-test	1999	Estonia	Estonian Biocentre
Athleticode, Inc.	www.athleticode.com	2009	CA, USA	
Atlas Sports Genetics, LLC	http://www.atlasgene.com/	2008	CO, USA	Zybek Sports, LLC; Zybek Athletic Products, LLC; Genetic Technologies Ltd; Epic Athletic Performance
Cosmetics DNA	http://www.cosmetics-dna.com/questions_answers.htm#I_want_to_test_my_DNA	unknown	Israel	UmaPuri Ltd; Dr. M. Burstein Ltd.; Bio Anti Aging Ltd.; Dr. Burstein Dead Sea Ltd., (DBS)
CyGene Direct *	http://www.cygenedirect.com/browse-10873/Optimum-Athletic-Performance-Dna-Analysis.html	2003	FL, USA	CyGene Laboratories Inc.
DNA4U *	http://www.gonidio.com/test.php?id=2	unknown	Greece	Gonidio
Family Tree DNA	http://www.familytreedna.com/Default.aspx	2000	TX, USA	Genealogy by Genetics, Ltd.
Genetic Technologies Limited *	http://www.gtpersonal.com.au/sports_performance.php	1989	Australia	
My Gene *	http://www.mygene.com.au/product/sport-genetic-test	unknown	Australia	
Warrior Roots	www.warriorroots.com	2008	MD, USA	Sorenson Genomics

List was prepared May 2011. * Indicates companies that, while clearly marketing direct-to-consumer (DTC), may not be selling DTC, as suggested by broken or nonfunctioning hyperlinks on company websites or absence of online purchase options.

Figure 2.
Companies providing sports-related DNA tests direct-to-consumer (DTC) for sport performance or related traits. Wagner, J. K., & Royal, C. D. [47].

Company	Product Name	Price	Number of Markers Tested	Markers Tested
23andMe, Inc.	"23andMe Kit" ("Muscle Performance" is a trait included as a 4-star "established research report")	$399.00	1	ACTN3
Advanced Health Care Inc., India	"Sports DNA Test: First Genetic Test"	$275.09	1	ACTN3
	"Sports DNA Test: Pro Genetic Test"	$1,127.37	1	ACTN3
American International Biotechnology Services (AIBiotech; SportsXFactor)	"Sports X Factor Standard Panel"	$180.00	12	ACTN3, ACE, PPARGC, DI01, VEGFR, NOS3, IL6, APoE, HCM (MYH7, MYBPC3, and TNNT2), SCN5A
	Sports X Factor Standard Panel with all add-on options ("additional ACL/Soft Tissue Injury Panel"; "additional Hereditary Hemochromatosis"; "additional Cardiac Marker Panel"; and "additional Customized Workout")	$900.00	17	ACTN3, ACE, PPARGC, DI01, VEGFR, NOS3, IL6, APoE, HCM (MYH7, MYBPC3, and TNNT2), SCN5A; COL1A1, COL5A1, COL12A1, TNC, and MMP3
Asper Bio Tech	"Athletic gene test"	$118.64	2	ACE and ACTN3
Athleticode, Inc.	"Race Time Kit"	$79.99	1	COL5A1
	"Body Scope Kit"	$189.99	5	COL5A1, COL1A1, COL12A1, MMP3 and GDF5
Atlas Sports Genetics, LLC	"Atlas First"	$169.99	1	ACTN3
	"Atlas Pro"	$999.99	1	ACTN3
Cosmetics DNA	"Athletic Performance"	$519.75	"60 Genes/ 79 SNPs"	n/d

Figure 3.
Examples of companies selling direct-to-consumer (DTC) genetic tests for sport performance or related traits. Genetic test prices range from approximately US$80–200 across these different tests. Wagner, J. K., & Royal, C. D. [47].

within the past 2 years. Many firms use the results of their customers' genetic tests as opportunities to supply alternative aspects of their business activities, however need further fees, like coaching recommendation, particularly biological process supplements. There's an agreement within the medical profession that genetic testing will solely be meted out once the relevant personnel have free and consent. This info will solely be provided if the patient has obtained adequate info regarding genetic testing (such because the risks, benefits, limitations, and effects of genetic testing with long-run or indirect effects).

5. Inexpediency to use genetic information for talent identification

Identifying talent for future athletic performance is a major concern for many groups due to the challenges of finding and developing potential elite athletes. Since genetic factors are associated with many performance-related traits (strength, endurance, etc.), the natural tendency is to consider adding genetic testing to the capacity of asset identification programs. Genetic testing may positively inform talent identification is less certain. The application of genetic testing for health related purposes is becoming a popular topic in the field of medical sciences. In sports, athletes and coaches often focus on conflicting nutrition and training strategies to develop training performance. For this reason, athletes and coaches may risk the allure of direct genetic testing believing that their results will help improve performance. Giving inaccurate or unreliable advice can be harmful to the health of athletes. Other studies have consistently supported the view that the ACE and ACTN3 genotypes influence human performance compared to sprint / strength or endurance events. A systematic review and meta-analysis concluded that there is strong evidence for an association between the ACE II genotype and endurance events and between the ACTN3R allele and force events. Although there is a correlation between several genes and elite athletic performance, there is no scientific evidence for the predictive value of genetic profiles in athletic performance. Genetic profile testing alone currently cannot reliably predict athletic performance3 Most sports have a combination of sprint/strength and endurance components along with many other factors including many genetic, physical factors. Environmental and psychological. Genetic quality is just one of many factors that contribute to success in sports.

The Australian Law Reform Commission and the NHMRC, in their 2003 report Basically Yours, recommended that "discrimination laws be amended to explicitly prohibit unlawful discrimination based on status a person's actual or perceived genetics". This type of discrimination is addressed in the anti-discrimination laws of the Commonwealth, states and territories. Potentially, any of the grounds or provisions listed in Australian anti-discrimination law could involve discrimination on the basis of genetic status. Extending this premise to sport indicates that knowledge of an athlete's genetic makeup cannot be used to preclude the selection of that sport for a particular program or team. It is also unethical to use genetic testing for affirmative action.

Several commercial organizations now make "predictions" of athletic ability using direct-to-consumer genetic testing. Direct-to-consumer testing provides genetic performance analysis related to athletic achievement and athletic talent primarily based on ACE and ACTN3. However, each company differs in the additional genes tested as part of a commercial trial. There are several cases involving the effects of genetic testing on individual athletes using direct-consumer testing, especially when it involves children. Sports activities. Inappropriate advice can, in turn, adversely affect an individual's physical or psychological well-being. In a review, which uses genetic analysis to identify talent.

Current genetic testing is not predictive for identifying talent and should not be used by sports organizations, athletes, coaches or parents using 'Using the genetic phenotype as an absolute predictor of sport'. Sport selection is unscientific and unethical.

Tests of this type in young athletes are particularly problematic because they can be misinterpreted and restrict children's choices about potential activities. Given the multifactorial nature of human athletic performance, the information obtained from genetic testing should never be used for inclusion or exclusion in identifying talent.

So we have finally reached the point that genomics is a growing field in all branches of health including exercise and sports medicine. Advances in technology and cost reductions have made genetic research and genetic testing more accessible to many sports organizations and individuals. AIS is committed to keeping abreast of the latest scientific and technological developments without compromising the integrity of the sport. The AIS will maintain a clear and unchallenged focus on the safety and well-being of the athletes. This position statement explains the ethical framework within which genetic testing and genetic research will be carried out in Australian sport. The Australian Institute of Sports position for genetic research and testing for genetic testing of Australian athletes for health purposes will be ordered by a doctor. Genetic testing will be requested for health-related purposes along with genetic counseling. If people choose to undergo direct-to-consumer genetic testing, they should be prevented from following the recommendations of commercial companies without asking a doctor for clarification. As part of the research project, genetic testing will only be performed with the knowledge and written consent of the participants. Will clearly explain to athletes the purpose of using genetic information. Participants in genetic research will be informed of the possibility of unintentional discoveries, which may have a potential impact on the health of the participants or the health of their family members. Athletes have the right to refuse genetic testing. Athletes who refuse genetic testing will not be discriminated against. Before participating in the research, the management and confidentiality of genetic test results will be clearly communicated to athletes.

6. Conclusion

Improving concussions in sports science among teens in school to young adults, furthermore because the military and their dependents, this report recommends actions which will be taken by a good vary of audiences, together with funding agencies. From analysis, state and faculty principals and athletic administrators, military organizations and instrumentality makers, furthermore as young athletes and their folks to enhance what's acknowledged regarding concussions and scale back their events. Sports Related Concussions in Youth found that whereas some studies offer helpful data, a lot of remains unknown regarding the extent of concussions in young adults; a way to diagnose, manage and forestall concussions; and short and long run effects furthermore as head connected effects that do not cause concussion symptoms.

Sport culture negatively affects athletes' self-reporting of concussion symptoms and their compliance with come pointers. Athletes, their teammates and, in some cases, coaches and fogeys might not be absolutely ancillary of the health threats exhibit by concussions. Likewise, recruits ar immersed in a very culture that has a commitment to duty and self-service, and also the severe nature of concussions will usually go forgotten. in step with Sports Related Concussions in Youth, if the youth sports community will believe that concussion could be a serious injury drawback and specialize in caring for concussion players till they absolutely recover, then the culture during which these athletes perform and contend can become a lot of safer.. an improved understanding of the extent, causes, effects and hindrance of sports-related concussions is of significant importance to the health and well-being of young athletes. Our ambition is to supply analysis direction to attain this goal. Each four years, everybody waits for the athletic competition. we have a tendency to marvel at the gymnasts' talent or guess what percentage gold medals Michael Phelps can win. we have a tendency to encourage athletes World Health Organization participate in events that have existed since the primary athletic competition. Running is that the most natural sport as a result of no special instrumentality is needed and may be practiced by anyone in sensible physical form. it's thus outstanding that the sprint is dominated by one group: folks of West African descent. Of the highest five hundred sprinters within the 100 m, solely 2 ar good non-Americans; There are not any Asians or perhaps East Africans during this prime cluster. The foremost frequent rationalization for this development is that the atmosphere and education ("These kids got to run to high school once they ar young", etc.). Scientists say the other. Most scientists and researchers agree that biology plays a very important role in distinctive these elite sprinters from the remainder of the herd. Whereas there ar several genes related to athletic performance, the one that's best studied for its role in running is understood as ACTN3. ACTN3 is expressed in glycolytic kind II muscle fibers, that ar concerned in speedy and powerful contractions. There are 2 variants of this gene: R577R and R577X. Studies have urged that elite athletes in power sports (such as sprinting) ar additional doubtless to own the RR genotype, whereas elite endurance athletes ar additional doubtless to own the RR genotype. The chance is XX. However, the results vary betting on the population studied, as an example Africans versus Australians and Europeans. Even studies showing a positive association with strength sports and also the RR genotype or endurance sports and genotype XX assume that the ACTN3 cistron contributes solely a modest portion to elite sport.

Though scientific understanding of the ACTN3 genotype and athletic performance continues to be current, firms are attempting to take advantage of the association for years. as an example, Atlas Sports biology offers ACTN3 genetic testing for beneath $200. The take a look at is conferred to oldsters as a tool to create an wise call once selecting the simplest sport for his or her kid. The Atlas Sports biology web site states that the take a look at "… provides folks and coaches with early data regarding their child's genetic predisposition to success in speed/strength or power sports. Enduring as a team or as AN individual". while not a doubt, these firms are twisting the science behind the testing and exaggerating the importance of the ACTN3 genotype for athletic ability. These firms follow restrictive protocol and it's tough for the central to intervene. AN recent locution applies to the present new technology: consumers beware! but, it's doubtless that future genetic tests are going to be additional correct in predicting athletic ability. Such a take a look at may attractiveness to oldsters World Health Organization wish to create the foremost of their child's free time as several kids lead terribly busy lives lately. Is directional {a kid|a toddler|a baby} to a sport they are sensible at a lot of completely different than hiring a music teacher for a music kid or an educator to assist speed up a precocious kid in math? Why not offer your child AN allowance if it's available? [48].

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Section 3

Sports Education

Chapter 17

Human Empowerment between Ethics and Law

Camilla Della Giustina

Abstract

The aim of this work is to highlight the problems that human empowerment poses in the sports field. The phenomenon of sport doping is precisely analyzed as an expression of enhancement in the light of a biogiuridic and bioethical reflection. The question that animates all the digression essentially concerns the definition of doping and therefore whether the same depends on purely legal qualifications and classifications or whether it is a social and cultural phenomenon and therefore whether it is the cultural context of reference to define a given phenomenon, substance or practice as a dopant. To pursue this objective, it was decided to provide a first definition of human empowerment in order to delimit the field of investigation and then analyze only one of the different expressions of this phenomenon, doping precisely. Consequently, it was decided to provide a study of the doping phenomenon both from a legal and ethical point of view within the macro-context doping in sport.

Keywords: human empowerment, doping, sports law, sports ethics, sports bioethics

1. Introduction

From the moment when there is written news, man has always sought the aid of substances, whether natural or chemical, to seek support in the face of activities that he had to carry out.

Wanting to provide a historical excursus, the first information on doping date back to 2700 BC: the source is a Chinese text in which reference is made to a plant defined almost miraculous and containing the alkaloid Machmane.

In addition to this, in 300 B.C. athletes used to take an alkaloid during sports activities, namely ephedrine. Also during the same period, Greek Olympic athletes took decoctions prepared with mushrooms and herbs while Macedonian athletes used donkey nails boiled in oil and accompanied by rose petals. In Rome, however, more horses than athletes were the recipients of doping substances with the exception of gladiators. The latter to increase their resistance to fatigue took plant stimulants such as betel nuts and ephedrine.

The first evidence of condemnation of the use of these substances is found only in 200 A.D. in a written by the philosopher Flavio Filostrato who in his work "Gymnastikos" argues that athletes should not take mud or other dangerous medicines.

Despite this first act of denunciation the practice of providing empowering, energizing substances to athletes continues to be the constant: In 1800, to increase sports performance, more elaborate and sophisticated substances were used than those used by Greek and Roman athletes. The new methods of strengthening favor the intake of opium, morphine, caffeine, nitroglycerin, sugar cubes dissolved in diethyl ether as well as strychnine. Unlike in the past, attempts are made to identify the exact substance to be taken by a certain athlete, thus arriving at a differentiation between substances based on the activity that is carried out [1].

The high point in the use of doping throughout the world of sport is only reached during the decade 1950–1960: these are years characterized by the taking of stimulants especially in the performance of those activities that require great effort and great durability as cycling, marathon, football, basketball and American football.

During the '80s the substances that impose themselves most as enhancers the use of cocaine and anabolic; The 1990s were characterized by the spread of peptide hormones (in particular hgh and EPO) and blood doping carried out through the autologous and heterologous blood transfusion process. In contemporary times, the danger comes from what has been defined as genetic doping, that is, from the applications of genetic research consisting in the partial activation or inhibition or suppression of human genes for sports enhancement and therefore doping [2].

The last frontier of doping, genetic doping, poses problems not only in relation to sports ethics and fair play but also integrates unpredictable risks for the same athlete. They are closely related to the difficulty of controlling the expression of the gene that is inserted as well as to the method that is adopted to implement genetic transfer. Side effects include possible morbidity, inflammation stages and immune responses that can be defined as uncontrolled.

To this must be added how the current methods of analysis that are used to detect the presence of any doping substances have been defined as totally inadequate and ineffective to detect those that are defined as "doping genes" as impossible to distinguish from end1ogenous ones.

The advantage of genetic doping, in other words, is that it is not detectable with the survey tools currently in use [3].

If these are the origins and the problems that have always characterized the relationship man/physical performance and man/sports performance, the focus of this work concerns the classification of doping as a method of human enhancement.

In order to pursue this objective, it was decided to start from a definition of the concept of human empowerment and then to address one of the aspects in which the very concept of empowerment is developed, namely doping.

Following this premise, the reflection focused on the problem that doping poses within the sports world not only from a strictly legal point of view but also from an ethical point of view. In other words, the question has been raised as to whether the definition of a particular practice has an impact on its acceptance or not.

The conclusions, on the basis of this line of interpretation, arrive at analyzing the hypothesis of athletes who, due to a genetic pathology, are possessing an empowerment that could be defined "natural". In this hypothesis is it right that they are excluded from the competition or not because of their genetic structure?

2. Human empowerment: definitions and delimitation of the scope of investigation

The term human empowerment refers to an improvement of the human condition through the use of *techne*, precisely nanotechnologies, biotechnology and computer technologies are used to achieve this goal. These biomedical technologies or, alternatively, the use of drugs are applied to pursue, as a final purpose, the increase of the normal functioning of the body and/or psyche.

In other words, scientific and technical knowledge is not used to treat a disease or disease processes, but to improve natural human performance through overtaking [4].

This phenomenon involves the use of psychopharmacological products studied, created and tested to solve, at first, the disorders and therefore having strictly therapeutic purposes, to be used to manipulate in the sense of improving minds not affected by pathologies, that is, normal minds.

In contemporary society there is a medicalization of life and the corresponding creation of a need for care for any human condition, not pathological but physiological; This is an appropriate aspect to determine the promotion of any successful drug [5].

This reflection leads to question the distinction between normality and abnormality, between physiological and pathological event and finally between therapeutic treatment and enhancement.

In order to investigate the latter binomial, the present literature is used, according to which, by treatment, reference should be made to employment, the use of biotechnological means and pharmacological treatments to treat individuals with known diseases or disabilities in order to restore a normal state of health [6].

Strengthening, on the contrary, concerns all interventions intended to improve the human condition both in its physical and mental condition regardless of what is necessary to maintain or restore health [7].

The distinction just presented is based on two crucial points.

The former has moral connotations and tries to distinguish between acceptable uses and uses that cannot be defined as such: if medicine is considered as a good, from an ethical point of view, empowerment would bring with it aspects that can be defined as suspicious. In addition to this, on the basis of this first criterion, the priorities of medicine could be defined, namely that of treating patients, in the first instance, and subject to the application of practices aimed at improving certain characteristics.

The second concerns a strictly political-economic aspect and, according to this criterion, only therapeutic treatments are subsidized in an almost integral way, while the improvement treatments remain the responsibility of the individual.

The above distinction has its pitfalls, since it must be considered that any therapeutic treatment is proposed to offer an improvement and that a complete restoration of normality is often not possible [8]. Another consideration concerns the reflection that it is almost impossible to distinguish unequivocally between therapy and empowerment as concepts with a cultural foundation and convention and therefore not a certain definition. This statement is of greater importance in the light of the historical and cultural evolution that has affected the concept of health [9, 10] and disease which, in turn, have uncertain and blurred boundaries in the light of biotechnology evolution [11].

The idea behind the strengthening is that of a new concept of health based on a subjective conception: we are witnessing a transition from a concept of objective health, that is to say as psycho-physical integrity and assessed on the basis of certain biological parameters, to a modern understanding of health based on a strictly personalistic meaning [12]. The latter would have as parameters not only the biological ones currently in use but also the experience of the person and, of consequences, dynamic and relational aspects of the context in that particular individual is to live.

The new meaning of health is also supported by normative sources: the Constitution of the World Health Organization (WHO) defines health as «a state of complete physical, mental and social well-being, and not only absence of disease or infirmity». This definition provides an all-round picture of health which is composed of two elements: one negative understood as absence of disease and one positive integrated by a complete state of well-being [13].

In the light of this it emerges that the state of complete physical, mental and social well-being belongs to the world of desire and not to reality, In addition, if a subjective notion of health is adopted, every form of empowerment must be qualified not only as lawful but also as a genuine right forming part of the evolution of mankind. Consequently, if the objective becomes the pursuit of the desired state of well-being, then an indiscriminate use of the new technologies that technical and scientific evolution makes available to the individual will be admissible. At the same time, however, a concept of health totally detached from a previous state of pathology or in any case not characterized by a preventive or curative purpose is served by the limited financial resources that a State can make available to an individual.

An attempt to delimit between enhancement and therapeutic treatment was made by the Science and Technology Options Assessment (STOA) which in the "Human Enhancement Study has tried to delimit the field between three different types of intervention:

1. The non strengthening, that is the treatment of a disease;

2. Therapeutic enhancement that is the treatment of a disease with effects exceeding the restoration of the initial state of health;

3. The non therapeutic strengthening that is the treatment aimed at improving a functioning already considered as "normal" [14].

Given the problems highlighted briefly, five different models of possible regulation have been proposed.

The first is that of prohibition, as opposed to this is that of total laissez-faire, the third is characterized by an approach that can be defined as moderate and proenhancement, the fourth from a restrictive approach and the last from the case by case approach model [15].

At present, the greatest moral and ethical problem is the impact that new technologies of empowerment could have on the nature and authenticity of man understood as identification of the individual with their own fundamental abilities and characteristics that could be altered by interventions which are not strictly therapeutic and medical [16].

3. Doping as human empowerment

Doping has been defined as one of seven types of enhancement (cosmetic surgery, prohibition of eugenics selection, smart drugs, deep brain strimulation, military enhancement and biological enhancement. Doping is therefore a strengthening technique whereby the physical and/or biological conditions of the athlete are artificially altered through the administration of substances and certain methods.

At a time when we are dealing with the problem of doping, we must remember, as has been said, that if every historical moment provides for the creation of its own sport at the same time, every epoch is inclined to create its own doping.

The very essence of doping appears to be closely linked to the results of medical and pharmacological research, whereas.

The assessment of the eligibility of substances suitable for enhancing an artificial performance depends on a strictly legal choice as well as anthropological, moral and social based on the definition of the model of man and opponent that you want to admit.

From an etymological point of view the word doping seems to derive from the term “dap” that was used in the Dutch colonies in Africa and that indicated a fortifying alcoholic drink that was taken by the warriors of the Zulu ethnic group to face the battle with the best possible personal performance.

A further origin of the noun doping seems to be “dope” that is a trade name of a liquid used by the pioneers of North America to be able to harden the leather already used to then obtain soles from shoes. For others, doping should come from the word “doop” which indicated an exciting drink that was used by hunters in the Hudson Basin to withstand the physical difficulties of the environment.

In doctrine and literature it has been argued that the most credited hypothesis of the word doping would be nothing more than a transcription in English of the word “dop” with which was indicated an exciting drink used by the Kafir tribe during the performance of ritual dances.

The date certain concerning the first appearance in the word doping is 1889 year in an English vocabulary, in the same year the term sees its introduction in the world of sport to indicate a mixture formed by opium, other narcotics and tobacco that is administered to racehorses in North American racecourses to reduce performance and then to control the results of races and the related money from illegal betting.

Despite the controversial origins of the etymology of the term, the greatest difficulty is in arriving at a definition of this word. The most problematic aspect is that the expression doping is suitable to indicate an extremely heterogeneous phenomenon.

In 1962, the Italian Sports Medicine Federation (FMSI) qualified the doping phenomenon as the intake of substances suitable to artificially increase the performance in the race of competitors thus affecting the moral and physical and mental integrity.

The Council of Europe considered doping the ingestion or use of non-biological substances of any nature or physiological substances by healthy individuals with the aim of artificially and unfairly improving its own advantage in anticipation of a competition.

3.1 Doping and law

The first bans on the use of substances capable of exceeding the natural limits [17] of the human body were banned only from 1920: from that date on, due to the progressive spectacularization of sports performance, be it single or collective. Only between the ‘40s and the ‘70s of the previous century was created an organism (AMA-WADA: Agence Mondiale Antidopage - World Anti-doping Agency) aimed at carrying out scientific research and controls to combat doping in the sports world.

The main objective of the AMA-WADA is to promote and coordinate worldwide the fight against doping in sport in all its forms (art.4) in order to support ethical principles for the practice of doping-free sport and to contribute to the protection of the health of athletes (Art. 4 co.2) [18].

Internationally protected and regulated core values are:

1. Support ethical principles for the practice of sport without doping;

2. To contribute to the protection of the health of athletes.

3. These are provisions contained within the Code Mondial Antidopage which is defined as mandatory by art. 43 of the Olympic Charter. This code was adopted for the first time in 2003 and entered into force the following year.

The main features of the World Anti-doping Programme are:

1. The same Code;

2. International Standards;

3. Good practice models and guidelines [19].

The intrinsic value that animates and pervades this document is the pursuit of human excellence through the perfection of natural talents that each subject possesses. It is a principle that has some declinations, such as: ethics, fair play and honesty, health, excellence in sports performance, fun and joy, teamwork, compliance with rules and laws, respect for oneself and the other participants, courage, group spirit and solidarity. The use of doping is contrary to all the principles mentioned above [20].

The same Code also contains a definition of doping: the violation of one or more of the rules of the Code among those contained in art. 2 from paragraph 1 to paragraph 1; art. 2 co.1 stresses that the presence of a prohibited substance, or of its metabolites or markers in the sample provided by a sportsman, is considered a violation of the anti-doping rules; the violation is independent of intention, the error, negligence or conscious use of the substance. There is therefore an objective responsibility of the athlete who must ensure that no substance among those prohibited is present within his body [21].

This objective responsibility of the athlete is mitigated if it is not relevant the existence of the prohibited substance but a quantity of it or if it can be demonstrated that a certain substance has been produced by the organism endogenously [22]. In such cases, the responsibility of the athlete appears to be subject to further investigation consisting in the exact determination of the prohibited substance or the determination that the substance was produced endogenously by the organism.

Finally, art. 4 co.4 contains a hypothesis of non-existence of responsibility if a specific authorization for the use of the prohibited substance is found: it is an authorisation for therapeutic purposes in favor of the athlete which has been issued in accordance with procedural rules contained in international standards.

3.2 Doping and sport ethics

The reflection of the practice of doping within sport [23, 24] has not only a legal but also an ethical aspect. When a definition of doping is approached, reference is made to regulatory requirements or an attempt is made to reach a clear and unambiguous definition.

The problem is that doping is not a theoretical and abstract concept but is closer to the definition of Greek pharmakon [25], ie poison and antidote, good and evil at the same time. Consequently, if we do not have a clear distinction for drugs, we cannot look for a legal framework to establish ex ante what doping is because the problem of doping in sport is the result of ethical and political influences [26].

The logical consequence of this is that the answers sought, be they philosophical, political, sociological, medical and legal, are qualified as mere rhetorical experiments insufficient to understand this practice. The understanding of the practice of doping depends, in fact, not only on the impossibility of adopting an objective and exhaustive definition but also on the circumstance under which it is a cultural construction in continuous mutation.

Ultimately, doping is defined as undecidable, that is, a concept whose definition is always under construction and training and whose meaning is increased on the basis of binary opposition: good or evil, admitted or forbidden, for example.

The beating heart of the problem is that doping is going beyond any limit that is placed: it becomes the tool to extend natural limits, to overcome human potential but also to go beyond the limits set by the rules that govern it. It is therefore clear that doping is essentially a cultural problem because it requires reflection and distinction between natural and artificial [27].

A further consideration is the distinction between two aspects of doping: the hemical and the ethical. The first refers to the personal point of view, the second concerns the values existing in society. The hemi-point of view makes athletes argue the need to take doping substances while the ethical perspective imposes as necessary the condemnation of doping. Part of the doctrine also argued that the regulation of doping in sport has become maniacal as if the aim was to seek and then find in sport forms of disease, of corruption, of ethical degeneration forgetting the neuralgic aspect of sport, that is, the playful dimension.

The latter is the great absent because very often sports competitions can be defined as "zero sum game": the victory is interpreted as a definitive and irreparable achievement by the winner. It is clear that it appears to be extremely contrasting with the pedagogical function of sport which qualifies sport as a confrontation between peers who are confronted to highlight their skills and to deserve a prize that derives not only from the value that has been but also by respecting the rules that govern that specific activity.

Also from an ethical and philosophical perspective, similarities between sport and doping have been found: Practicing sports involves exceeding a limit and provides a feeling of pleasure to people as exercise releases endorphins that cause a feeling of pleasure and are substances similar to morphine and opium.

By adhering to this reconstruction the same sport can be defined doping place that the first one meets all the requirements to determine the overcoming of human limits; to pursue this objective means are used, tools and practices needed to increase physical effectiveness. It therefore emerges that overcoming oneself is one of the peculiar characteristics of both sport and drugs in general [28].

In conclusion, it can be said that sport behaves like a form of doping and drugs for the following reasons:

1. It can lead to dependence and habituation in the masses which are reduced to mere consumers without consciousness;

2. It is a tool to strengthen and extend the body, implying an overcoming of the human not only in his physical but also psychic dimension [29].

4. Conclusions

The reflections expressed in the previous paragraphs have highlighted how the concept of doping and its discipline, regulation appears to be a cultural product and, consequently, just as social and cultural perception leads to a certain definition of a substance as a dopant.

At the same time, it has been stressed that it is necessary to curb the phenomenon of human empowerment implemented and implemented through the use of medicines or special techniques cannot be separated from an education aimed at making the true essence of values and mentality that permeates the world of sport.

One of the peculiar and difficult aspects of definition and solution concerns the situation of athletes who, due to an endocrine disease, possess a high concentration in the blood of anabolic hormones. In other words, they are women characterized by a masculine appearance with particular reference to muscle mass or athletes with peculiar genetic conditions that allow a higher supply of oxygen in the blood.

The cases that will be analyzed have as their main characteristic to relate with athletes who, like equal climatic and training conditions, they have in the abstract an objective advantage over others precisely because of their genetic constitution.

Precisely a particular pathology from which a particular individual is affected can turn into a positive aspect in a specific situation, namely, in the case of a species a sports competition.

If this is the premise, the question that animated the bio-ethical and bio-legal debate is whether it is possible to exclude legitimately from the competition the subject that should be in that situation.

This would protect the needs of justice in the broad sense, but it would bring with it problems of discrimination: a person suffering from a genetic disease would suffer unfavorable treatment precisely because of the effect that this disease determines. In this sense it should be clarified that no subject can be recognized the merit to be born with a certain DNA profile or a certain genetic profile suitable to make it "more powerful" than others [30, 31].

The "naturally" enhanced subjects refer to the epithet that was attributed to Achilles, that is, the fastest Achilles. This expression indicates that the Achaean hero had in his point of weakness, namely the heel, his point of strength and, in the opinion of the writer, Achilles can become the paradigmatic example of naturally enhanced subjects due to a genetic mutation that characterizes them. As Achilles found his weak and strong point in the heel, athletes who possess a genetic characteristic that many times results in pathology their most important aspect compared to others during the course of a sports competition. The comparison just made could also flow into a pedagogical perspective, Educational and sports inviting to reflect how the limit of each individual subject can be transformed into the point of strength and how it is crucial to exploit their weaknesses to make them become virtues.

By adopting a strictly legal view it is stated that the objective responsibility of the athlete for doping concerns the introduction of one of the substances defined as prohibited within the body of the athlete as it is the duty of the latter to use so that no entry is made, penetration of one of the prohibited substances into his body.

In the present case, it is a biological, genetic, peculiar characteristic of that particular subject that does not derive from the intake of particular substances or from the penetration of those substances within his organism. On the contrary, its genetic peculiarity is the source of the empowerment itself.

If that is the legal response, then bioethics is faced with two alternatives. The first is the exclusion of the athlete enhanced because of his pathology in order to establish competitions reserved for subjects with the same characteristics.

The second, on the other hand, proposes the possibility of allowing other athletes to use biotechnology to make genetic endowment homogeneous. This is a very problematic solution because it is in contrast with the principles that inform sports practice to the point of shifting the focus from the importance of commitment, training to the creation and establishment of laboratories capable of studying, analyze and then administer biotechnological and genetic substances and treatments in order to make the performance of athletes homogeneous.

In addition to the risk, should it be decided to follow this second option, is to provide an almost unlimited power to the scientific technical power as the only objective that animates the life of men is to become more and more enhanced than the other. In this way the danger is that the other becomes more and more a model to reach and in which we see only the aspects of empowerment that he possesses when we relate to ourselves.

This is a dangerous mechanism because it risks leading to the qualification of empowerment as a right of absolute freedom [32]. But even the latter could be problematic as it is suitable to conceal the risk of a possible exploitation [33] by technology, science, biopolitics and bioeconomy excluding any judgment of lawfulness [34–36].

Human empowerment is a subject that turns out to be extremely complex mainly because of its transversality and with respect to which it is necessary to adopt an attitude of study and analysis that draws from different perspectives declining their convictions in the light the different fields of possible application [37]. In other words there is no definitive and conclusive answer as it is impossible to adopt a position of total acceptance or totally uncritical refusal [38].

The method of approaching the problem is to reflect on the circumstance that man inevitably tends to the process of improvement and that, at the same time, the advances that technical evolution [39]. The European Commission has made it possible to achieve these objectives by defining them as new instruments but at the same time considered essential for achieving the objectives.

At the same time it is necessary to reflect on the goal of improvement, that is, which objectives are pursued and relate them to one's own experience [40] in addition to past, present and future society, always remembering the existence of a limit [41]. The latter indicates the characterizing aspect of the human being and the concept of humanity beyond which it is not possible to continue to use the concept of the human being [42, 43].

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Chapter 18

The Use of Exergames in Motor Education Processes for School-Aged Children: A Systematic Review and Epistemic Diagnosis

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Abstract

This study aimed to diagnose the current state of knowledge about the use of exergames in the motor education processes of school-aged children. We conducted a systematic review following the PRISMA recommendations. Web of Science, MedLine (via PubMed), ScienceDirect, and Scopus databases were searched in December 2020 with the terms "exergames", "motor education", and "children". We used the Jadad scale and the Systematization for Research Approaches in Sports Sciences instrument to evaluate the surveyed material. Seventeen articles met the inclusion criteria. We observed that: 1) the use of exergames by children can increase the motor skills of locomotion and control of objects, in addition to the levels of physical fitness, but the magnitude and duration of these increments remain inconclusive; 2) the articles exhibited theoretical and methodological weaknesses; 3) empirical-experimental investigations centered on intervention studies are hegemonic; 4) the theories of Sports Training, Didactics, and Human Movement underlie the studies, referring to an interdisciplinary crossing between Sport Psychology, Sport Pedagogy, Sport and Performance, and Sport and Health; 4) researches with alternative designs are necessary; 5) we recommend to approach this issue according to other perspectives, such as Biomechanics applied to Sport, Sports Medicine, Sociology of Sport, and Philosophy of Sport.

Keywords: child, motor skills, video games, schools, physical education

1. Introduction

The development of fundamental motor skills is an essential prerequisite for the competent performance of several types of physical activities [1]. Evidence shows that the triggering of this process in a systematic way since childhood affects both the practice of efficient sports performances in youth and the adoption of active lifestyles in adulthood [2–4].

In theoretical terms, fundamental motor skills can be subdivided into two broad classifying categories: locomotion skills and object control skills [5]. Locomotion skills include running, jumping, marching, climbing, riding, swimming, skating, among others, while object control skills refer to transporting, intercepting, wielding, designing, and controlling implements in actions related to receptions, throws, bouncing, conduction with feet and hitting [6]. The development of physical fitness regarding balance, coordination, agility, speed, and reaction time contributes positively to the increase of these two types of skills, as they enable the body to perform them properly [7, 8].

Overall, the first manifestations of fundamental motor skills occur after the child stabilizes the bipedal posture and starts to walk alone. Participation in games is relevant to, even at random, have the opportunity to perform body skills in the challenges inherent to these activities. The continued exposure to such stimuli contributes, over time, to acquire increasing levels of motor proficiency [9, 10].

On the other hand, any obstructions in the course of motor evolution even in the first years of life can cause delays with an extension until puberty if they are not properly reversed in a timely manner. If they remain unchanged for long periods, deficits in locomotion and object control skills affect the behavioral and psychic domains. This can decrease the interest in the practice of physical activities, perturb self-esteem, and cause distortions in body image [11].

School Physical Education programs represent a strategic possibility of facing this scenario if they are given diligently with regard to content planning and execution. Likewise, the provision of public leisure policies focused on combating sedentary lifestyles among young people should be seen as measures of equal significance [12, 13]. Although such actions are essential, public health indicators attest that, by themselves, they are limited to promote the increase of basic motor skills of infants and adolescents related to the actions of running, jumping, swimming, throwing, launching, among others, according to minimally reasonable standards of technical effectiveness [14, 15]. In a 13-year longitudinal study, Hardy et al. [16] investigated the development levels of fundamental motor skills in children and adolescents. In the end, they observed that less than 50% exhibited basic motor skills at satisfactory levels. Similarly, Brian et al. [17] found in a recent study carried out in the United States of America (USA) that approximately 77% of the analyzed sample of infants and pubescents were in a situation of delayed motor development [17].

The cogency of this context and the urgency to face it has led academics and professionals in the area of human motricity to research and propose original solutions during the last two decades. One of them refers to the use of active video games (exergames) in children's motor education processes [18–20]. Supporters of this idea state that exergames can be helpful tools for teaching, acquiring, and improving the motor skills of children and adolescents of different ages, sex, biological maturity, and clinical conditions. The undeniable popularity of these types of games among young people, mainly as a residential entertainment option, is the main justification to support such a suggestion. Conceptually, exergames are digital games that require movement of the body as a whole, through devices that convert the individual's real movements to the virtual environment. This allows them to practice simulated sports, fitness exercises, and/or other playful and interactive physical activities. Unlike conventional video games, exergames require physical effort [18–20].

The innovative character of this approach not only ratifies the creativity of its proponents but also demonstrates the commitment to try to equate and solve the problem at hand. However, as it is a recent issue, it is legitimate to raise the hypothesis that studies related to the theme are still in an early stage. Thus, identifying the characteristics of the exergames as to the criteria for demarcating objects, data treatment techniques, sample compositions, and the applicability of the results is a necessary task both to have a broader view of their theoretical-methodological profiles and for the emission of epistemic diagnoses/prognoses. Therefore, the objective of this study was twofold: 1) to identify, through a systematic review, the ways of using exergames in the processes of motor education of school-age children; 2) to diagnose the epistemic state of this use in the context of Sport Sciences.

2. Method

This systematic review was drafted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations [21].

2.1 Search strategy

A search was made without time or language filters in December 2020 in the Web of Science, MedLine (via PubMed), ScienceDirect, and Scopus databases. We used the keywords "exergames", "motor education", and "children". The search phrase was obtained using the Boolean operators OR (between the synonyms) and AND (between the descriptors). Two independent evaluators performed the search. Any disagreements were solved by a consensus meeting or decided by a supervisor.

2.2 Inclusion and exclusion criteria

We included peer-reviewed articles that investigated the use of exergames on the acquisition and development of at least one type of locomotor skill or object control both in Physical Education classes and in non-formal educational contexts (clubs, gyms, residences) in school-aged individuals. The exclusion criteria consisted of: (1) opinion articles, reviews, case reports, annals of congresses, books, book chapters, theses, dissertations, and technical reports; (2) games unsuitable for residential or educational use, as well as computer games; (3) research related to the rehabilitation of special groups.

2.3 Data collection process

Data extracted from included studies comprised the following analytical matrices: (1) author, year of publication, and country of the study; (2) purpose of the study; (3) descriptive characteristics of the participants; (4) methodological aspects; (5) results.

2.4 Methodological quality evaluation and epistemological diagnosis

The methodological quality of the studies was evaluated by the Jadad scale [22], which consists of the punctuation of the scores from 11 domains, namely: 1a) the study was reported as randomized; 1b) the randomization was properly performed; 2a) the study was a double-blind trial; 2b) the blinding was properly performed; 3) the sample loss was described. If items 1a, 2a, and 3 were performed, the study got 1 point per item. If items 1b and 2b were observed, the study received another point per item. In the case of items 1b and 2b were not met, the study lost 1 point concerning items 1a and 2a, respectively. On this scale, the scores ranged from 0 to 5. Studies with scores equal to or lower than 3 points were considered at a high risk of bias. Two independent and qualified researchers applied this instrument. A third author was consulted in case of any divergence.

The epistemological evaluation of the surveyed material occurred through the Systematization for Research Approaches in Sports Sciences (SRASS) instrument [23]. The SRASS aims to determine the epistemic approaches of studies regarding their guiding paradigms (empirical-experimental paradigm; critical-dialectic paradigm; hermeneutic-phenomenological paradigm); nature of the study (intervention study; cross-sectional study; case study; laboratory study); support theories (theories of human movement; game theories; theories of sports training; theories of didactics applied to sport) and subareas of linkage to Sport Sciences (Sports Medicine; Biomechanics applied to Sport; Sport Psychology; Sport Pedagogy); Sociology of Sport; History of Sport; Philosophy of Sport; Sport and Health; Sport for Special Groups; Sport and Media; Sport of Participation) [23, 24].

3. Results

In total, 120 studies were found following the proposed research methodology (Web of Science = 12; MedLine via PubMed = 17; ScienceDirect = 71; Scopus = 20). After using the selection criteria, 17 studies were included (**Figure 1**).

Table 1 shows the descriptive characteristics of the studies included in the present review. The year of publication of the studies ranged from 2012 to 2020. The sample size in each group (intervention and control) ranged from 5 to 557 participants. The samples included both girls and boys, except the study by EbrahimiSani et al. [26] that included only girls. The total number of participants was 2,631 (1,338 in the intervention group and 1,293 in the control group). The age of the participants ranged from 4 to 14 years old.

n: sample size; IG: intervention group; CG: control group; ♀: female; ♂: male; DCD: developmental coordination disorder.

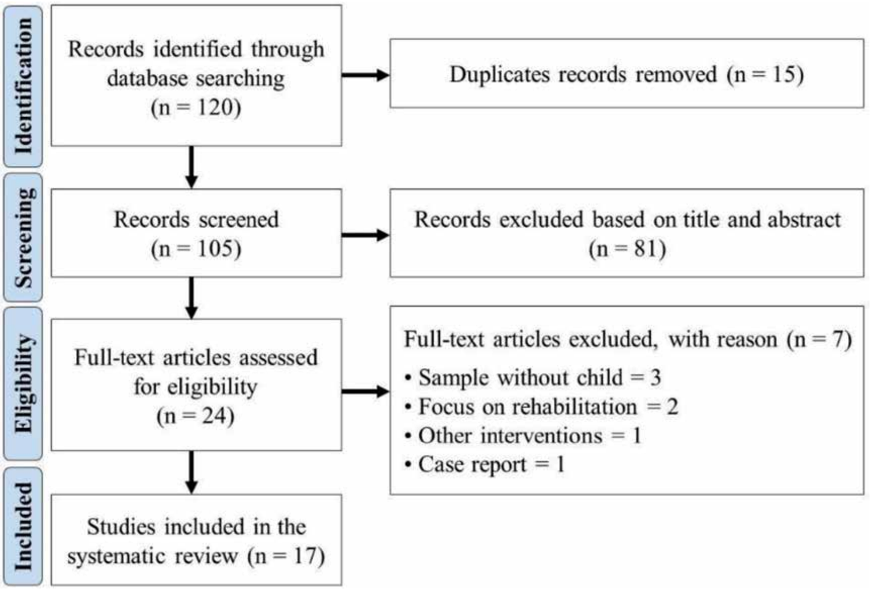

Figure 1.
Flow chart of the included studies.

Author and year	Country	Groups (n)	Age (years)	Sex	Participants' profile
Barnett et al., 2015 [25]	Australia	95	4 to 8 6.2 ± 0.95	♀♂	Neurotypical
EbrahimiSani et al., 2020 [26]	Iran	IG: 20 CG: 20	7 to 10 8.9 ± 1.07	♀	DCD
Edwards et al., 2016 [27]	Australia	IG: 11 CG: 19	6 to 10	♀♂	GI: autism GC: neurotypical
Gao et al., 2018 [28]	USA	IG: 20 CG: 36	4.45 ± 0.46	♀♂	Neurotypical
Johnson et al., 2015 [29]	Australia	IG: 15 CG: 14	6 to 10 7.9 ± 1.5	♀♂	Neurotypical
Lwin and Malik, 2012 [30]	Singapore	IG: 557 CG: 555	10 to 12	♀♂	Neurotypical
McGann et al., 2019 [20]	Ireland	IG: 20 CG: 20	5 to 7	♀♂	Neurotypical
Medeiros et al., 2018 [31]	Brazil	IG: 6 CG: 5	8 to 10 9.09 ± 0.75	♀♂	DCD
Pope et al., 2015 [32]	USA	G1: 63 G2: 95 G3: 47	8 to 14 11.17 ± 1.1	♀♂	G1: progressive children G2: stable children G3: regressive children
Quintas et al., 2020 [33]	Spain	IG: 226 CG: 191	10 to 12	♀♂	Neurotypical
Rhodes et al., 2017 [34]	Canada	IG: 39 CG: 34	10 to 14	♀♂	Neurotypical
Sheehan and Katz, 2013 [35]	Canada	IG: 21 CG1: 21 CG2: 19	9 to 10	♀♂	Neurotypical
Smits-Engelsman et al., 2017 [36]	South Africa	G1: 9 G2: 9	6 to 10	♀♂	G1: DCD (dyspraxia) G2: neurotypical
Smits-Engelsman et al., 2020 [37]	South Africa	G1: 33 G2: 28	6 to 12	♀♂	G1: DCD (dyspraxia) G2: neurotypical
Sun, 2012 [38]	USA	IG: 46 CG: 42	9 to 12	♀♂	Neurotypical
Ye et al., 2018 [39]	USA	IG: 135 CG: 115	7 to 9 8.25 ± 0.66	♀♂	Neurotypical
Vernadakis et al., 2015 [40]	Greece	IG: 22 CG1: 22 CG2: 22	6 to 7	♀♂	Neurotypical

Table 1.
Descriptive characteristics of the included studies.

Table 2 presents the methodological characteristics and the main results of the selected studies. The exergames used were Nintendo Wii, Xbox 360 Kinect, and PlayStation. The training frequency varied between 1 to 5 times per week, with a total of 8 to 60 minutes of intervention per week, for 2 to 36 weeks.

Study	Protocol	Volume	Evaluation	Results
Barnett et al. [25]	One hour after school Nintendo Wii® session	1×/week 60 min 6 weeks	A1: TGMD-2 A2: PMSC	A2 ($p < 0.05$)
EbrahimiSani et al. [26]	IG: virtual reality with Xbox 360 Kinect games CG: no intervention	16 sessions 30 min 8 weeks	A1: hand rotation task A2: anticipatory action planning A3: rapid online control	A1 ($p < 0.05$, IG *vs*. CG)
Edwards et al. [27]	IG: Xbox 360 at home with specific mini-games (e.g., baseball, golf, tennis, table tennis, soccer, bowling, volleyball, and football) CG: Xbox 360 during school lunchtimes	IG: 3×/week 45–60 min 2 weeks CG: 1×/week 50 min 6 weeks	A1: TGMD-3 A2: PMSC	IG and CG without significant difference pre- and post-intervention
Gao et al. [28]	IG: exergaming (Wii or Xbox Kinect) Dance for Kids, Wii Nickelodeon Fit, Kinect Just Dance for Kids CG: no structured PA	8 weeks 20 min	A1: PSPCSA A2: TGMD-2 A3: ActiGraph GT9X Link accelerometers	A1 ($p < 0.05$, IG *vs*. CG)
Johnson et al. [29]	IG: Xbox Kinect games (Specific mini-games: baseball, golf, tennis, table tennis, soccer, bowling, volleyball, and football)	1×/week 50 min 6 weeks	A1: TGMD-3 A2: PMSC	A1 and A2: no significant difference
Lwin and Malik [30]	IG: PE lesson with Wii active video games (DDR, Wii tennis, and Wii boxing) CG: PE lesson without Wii	1×/week 8–10 min 6 weeks	A1: attitude scale A2: subjective norm scale A3: perceived behavioral control scale A4: intention scale A5: exercise behavior questionnaire	A1 ($p < 0.001$, IG *vs*. CG) A2 ($p < 0.05$, IG *vs*. CG) A5 Strenuous exercise ($p < 0.05$, IG *vs*. CG)
McGann et al. [20]	IG: Kinect® (Slide Ball, Hop Ball, Jump Ball, Skip Attack) CG: commercial exergames	1×/week 60 min 8 weeks	TGMD-2	$p < 0.001$, IG *vs*. CG
Medeiros et al. [31]	IG: XBOX-360 Kinect Sports 1 (soccer and athletics), Kinect Sports 2 (skiing, tennis, and shooting), Kinect adventure CG: no playing	2×/week 45 min 9 weeks	MABC-2	$p < 0.05$, IG *vs*. CG
Pope et al. [32]	6 DDR stations were set up each with 2 master dance pads connected to a PlayStation Gaming System	1×/week 30 min 18 weeks	Decisional balance	$p < 0.05$, G1, G2, and G3 post-intervention

Study	Protocol	Volume	Evaluation	Results
Quintas et al. [33]	IG: Just Dance Now + MDA CG: danced by imitating the teacher live	12 sessions 9 hours 4 weeks	A1: Motivation A2: Dispositional flow A3: Basic psychological needs A4: Rhythmic Motor Skill A5: Commitment to and behavior toward learning	A1, A2, A3, A4, and A5: no significant difference after intervention
Rhodes et al. [34]	IG: exergame bike in Sony Playstation3® CG: stationary bike in front of a TV	3×/week 30 min 12 weeks	Weekly bike use recorded in a logbook	$p < 0.05$, IG *vs*. CG
Sheehan and Katz [35]	IG: iDance™ + Wii Fit™ Plus + XR-Board™ + Lightspace™ Play Wall CG1: PE class geared toward ABC improvement CG2: typical PE curriculum class	4–5×/week 34 min 6 weeks	Balance tests on the HUR BT4™ platform	$p < 0.05$, IG and CG1
Smits-Engelsman et al. [36]	G1 and G2: active Nintendo Wii Fit gaming on the balance board	2×/week 20 min 5 weeks	A1: FSM A2: 10 × 5 meter sprint A3: 10 × 5 meter slalom A4: Balance and running speed & agility subtests of the BOT2	A1, A2, and A3 ($p < 0.05$, IG and CG) A4 ($p < 0.05$, G1 *vs*. G2)
Smits-Engelsman et al. [37]	Wii ski game	2×/week 30 min 10 weeks	MABC-2	$p < 0.05$, G2 *vs*. G1
Sun [38]	IG: exergaming (Cateye Gamebikes, Xavix Boxing, 3-kick, Dog Fight Flight simulators, Nintendo Wiis, DDR, Gamercize activities, and XrBoards) CG: traditional fitness-education unit	2×/week 30 min 4 weeks	A1: in-class PA level by RT3 accelerometers A2: situational interest scale A3: initial interest A4: situational interest change	A2 ($p < 0.05$, IG *vs*. CG)
Ye et al. [39]	IG: exergaming (Kinect Ultimate Sports, Just Dance, Wii Sports, and Wii Fit) and PE program CG: only PE	2×/week 25 min 36 weeks	A1: Motor skill competence (MSC) A2: Health-related fitness (HRF)	A2 ($p < 0.05$ IG *vs*. CG)

Study	Protocol	Volume	Evaluation	Results
Vernadakis et al. [40]	IG: Xbox Kinect games CG1: typical FMS training program CG2: no structured training program	2×/week 30 min 8 weeks	A1: TGMD-2 A2: PA enjoyment scale	A1 ($p < 0.05$, IG and CG1 *vs*. CG2) A2 ($p < 0.05$, IG *vs*. CG1 and CG2)

IG: intervention group; CG: control group; A: assessment; DDR: Dance Dance Revolution; TGMD-2: Test of Gross Motor Development-2nd Edition; TGMD-3: Test of Gross Motor Development-3; MABC-2: Movement Assessment Battery for Children-Second Edition; PE: Physical Education; PA: physical activity; ABC: agility, balance, and coordination; FSM: Functional Strength Measure; BOT2: Bruininks Oseretsky test of motor proficiency 2; MDA: Mechanics-Dynamics-Esthetics; PSPCSA: Pictorial Scale of Perceived Competence and Social Acceptance; PMSC: Pictorial Scale of Perceived Movement Skill Competence; FMS: fundamental motor skills.

Table 2.
Methodological and outcomes data extracted from the studies.

Studies	1a	1b	2a	2b	3	Score
Medeiros et al. [31]	1	1	1	1	1	5
Rhodes et al. [34]	1	1	1	1	1	5
EbrahimiSani et al. [26]	1	1	1	−1	1	3
Vernadakis et al. [40]	1	1	0	0	0	2
Barnett et al. [25]	1	−1	0	0	1	1
Gao et al. [28]	0	0	0	0	1	1
McGann et al. [20]	1	−1	0	0	1	1
Quintas et al. [33]	0	0	0	0	1	1
Sheehan and Katz [35]	1	−1	0	0	1	1
Smits-Engelsman et al. [36]	0	0	1	−1	1	1
Smits-Engelsman et al. [37]	0	0	0	0	1	1
Ye et al. [39]	0	0	0	0	1	1
Johnson et al. [29]	1	−1	1	−1	0	0
Lwin and Malik [30]	0	0	0	0	0	0
Pope et al. [32]	0	0	0	0	0	0
Edwards et al. [27]	1	−1	0	0	0	0
Sun [38]	0	0	0	0	0	0

1a: randomized study; 1b: adequate randomization; 2a: double-blind study; 2b: proper blinding; 3: description of the sample loss.

Table 3.
Methodological quality evaluation through the Jadad scale.

The methodological quality evaluation is shown in **Table 3**. Only two studies [31, 34] presented a low risk of bias.

Table 4 shows the epistemological characteristics of the studies according to the STRASS criteria.

Study	Paradigm	Nature of the study	Theoretical bases of support	Linking sub-areas
Barnett et al. [25]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology
EbrahimiSani et al. [26]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology
Edwards et al. [27]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology
Gao et al. [28]	Empirical-experimental	Intervention study	Theories of Human Movement/Theories of Sports Training	Sport Psychology/Sport and Health
Johnson et al. [29]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology
Lwin and Malik [30]	Empirical-experimental	Intervention study	Theories of Human Movement/Theories of Sports Training	Sport Psychology/Sport and Health
McGann et al. [20]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology
Medeiros et al. [31]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology
Pope et al. [32]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology
Quintas et al. [33]	Empirical-experimental	Intervention study	Theories of Human Movement/ Theories of Didactics applied to Sport	Sport Psychology/Sport Pedagogy
Rhodes et al. [34]	Empirical-experimental	Intervention study	Theories of Human Movement/Theories of Sports Training	Sport Psychology/Sport and Health
Sheehan and Katz [35]	Empirical-experimental	Intervention study	Theories of Sports Training/ Theories of Didactics applied to Sport	Sport Pedagogy/Sport and Performance
Smits-Engelsman et al. [36]	Empirical-experimental	Intervention study	Theories of Sports Training	Sport and Performance
Smits-Engelsman et al. [37]	Empirical-experimental	Intervention study	Theories of Human Movement/Theories of Sports Training	Sport and Performance
Sun [38]	Empirical-experimental	Intervention study	Theories of Human Movement/ Theories of Sports Training/ Theories of Didactics applied to Sport	Sport and Health/ Sport Psychology/Sport Pedagogy
Ye et al. [39]	Empirical-experimental	Intervention study	Theories of Human Movement/Theories of Sports Training	Sport Psychology/Sport and Health
Vernadakis et al. [40]	Empirical-experimental	Intervention study	Theories of Human Movement	Sport Psychology

Table 4.
Epistemological characteristics of the studies.

4. Discussion

This study aimed to identify, through a systematic review, the ways of using exergames in the motor education processes of school-aged children and to diagnose the epistemic state of this use in the context of Sport Sciences. Technically, exergames gather the main dimensions of virtual realities: interaction, involvement, and immersion. The interaction is related to the environment's ability to respond to user actions interactively through devices. Some devices can naturally capture users' movements. The involvement is the ability to maintain the user's attention, seeking to explore their different senses, keeping the user attracted and motivated to remain in the environment. Immersion refers to the ability to make the user feel present in the simulated environment, seeking to distance them from the real environment [18].

A dominant feature of the investigations raised on exergames in our study concerns the fact that most of them focused on samples of neurotypical infants. Neurotypical individuals are those who do not fit the autism spectrum, exhibiting linguistic, sensorimotor, affective, and cognitive aspects consistent with those expected for their chronological age [41]. Eleven of the included studies [20, 25, 28–30, 33–35, 38–40] exemplify this trend. Conversely, four included studies [26, 31, 36, 37] analyzed the motor behaviors of children with developmental coordination disorder. The other two studies included, as target subjects, groups of neurotypical and autistic individuals [27] and young people in different stages of motor performance [32].

In summary, it is noted that the dominant neurological characteristic of the investigated subjects refers to neurotypical people, that is, situated within frames considered normal. Contrariwise, neurodivergent or neuroatypical analyzes are in the minority. Moreover, all authors focused on sample groups of infants of both sexes, except EbrahimiSani et al. [26], who prioritized only girls. It is concluded then, in this regard, that the investigations do not privilege the masculine gender over the feminine and vice versa. Still with respect to the sample groups, it is reiterated that the samples were heterogeneous in terms of the number of individuals analyzed, chronological ages, and levels of biological maturation.

Another demographic item to be highlighted is the fact that the investigations are distributed by teams of researchers located in different countries. This means that the theme of the effects of exergames on the acquisition and development of motor skills of schoolchildren has a global connotation.

In terms of the methodological characteristics of the investigations, despite the different training volumes and motor stimuli applied, in almost all studies some type of significant result was obtained from the intervention groups when compared to the control groups. At first, this means that exergames may have positive effects on the gross motor skills and physical fitness levels of children with different levels of training. Only one study [33] showed no change in any variable. However, such gains should be viewed with caution, as it is not possible to confirm whether they will continue, and in what proportion, as the infant's biological maturation progresses and the training status changes.

This diagnosis is reinforced when it is observed that, among the 17 selected studies, only two [31, 34] were considered to be of high theoretical and methodological quality. Hence, they correspond to those of greater scientific credibility. In compensation, 15 investigations received a rating of three or less on the Jadad scale [22], which denotes compromises in their quality in terms of scientificity. Thus, they are research with coherence, consistency, objectivity, and control of subjectivity subject to criticism. As a result, the verisimilitude of the conclusions they announce must be interpreted with caution [42].

To paraphrase Miller [43], situations of this nature are relatively usual when a given object of study is still recent, in the sense that the scientific community to address it is still in the early stages of theoretical problematization. Consequently, the demarcations of the object have little depth, as well as the investigative horizons considered more pertinent in the medium and long terms.

Regarding the epistemological profile of the studies surveyed, it can be seen that, in full, all consisted of empirical-experimental intervention studies. Research with this bias has, as a guiding axis, the exposure of individuals to certain stimuli to verify their random impacts on one or more pre-established variables. In this type of conception, the researcher pre-understands that certain factors are hypothetically capable of engendering transformations in structural elements of the object. In the case of the present study, it is reasonable to conclude that researchers in exergames assume that such a class of games is capable of influencing the biopsychic construction of the motor skills of school-aged individuals. Hence the need for them to seek reliable evidence on such a process [24, 42].

The conceptual basis adopted to support the selected investigations refers almost exclusively to the Theories of Human Movement with an emphasis on Sport Psychology of a behavioral nature. However, it was possible to identify, in some of them, the existence of interfaces with the areas of Sport Pedagogy, Sport and Performance, and Sport and Health. Mediating this junction are the theories of Sports Training and Didactics. As a complement, we reiterate that no study mentioned Game Theories, which are among the classic bodies of knowledge of Physical Education and Sport Sciences.

The previous observation shows two contexts that are interconnected. The first goes back to the detection that, despite behavioral Sport Psychology being the Sports Science sub-area to endorse most of the inventoried works, it is possible to perceive the search for an incipient interdisciplinary dialog with the other mentioned theoretical fields. On the other hand, and this is the second consideration, Sports Training, and Didactics, under the aegis of Sport Pedagogy, Sport and Health, and Sport and Performance, constitute disciplines that go back to the structuring nucleus originating from Physical Education and Sports Science [24]. Therefore, it can be seen that, given the emergence of the relationship between exergames and the development of motor skills in childhood, given that it is a relatively recent object of study, a return to the knowledge bases that support the epistemic tradition of Physical Education and Sport Sciences is outlined. In terms of Theory of Knowledge, attitudes like these are consistent with the notion called Fundationalism, which alludes to the search for theoretical support for new ideas in knowledge that history has endorsed and endorse as legitimate in the flow of time [44].

The present study has some limitations. The first concerns the selection of articles from four electronic databases. Although the investigated databases catalog a vast number of scientific journals worldwide, some articles published in other journals that address this issue may not have been found. Studies from a larger number of search engines could enrich the analysis and discussions.

5. Conclusions

The present study allows the announcement of some conclusions. Effectively, the use of exergames by school-aged children can promote an increase in motor skills both in locomotion and in object control. Their physical fitness levels are also capable of improving. However, the magnitude and duration of these increments remain inconclusive.

In epistemological terms, the state of knowledge of the productions related to the theme is in an embryonic state. Furthermore, the quality of the articles exhibits theoretical and methodological weaknesses that must be overcome. Investigations of an empirical-experimental nature focused on intervention studies are hegemonic. At the conceptual level, the theories of Sports Training, Didactics, and Human Movement have been chosen to provide the theoretical foundation, referring to the existence of an interdisciplinary intersection, in the field of Sport Sciences, between Sport Psychology, Sport Pedagogy, Sport and Performance, and Sport and Health.

Based on this diagnosis, it is urgent to affirm that, for example, research that opts for alternative methodological designs is still necessary, such as case reports, cross-sectional studies, longitudinal studies, and even conceptual essays. In the case of Sports Science sub-areas, it is necessary to approach the subject according to other perspectives. As an option, we suggest Biomechanics applied to Sport, Sports Medicine, Sport Sociology, and Sport Philosophy.

Conflict of interest

The authors declare no conflict of interest.

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Chapter 19

Selected Aspects of Sports: Recreational Activity of German School Students

Zygmunt Sawicki

Abstract

This work focuses on empirical research regarding the sports-recreational activities of school students living in the Alpine region of Germany. The main objective of the work is to examine the conditions of participation in sports activities depending on such criteria as: forms, intensity, motives, manners, places and possibilities for practicing sports, including the gender of the participants and their environmental conditions (large city, small town). 387 persons at the age of 18 ($M = 18.48 \pm 0.31$ years) from technical colleges and high schools in Bavaria were surveyed. The following research tools were used in the study: - a scale of attitudes aimed at examining the motives for undertaking sports-recreational activity by the examined school students, - a questionnaire regarding attitudes and behavior towards free time sports-recreational activity. The collected material was subjected to mathematical and statistical analysis using the ROC method (Receiver Operating Characteristic). Own research has shown a high level of sport-recreational activity related mainly to such aspects as the frequency of practicing sports, the number of sports disciplines practiced and different places for practicing sports.

Keywords: sports-recreational activity, school students, Alpine region, Bavaria, Germany

1. Introduction

Sports-recreational activity plays a large role in the life of modern humans. It is directly related to leisure time, the rational use and management of which demands an appropriate level of not only required skills but also awareness. Nowadays, the dynamically growing popularity of passive leisure behaviors can be observed, especially among the young generation of highly developed countries, which in excessive numbers, may cause various psychophysical development dysfunctions in children and adolescents. In connection with such tendencies, it is necessary to permanently emphasize the importance of educational activities, thanks to which it is possible to encourage young individuals to take up active forms of free time activity. Sports-recreational activity, due to the wide range of its forms, is an important component of well-organized leisure time spent by young people, while sports and recreational behavior can be analyzed in the context of psychophysical development, personality, regeneration of vitality, contact with nature, active rest, relaxation, etc. The most important entities that can have significant impact on the level of physical activity of children and adolescents include, first of all, family, school, peer groups, as well as educational organizations, sports-recreational associations, clubs and the media. A special role in the area of physical activity encouragement falls on the family, where a pro rational development of free time activity in children who are not yet subject to the obligation of school education first occurs. A different but equally important place related to education of physical activity among students is school and especially physical education, which in its assumption, in addition to physical education classes, prepares young people for independent and systematic physical activity in their free time. This process consists primarily in shaping appropriate attitudes, habits and physical and fitness skills conditioning participation in physical culture, awareness of the broad health benefits of systematic physical activity, as well as equipping the youth with the ability to use sport and recreational opportunities offered at their place of residence. Recognition of these aspects can be very helpful not only in determining the general level of physical activity of adolescents but it can also be a guide to better plan and organize physical recreation of young people.

In the German-language literature, the term sports-recreational activity is associated with practicing sports in one's free time (the German: *Freizeitsport*). Unlike competitive and professional sports, low-level sports are targeted at people representing different age groups, who see the possibility of achieving primarily health-related goals in this activity [1]. Friedrich Ludwig Jahn was a pioneer of the free time sports movement called *Turnerism*. In 1811, at Turner square in Hasenheide near Berlin, he set about promoting gymnastics and motor games initially among schoolchildren and later representatives of the working class. In the course of further history, the typically gymnastic nature of motor activity ("the German model") was influenced by the so-called "English model" of sport based on the rules of sports competition and the pursuit of records. According to Dieckert [2] at the turn of the 19th and 20th century, two separate systems were in operation: gymnastics (*Turnerism*) for everyone, and sport - for those who preferred to obtain top sports results via ruthless rivalry. At present, the boundary between these systems is blurred and leisure sport in Germany includes both gymnastics and games as well as other forms of mild-mannered sports competition. This confirms the choice of these forms of sport activity undertaken by German recreational and amateur athletes belonging to different age groups. Prohl and Scheid [3] define leisure sport as a form of activity not related to competitive sport, characterized by volunteering and satisfaction, having its own rules and being for all age groups. Within free time sports, they identify such forms as:

- alternative sport,
- health sport,
- compensational sport,
- mass sport,
- holiday sport,
- family sport,
- lifetime sport,
- recreational sport,

- fitness sport,
- adventure sport,
- national sport.

Participation in sports-recreational activities is dependent on numerous factors that Nahas et al. [4] call the determinants of this activity. They include:

- demographic factors (e.g. gender, age, education level, socio-economic status),
- biological factors (e.g. height, weight, physical body constitution, motor-sports aptitude),
- psychological and cognitive factors,
- behavioral skills and attributes,
- social and cultural factors,
- physical environment factors (e.g. sports performance opportunities, time of the year, environmental pollution, access to sports-recreational infrastructure),
- features of physical activity (e.g. exercise attractiveness, intensity, volume, frequency, duration of physical activity).

The most important elements of physical recreation include various content which in practice reflect the actual activity of human sport and recreation [5–7]. These include:

- recreational and motor games (e.g., Frisbee, bowling),
- individual sports (e.g. tennis, table tennis, squash, golf),
- team sports (e.g. football, volleyball, basketball),
- water sports (e.g. swimming, canoeing, sailing),
- winter sports (e.g. skiing, sledding, skating),
- marches, walks, runs, lowland and mountain hiking,
- cycling,
- gymnastics,
- preventive health exercises,
- other (e.g. strength-fitness exercises, horse-riding).

This work focuses on empirical research regarding the sports-recreational activities of school students living in the Alpine region of Germany. The main objective of the work is to examine the conditions of participation in sports activities depending on such criteria as: forms, intensity, motives, manners, places and possibilities for practicing sports, including the gender of the participants and their environmental conditions (large city, small town). The 18-year-old youth (387 people in total) were deliberately selected for the study, characterized by a relatively stable level of sports and sport-motor habits.

The following research questions were posed:

- What is the place of sports-recreational activity of school students from Germany compared to other free time activities?
- What are the motives for young people performing recreational sports?
- What is the frequency of performing recreational sports?
- In what places are sports performed?
- Which sports are most frequently performed by school students?
- How does the surveyed youth assess the possibilities for the performance of recreational sports at their place of residence?
- What are the predictions regarding the youths' sports performance after graduation?
- Do gender and environmental conditions of the studied youth diversify their participation in recreational sport?

The following research tools were used in the study:

- a scale of attitudes aimed at examining the motives for undertaking sports activity by the examined school students,
- a questionnaire regarding attitudes and behavior towards free time sports activity.

2. Selected aspects of sports: recreational activity of German school students

2.1 Material and methods

2.1.1 Participants

387 persons at the age of 18 ($M = 18.48 \pm 0.31$ years) from technical colleges and high schools in Bavaria were surveyed, included 91 boys and 97 girls from a large city (more than 1 million inhabitants) as well as 93 boys and 106 girls from a small town (less than 15,000 inhabitants). The research was personally carried out by the author of this work. The youth included in the study was selected in accordance with the rules of random sampling, based on random selection of school classes [8].

2.2 Research methods

In the diagnostic survey method, a questionnaire technique was used, thanks to which it was possible to obtain written responses from respondents to the questions.

Two research tools were used in the study on the sports-recreational activity of school students. The first of them is the so-called Sport Activity Motive Questionnaire [9], based on the scale of attitudes towards physical activity [10, 11]. The aim of this part of the study was to check the quality of motives of sports-recreation activity in the studied pupils. The questionnaire used in the study consisted of 24 questions. 6 groups containing motivational elements of sports activity were specified. These were: esthetics, health, relaxation, ascetic, social aspects and risk. Each group contained four specific questionnaires for each of them, to which the respondents after giving affirmative answers, identified themselves with a given motive or in the case of negative answers, the given motive was rejected.

The second method used in the study is the so-called Questionnaire of Attitudes and Behaviors Towards Sports Activity (own elaboration, based on Baur and Burrmann [12]). It consists of 6 parts:

- Forms of free time activity (social gatherings, listening to music, practicing sports, computer/Internet, reading, music, art).
- Frequency of practicing sport in free time (lack of practicing, rarely, e.g. 1–2 times a month, often, e.g. 1–2 times a week, very often, e.g. 3 or more times a week).
- Place of practicing sports (sports club, extracurricular school-activities, open areas, public sports facilities, fitness clubs).
- Possibilities for practicing sport at the place of residence (large, average, small).
- Sports disciplines practiced regularly (ranking list of sport disciplines).
- Declarations regarding sports performance after graduation (confirming, denying, no decision).

2.3 Statistical analysis

The collected material was subjected to mathematical and statistical analysis using the ROC method (Receiver Operating Characteristic). This method aimed at determining the significance of differences among variables: gender and environmental conditions of the studied youth, as well as determining the value of the relative possibility for participation of respondents in a given activity, their occurrence of a certain behavior or motive, etc. This was determined via the Odds Ratio (OR) [13]. Furthermore, the level of significance was set at $p < 0.05$.

2.4 Results

The significance of performing sports within the spectrum of other free time activities among German school students.

The aim of research was to present the most popular forms of free time activities among German school students. The place and importance of practicing sports in the context of other leisure activities was also taken into consideration.

The study results confirm (**Figure 1**) that the most important forms of utilizing free time among the studied German youth, regardless of gender or social origin, are meeting friends (82%), listening to music (81%) and practicing sports (66%).

Based on the results of the Receiver Operating Characteristic (ROC) statistical analysis presented in **Table 1**, it can be concluded that practicing sports is significantly more important for boys than girls ($p < 0.0001$), while the relative possibility to actually participate in this activity, expressed as the Odds Ratio (OR), is almost 1 ½ times greater in boys (OR = 1.42). Similar dependencies are related to computer activities which are much more popular among boys ($p < 0.0001$; OR = 1.59). The greater probability of watching television among the studied boys is also worth mentioning. Although there were no statistically significant differences in this category ($p = 0.0786$), the relative odds of actual participation in this activity is almost 1 ½ times greater in boys than girls (OR = 1.41). The studied girls prefer listening to music ($p = 0.0298$) more than their male colleagues, with the relative possibility of actual participation in this activity being almost twice as high as in the case of boys (OR = 1.96). Statistically significant differences in favor of the examined girls were found for such leisure activities as reading and music ($p < 0.0001$), and the actual participation in these activities determined by the OR values is 1 ½ times higher in the studied girls than in boys (reading: OR = 1.51; music activities: OR = 1.47).

The results of the Receiver Operating Characteristic (ROC) statistical analysis presented in **Table 2** indicate that both boys from large cities and small towns have a similar preference for free time activities, as shown by the absence of statistically significant differences as well as similar opportunities for actual participation in all diagnosed forms of leisure time activities (OR from 1.02 to 1.13). Similarly as in the case of the boys, the tested girls from both backgrounds (**Table 3**) also show similar

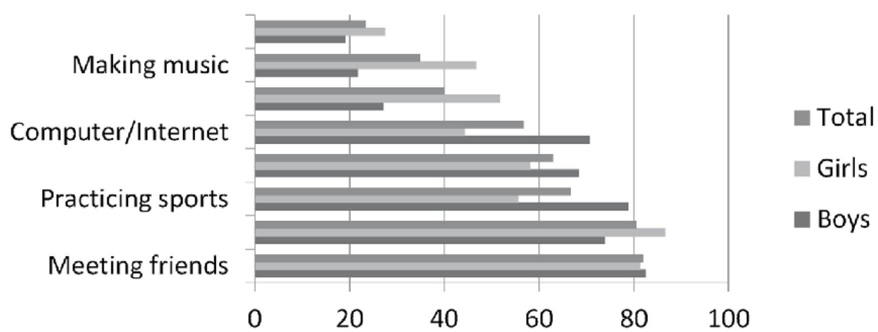

Figure 1.
Preferred leisure activities among German school students (in percentages).

Activity	AUC	SE	95% CI	*p*	OR
Meeting friends	0.5066	0.02941	0.4490 to 0.5643	0.82150	1.02
Listening to music	0.5639	0.02929	0.5065 to 0.6214	0.02983	1.96
Practicing sports	0.6157	0.02850	0.5598 to 0.6716	0.00000	1.42
TV	0.5518	0.02922	0.4945 to 0.6090	0.07865	1.18
Computer/Internet	0.6316	0.02833	0.5761 to 0.6871	0.00000	1.59
Reading	0.6228	0.02844	0.5670 to 0.6785	0.00000	1.51
Making music	0.6253	0.02837	0.5697 to 0.6809	0.00000	1.47
Doing handicrafts	0.5428	0.02925	0.4855 to 0.6002	0.14560	1.12

Table 1.
Preferred leisure activities among German school students (boys: n = 184; girls: n = 203).

Activity	AUC	SE	95% CI	*p*	OR
Meeting friends	0.5090	0.04267	0.4253 to 0.5926	0.83340	1.02
Listening to music	0.5189	0.04264	0.4353 to 0.6025	0.65780	1.05
Practicing sports	0.5077	0.04268	0.4241 to 0.5914	0.85610	1.08
TV	0.5034	0.04268	0.4198 to 0.5871	0.93610	1.02
Computer/Internet	0.5077	0.04267	0.4240 to 0.5913	0.85720	1.02
Reading	0.5138	0.04267	0.4302 to 0.5975	0.74610	1.11
Making music	0.5132	0.04267	0.4296 to 0.5969	0.75650	1.13
Doing handicrafts	0.5251	0.04261	0.4416 to 0.6086	0.55640	1.06

Table 2.
Preferred leisure activities among German male school students (large city: n = 91; small town: n = 93).

Activity	AUC	SE	95% CI	p	OR
Meeting friends	0.5114	0.04063	0.4318 to 0.5911	0.77870	1.03
Listening to music	0.5089	0.04063	0.4292 to 0.5886	0.82680	1.02
Practicing sports	0.5198	0.04062	0.4402 to 0.5994	0.62650	1.07
TV	0.5061	0.04066	0.4264 to 0.5858	0.88120	1.02
Computer/Internet	0.5197	0.04064	0.4400 to 0.5994	0.62820	1.09
Reading	0.5082	0.04066	0.4285 to 0.5879	0.84080	1.03
Making music	0.5159	0.04064	0.4362 to 0.5955	0.69660	1.07
Doing handicrafts	0.5174	0.04061	0.4377 to 0.5970	0.66940	1.05

Table 3.
Preferred leisure activities among German female school students (large city: n = 97; small town: n = 106).

preferences for free time activities, as indicated by $p > 0.05$ and the OR values (1.02–1.09).

In conclusion, due to sports activity performance, the studied boys are more physically active than their female peers who primarily prefer passive forms of free time activities such as listening to music, socializing or watching television, while the environmental conditions do not influence the preferences for selection of free time activities by the respondents.

3. Motives for undertaking sports-recreational activity of German school students

The study also included the motives of young people living in the alpine region for undertaking sports-recreational activities, taking their environmental and gender characteristics into account. The division of motives proposed by Steffgen et al. [9], which combines six elements: esthetics, health, relaxation, physical fitness, social aspects and risk, was used.

The results of the study presented in **Figure 2** show that the most important motives for performing recreational sport by German school students, regardless of gender or environmental conditions, are health, physical fitness and social aspects, understood as the willingness and the possibility for collective sports performance and human interaction.

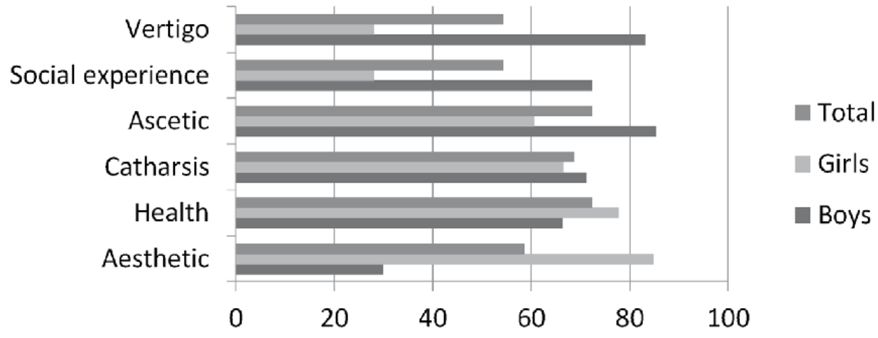

Figure 2.
Motives for undertaking sports-recreational activities of German school students (in percentages).

Motive	AUC	SE	95% CI	*p*	OR
Esthetic	0.7742	0.02474	0.7257 to 0.8227	0.00000	4.59
Health	0.5576	0.02930	0.5002 to 0.6151	0.05015	1.52
Catharsis	0.5235	0.02936	0.4659 to 0.5810	0.42520	1.07
Ascetic	0.6237	0.02834	0.5681 to 0.6792	0.00000	1.41
Social experience	0.5166	0.02939	0.4590 to 0.5742	0.57310	1.05
Vertigo	0.7754	0.02445	0.7277 to 0.8233	0.00000	2.96

Table 4.
Motives for undertaking sports-recreational activities of German school students (boys: n = 184; girls: n = 203).

Motive	AUC	SE	95% CI	*p*	OR
Esthetic	0.5131	0.04266	0.4294 to 0.5967	0.75970	1.04
Health	0.5181	0.04265	0.4345 to 0.6017	0.67190	1.06
Catharsis	0.5240	0.04262	0.4405 to 0.6076	0.57320	1.07
Ascetic	0.5038	0.04268	0.4202 to 0.5875	0.92830	1.01
Social experience	0.5133	0.04266	0.4297 to 0.5969	0.75550	1.04
Vertigo	0.5145	0.04265	0.4309 to 0.5981	0.73450	1.04

Table 5.
Motives for undertaking sports-recreational activities of German male school students (large city: n = 91; small town: n = 93).

Health as one of the most important motives for athletic activity is dominantly preferred by the studied girls, which according to the OR = 1.52 value of the Receiver Operating Characteristic statistical analysis, declare this motive more than 1 ½ times more often than the studied boys (**Table 4**). Even more distinct differences in favor of the esthetic motive ($p < 0.0001$), occurring in girls more than 4 times more often than boys, are evidenced by the OR = 4.59. For the studied boys, physical fitness and risk were very important motives for undertaking sport. The results show that there are greatly significant differences in the dominance of these motives when considering gender of the studied youth. Physical fitness as a motive for sport is more prevalent in boys than girls ($p < 0.0001$, OR = 1.41) These differences are even greater when considering risk, which is 3 times more likely to motivate boys than girls ($p < 0.0001$, OR = 2.96) Another important motive for

Motive	AUC	SE	95% CI	*p*	OR
Esthetic	0.5117	0.04068	0.4320 to 0.5915	0.77320	1.17
Health	0.5050	0.04065	0.4253 to 0.5847	0.90290	1.01
Catharsis	0.5147	0.04063	0.4351 to 0.5944	0.71710	1.05
Ascetic	0.5175	0.04265	0.4378 to 0.5972	0.66680	1.09
Social experience	0.5089	0.04067	0.4291 to 0.5886	0.82770	1.06
Vertigo	0.5075	0.04067	0.4278 to 0.5873	0.85290	1.06

Table 6.
Motives for undertaking sports-recreational activities of German female school students (large city: n = 97; small town: n = 106).

sport activity turns out to be relaxation, by which $^2/_3$ of all the respondents were guided.

Based on the analysis of the statistical results of the Receiver Operating Characteristic (ROC) on the intensity of boys' (**Table 5**) and girls' (**Table 6**) motives from large cities and small towns, environmental conditions have no influence on the intensification of diagnosed motives for taking up sport activity among the respondents (no statistically significant differences and similar values of chance of occurrence of examined motives).

4. Frequency of practicing sports of German school students

One of the most important aspects of sport and recreational activities is the frequency with which sports are practiced in free time. Based upon the results in **Figure 3**, it can be ascertained that the young German people tested, regardless of the gender and milieu, are generally very involved in practicing sport. A total of 43% of them declare that they practice sport once or twice a week, and almost 35% practice it very often (three times a week or more). Instead, the percentage of German school students who do not practice recreational sports at all (4%) is of marginal significance.

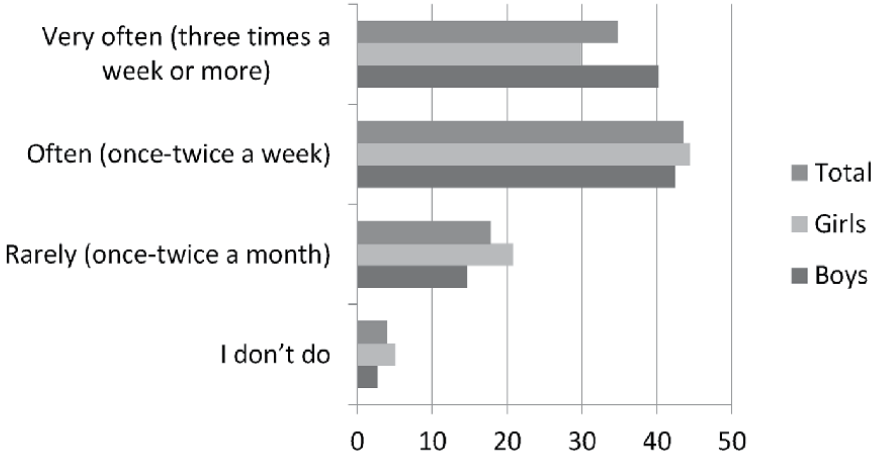

Figure 3.
Frequency of practicing sports of German school students (in percentages).

Cut-off	AUC	SE	95% CI	*p*	OR
Overall	0.5239	0.02946	0.4661 to 0.5816	0.4168	
>0.500					0.97
>1.500					1.34
>2.500					1.02
>3.500					1.33
Answer categories: 1. I do not practice, 2. Rarely, 3. Often, 4. Very often.					

Table 7.
Frequency of practicing sports German school students (boys: n = 184; girls: n = 203).

Cut-off	AUC	SE	95% CI	*p*	OR
Overall	0.5036	0.04270	0.4199 to 0.5873	0.9377	
>0.500					1.03
>1.500					1.01
>2.500					1.05
>3.500					0.93
Answer categories: 1. I do not practice, 2. Rarely, 3. Often, 4. Very often.					

Table 8.
Frequency of practicing sports of German male school students (large city: n = 91; small town: n = 93).

Cut-off	AUC	SE	95% CI	*p*	OR
Overall	0.5132	0.04061	0.4336 to 0.5928	0.7450	
>0.500					1.12
>1.500					1.02
>2.500					1.03
>3.500					1.03
Answer categories: 1. I do not practice, 2. Rarely, 3. Often, 4. Very often.					

Table 9.
Frequency of practicing sports of German female school students (large city: n = 97; small town: n = 106).

The results of ROC statistical analysis regarding the frequency of sports performance by boys and girls living in the Alpine region of Germany (**Table 7**) allow to conclude that the gender of respondents generally has no substantial impact on preferences in this area because no statistically significant differences were noted ($p > 0.05$), and the relative odds of choosing the analyzed categories regarding the frequency of practicing sports turned out to be similar in both the male and female population groups, except for the relatively higher preferences of girls in the category "I rarely perform sports" (OR = 1.34) and the relatively greater preferences of boys regarding the "I perform sports very often" category (OR = 1.33).

Based on statistical analysis of the Receiver Operating Characteristic (ROC) results presented in **Table 8**, it can be concluded that boys from both large cities and small towns in Germany have a similar preference for frequency of sports performance, as indicated by the absence of statistically significant differences ($p > 0.05$), as well as similar values of odds for all categories of sports performance intensity (OR from 0.93 to 1.05). Similarly to boys, the studied girls from both environments (**Table 9**) also demonstrate similar preferences regarding particular categories of sports performance frequency, as indicated by $p > 0.05$ and OR values (1.02–1.12).

5. Place of performing sports of German school students

Figure 4 shows the results of research regarding the various places for sport performance by the studied youth. The most popular areas are outdoors (56.5%), sports clubs, to which more than half of the studied respondents belonged, and commercial sports facilities (40.2%). Every $^1/_5$ subject participates in extra-curricular sports organized by the school. The least popular place in the opinion of German school youth is fitness club, declared only by 7.5% of the respondents.

Receiver Operating Characteristic (ROC) statistical analysis, as shown in **Table 10**, showed that outdoor areas (p = 0.00883, OR = 1.31) and commercial sports facilities (p = 0.00706; OR = 1.49) are significantly more popular places for performing sports among boys. Sports clubs are also more popular among the male youth (OR = 1.25) although there are no significant statistical differences (p = 0.05815) regarding this category.

Based on the analysis of the ROC statistical results on the popularity of places for performing sports by boys (**Table 11**) and girls (**Table 12**) from large cities and small towns, it can be concluded that environmental conditions do not significantly

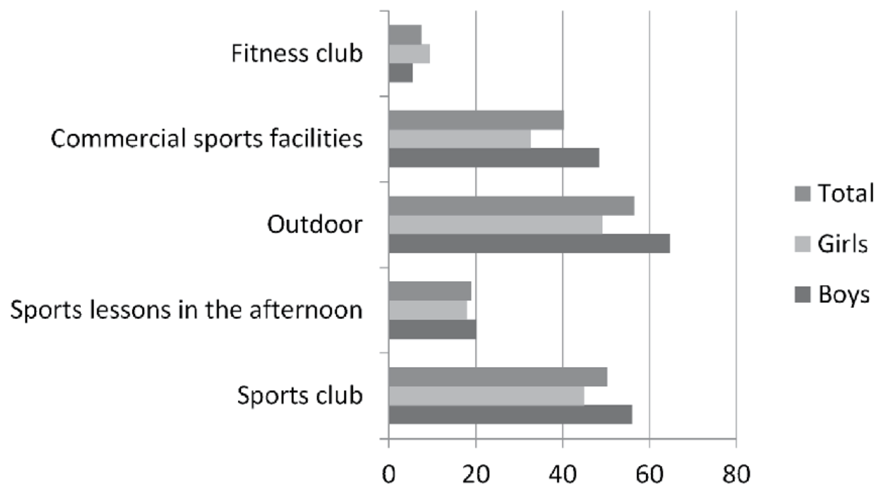

Figure 4.
Places of practicing sports declared by German school students (in percentages).

Place of practicing sport	AUC	SE	95% CI	p	OR
Sports club	0.5558	0.02924	0.4984 to 0.6131	0.05815	1.25
Sports lessons in the afternoon	0.5094	0.02943	0.4517 to 0.5671	0.74910	1.10
Outdoor	0.5771	0.02904	0.5201 to 0.6340	0.00883	1.31
Commercial sports facilities	0.5793	0.02909	0.5222 to 0.6363	0.00706	1.49
Fitness club	0.5196	0.02935	0.4621 to 0.5772	0.50480	1.04

Table 10.
Places of practicing sports declared by German school students (boys: n = 184; girls: n = 203).

Place of practicing sport	AUC	SE	95% CI	*p*	OR
Sports club	0.5333	0.04258	0.4498 to 0.6167	0.43580	1.13
Sports lessons in the afternoon	0.5576	0.04236	0.4746 to 0.6407	0.17720	1.16
Outdoor	0.5310	0.04261	0.4475 to 0.6145	0.46740	1.19
Commercial sports facilities	0.5542	0.04243	0.4710 to 0.6374	0.20440	1.25
Fitness club	0.5115	0.04268	0.4278 to 0.5951	0.78830	1.53

Table 11.
Places of practicing sports declared by German male school students (large city: n = 91; small town: n = 93).

Place of practicing sport	AUC	SE	95% CI	*p*	OR
Sports club	0.5150	0.04065	0.4353 to 0.5947	0.71260	1.07
Sports lessons in the afternoon	0.5462	0.04038	0.4670 to 0.6254	0.25610	1.12
Outdoor	0.5275	0.04060	0.4479 to 0.6071	0.49930	1.11
Commercial sports facilities	0.5539	0.04049	0.4745 to 0.6333	0.1848	1.39
Fitness club	0.5190	0.04069	0.4392 to 0.5987	0.64090	1.50

Table 12.
Places of practicing sports declared by German female school students (large city: n = 97; small town: n = 106).

affect the choice of places to practice sports both among boys and girls. There were no statistically significant differences in these declarations, and the relative odds of choosing the locations were similar in both the male and female populations, with the exception of the relatively larger participation of boys (OR = 1.53) and girls (OR = 1.50) coming from large cities in fitness club classes.

6. Possibilities for performing sports in the town of residence in the opinion of German school students

The studied German students had the opportunity to comment on the possibility of practicing recreational sport at their place of residence (**Figure 5**). More than ½ of the surveyed youth considered them as large and about ¼ as average.

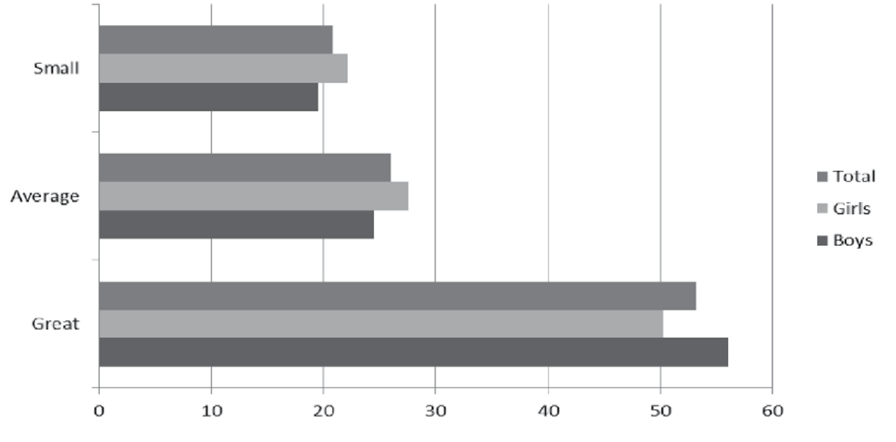

Figure 5.
Possibilities for performing sports in the town of residence in the opinion of German school students (in percentages).

ROC statistical analysis on the assessment of German youth regarding the possibility for practicing sports at the place of residence has shown that both boys and girls generally perceive these opportunities in a similar way (**Table 13**). This is confirmed by the lack of statistically significant differences, as well as the value of the Odds Ratio (1.03–1.11).

Statistical analysis of assessment related to the possibility for practicing sport at the place of residence has shown that boys from both large cities and small towns generally regard them in a similar way (**Table 14**). In none of the categories of responses were there statistically significant differences, while boys from a small town 1.39 times more often than boys from a big city were of the opinion that the opportunities to practice sports are small in their city, and in turn, boys from a big city declared 1.22 times more often that these possibilities are large. Analogous relations concerning the opinions of girls about the possibilities of practicing sports in both environments are shown via the results presented in **Table 15**.

Cut-off	AUC	SE	95% CI	*p*	OR
Overall	0.5288	0.02937	0.4712 to 0.5864	0.32810	
>0.500					1.11
>1.500					1.03
>2.500					1.05
Answer categories: 1. Good, 2. Average, 3. Poor.					

Table 13.
Possibilities for performing sports in the town of residence in the opinion of German school students (boys: n = 184; girls: n = 203).

Cut-off	AUC	SE	95% CI	*p*	OR
Overall	0.5624	0.04230	0.4795 to 0.6454	0.14350	
>0.500					1.22
>1.500					1.11
>2.500					1.39
Answer categories: 1. Good 2. Average 3. Poor.					

Table 14.
Possibilities for performing sports in the town of residence in the opinion of German male school students (large city: n = 91; small town: n = 93).

Cut-off	AUC	SE	95% CI	*p*	OR
Overall	0.5730	0.04021	0.4942 to 0.6518	0.07270	
>0.500					1.33
>1.500					1.09
>2.500					1.31
Answer categories: 1. Good, 2. Average, 3. Poor.					

Table 15.
Possibilities for performing sports in the town of residence in the opinion of German female school students (large city: n = 97; small town: n = 106).

7. Sports disciplines performed regularly by German school students

This part of the study focused on the most popular sports disciplines regularly performed by German school students in their free time. **Table 16** shows a list of the ten most popular types of sports performed by boys from large cities and small towns. As expected, the results of the research confirm the greatest popularity of football and cycling among boys regardless of their environment. Swimming and running are also common in both environments. Other popular sports also include skiing and snowboarding, individual and team sports as well as bodybuilding.

The results of ROC statistical analysis, presented in **Table 17**, refer to the comparison of preferences for regularly performed sports by boys from large cities and small towns. On the basis of these results, it can be concluded that the male youth from both backgrounds exhibit similar interests in sports ($p > 0.05$). However, it is important to note that in the case of boys from large cities, participation in basketball is more than two times greater (OR = 2.17) and 1.6 times greater in the case of tennis (OR = 1.61).

Kind of sport	Boys large city	Kind of sport	Boys small town
1. Football	51	1. Football	59
2. Cycling	33	2. Cycling	37
3. Basketball	19	3. Swimming	22
4. Swimming	16	4. Skiing/Snowboarding	19
5. Jogging	15	5. Jogging	17
6. Tennis	12	6. Bodybuilding	14
7. Skiing/Snowboarding	11	7. Table tennis	12
8. Bodybuilding	10	8. Basketball	9
9. Table tennis	8	9. Handball	8
10. Volleyball	5	10. Tennis	8

Table 16.
Sports regularly practiced by German male school students in their free time (in percentages).

Kind of sport	AUC	SE	95% CI	*p*	OR
Football	0.5268	0.04262	0.4433 to 0.6104	0.52970	1.12
Cycling	0.5180	0.04265	0.4344 to 0.6016	0.67390	1.06
Basketball	0.5504	0.04251	0.4671 to 0.6337	0.23780	2.17
Swimming	0.5251	0.04261	0.4416 to 0.6086	0.55640	1.06
Jogging	0.5036	0.04268	0.4199 to 0.5873	0.93270	1.01
Tennis	0.5228	0.04265	0.4392 to 0.6064	0.59310	1.61
Skiing/Snowboarding	0.5418	0.04250	0.4585 to 0.6252	0.32710	1.10
Bodybuilding	0.5204	0.04263	0.4369 to 0.6040	0.63210	1.05
Table tennis	0.5207	0.04263	0.4371 to 0.6043	0.62810	1.05
Handball	0.5376	0.04253	0.4543 to 0.6210	0.37790	1.08

Table 17.
Sports regularly practiced by German male school students in their free time (large town: n = 91; small town: n = 93).

The most popular sport practiced by all the girls studied is cycling (**Table 18**). Swimming and horse riding were also at the top of the ranking, which among the surveyed boys turned out to be completely unpopular. It is worth emphasizing, as in the case of boys, the similar popularity of skiing. Girls generally do not prefer sports activities that require high endurance, strength or fierce competition. This is reflected in the results of research regarding their favorite sports, which include typical female forms of activity such as aerobics and dancing. Team sports such as volleyball, handball or basketball are of smaller importance for girls from small towns.

The results of ROC statistical analysis (**Table 19**) refer to the comparison of preferences related to the regular practice of sports by girls from large cities and small cities. On their basis, it can be stated that girls from both backgrounds exhibit similar interests in sports disciplines. The exception is running, which is chosen twice more often by girls from large cities (OR = 2.01). Significant differences were also noted within this category (p = 0.02561). In addition, girls from large cities take part in handball more than 2 ½ times more often than the studied girls from small towns (OR = 2.6).

Kind of sport	Girls large city	Kind of sport	Girls small town
1. Cycling	46	1. Cycling	41
2. Swimming	39	2. Horse riding	37
3. Jogging	36	3. Swimming	32
4. Horse riding	24	4. Aerobic	21
5. Aerobic	21	5. Jogging	18
6. Handball	20	6. Skiing/Snowboarding	16
7. Volleyball	12	7. Dance	10
8. Dance	9	8. Volleyball	9
9. Skiing/Snowboarding	7	9. Handball	8
10. Basketball	6	10. Basketball	5

Table 18.
Sports regularly practiced by German female school students in their free time (in percentages).

Kind of sport	AUC	SE	95% CI	p	OR
Cycling	0.5291	0.04061	0.4495 to 0.6087	0.47380	1.14
Basketball	0.5236	0.04054	0.4441 to 0.6031	0.56190	1.05
Swimming	0.5355	0.04060	0.4559 to 0.6151	0.38270	1.22
Jogging	0.5908	0.04014	0.5121 to 0.6695	0.02561	2.01
Skiing/Snowboarding	0.5036	0.04268	0.4199 to 0.5873	0.27810	1.11
Horse riding	0.5654	0.04022	0.4866 to 0.6443	0.10780	1.21
Aerobic	0.5007	0.04066	0.4210 to 0.5804	0.98660	1.00
Volleyball	0.5147	0.04069	0.4349 to 0.5944	0.71810	1.31
Dance	0.5055	0.04064	0.4258 to 0.5852	0.89250	1.01
Handball	0.5602	0.04052	0.4808 to 0.6396	0.13880	2.60

Table 19.
Sports regularly practiced by German female school students in their free time (large city: n = 97; small town: n = 106).

Referring to the results of regularly performed sports by boys and girls (**Tables 17** and **19**), it should be noted that the following disciplines commonly practiced are:

- cycling,
- running.
- swimming,
- skiing/snowboarding,
- basketball,
- volleyball,
- handball.

ROC statistical analysis showed that for most sports, both boys and girls report similar preferences because no statistically significant differences were found with regard to the gender of the respondents. The exception is swimming, which is much more preferred by the studied girls (p = 0.00521; OR = 1.25) and basketball, which is statistically chosen over 5 ½ times more frequently by boys than girls (OR = 5.52). However, no statistically significant differences were noted in this category (p = 0.05876).

8. The declarations of German school students on practicing sports after graduating from school

The study also examined the opinions of German school students regarding their intended sport activity after completing school education. The vast majority of respondents (81%) declare their intention to practice sport after finishing school (**Figure 6**). At the same time, the very low percentage of the respondents who do not intend to be active in sports in the future (8%) deserves to be emphasized.

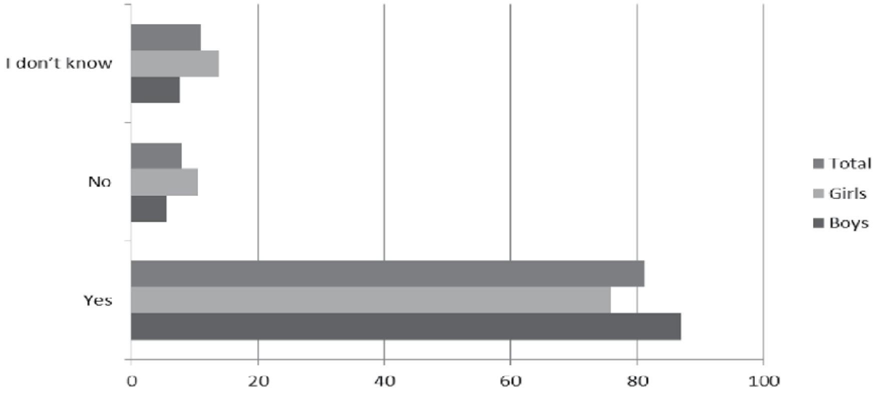

Figure 6.
The declarations of German school students on practicing sports after graduating from school (in percentages).

Cut-off	AUC	SE	95% CI	*p*	OR
Overall	0.5553	0.02914	0.4982 to 0.6124	0.06030	
>0.500					1.15
>1.500					1.80
>2.500					1.98

Answer categories: 1. Yes, 2. No, 3. I do not know.

Table 20.
The declarations of German school students on practicing sports after finishing school (boys: n = 184; girls: n = 203).

Cut-off	AUC	SE	95% CI	*p*	OR
Overall	0.5243	0.04265	0.4407 to 0.6080	0.56850	
>0.500					1.15
>1.500					1.01
>2.500					1.84

Answer categories: 1. Yes, 2. No, 3. I do not know.

Table 21.
The declarations of German male school students on practicing sports after finishing school (large city: n = 91; small town: n = 93).

Cut-off	AUC	SE	95% CI	*p*	OR
Overall	0.5150	0.04067	0.4353 to 0.5947	0.7126	
>0.500					1.04
>1.500					1.14
>2.500					1.09

Answer categories: 1. Yes, 2. No, 3. I do not know.

Table 22.
The declarations of German female school students on practicing sports after finishing school (large city: n = 97; small town: n = 106).

Taking into account all the opinions of the surveyed youth, it is possible to positively forecast their participation in sporting activities in the future.

ROC statistical analysis regarding German youth declaration on practicing sports after graduation (**Table 20**) did not show statistically significant differences between boys and girls ($p > 0.05$). It should be emphasized that the surveyed girls 1.8 times more often than boys declare that they do not intend to do sports after graduation and almost twice as often, that they have not yet decided whether they will practice sports in the future (OR = 1.98).

The results of ROC statistical analysis included in **Tables 21** and **22**, relate to declarations of German boys and girls from various residential environments about the intention to practice recreational sport after graduating from school. Based on the results of analysis, it can be concluded that both boys and girls report similar predictions because no response categories showed statistically significant differences ($p > 0.05$). It is worth emphasizing that boys from large cities almost twice as often as boys from small towns declare that they do not yet know whether they will play sports after graduating from school (OR = 1.84).

9. Discussion

The subject of this study was selected elements of the free time sports - recreational activity of youth coming from a large and small agglomeration of the Alpine region in Germany.

The author's research has shown that among the free time activities of the German youth, the most important are social gatherings, preferred by the majority of respondents, while practicing sports is in second place, which for boys, turned out to be much more important than for girls. In addition, computer-related activities are significantly more important for boys, while girls appreciate reading and music more. Based on the results of research related to the preferences of leisure activities, it can be stated that boys are more physically active than girls who prefer primarily passive forms of use such as listening to music, meeting friends or watching television, while sports, in fourth place on the list of the most popular free-time activities, play a far-reaching role in their lives. Similar results regarding free time forms of activity of German youth are presented by Henkel [14], Kurz and Tietjens [15], Urbutt [16], Tietjens [17], Maaz and Burrmann, [18]; Sonnenwald [19], Sawicki [20], Sawicki and Suchy [21], Schmidt [22], where the greater preferences of active forms of spending free time among male youth are underlined and greater preferences of physically passive forms of free time activity among the female youth.

Examining the motives for undertaking sports activity, it was shown that the strongest motivating factors for German school students are health, physical fitness and social aspects. Health and esthetics as motives of sports-recreational activity are valued more by girls, while for the studied boys, physical fitness and risk are significantly more important motives for practicing sports. These results are also confirmed by numerous research studies conducted by Steffgen and Schwenkmezger [23], Alfermann [24], Opper [25], Digel [26], Burrmann [27], Opaschowski [28], Sawicki and Suchy [21] and Wezyk et al. [29], which emphasize the dominance of similar motives of sports activity among German school students.

The level of sports-recreational activity is largely determined by the frequency of practicing sports in free time. The results of the author's research confirm the high level of youth involvement in its performance, regardless of sex or environmental conditions (large city, small town). Almost ½ of the respondents declared that they practice sports 1–2 times a week and 1/3 perform it 3 times a week or more often. The results of research by Steffgen and Schwenkmezger [23], Opper [25], Leyk et.al [30], Burrmann and Mutz [31] point to a similar level of sports activity among German school students in previous studies on the subject.

The assessed German school students, and in particular the boys, usually prefer open areas for sports activity. More than ½ of the respondents declare their membership at sports clubs. In addition, another place for practicing sport often visited by the young people under investigation are public sports facilities, enjoying considerably higher popularity among boys. German school students also attend extracurricular sporting activities at schools, attended slightly more often by boys than girls. Comparative results on this matter are also presented by Digel [26], Opper [25], Kurz and Tietjens [15], Brettschneider and Kleine [32], Burrmann [27], Sawicki and Suchy [21] and Mutz [33].

The respondents had the opportunity to comment on the assessment of the possibility for practicing recreational sports at their place of residence. According to ½ of the surveyed youth, these possibilities are large, ¼ of respondents considered them to be average, and only 1/5 of respondents considered them as small, but in the comments, one can notice the tendency of higher assessment of these possibilities for the large agglomeration.

Among the regularly performed sports, the most popular among boys regardless of environment are football and cycling. Swimming and running are also very popular in both environmental groups. In addition, boys from a small town more often practice skiing/snowboarding than their colleagues from a large agglomeration. Other popular sports played by boys include individual and team sports games. The most popular sports practiced by the examined girls were cycling, swimming and horse-riding. The popularity of ski sports, especially among girls from a small town, deserves to be emphasized, as in the case of boys. In addition, as expected, typically female forms of activity such as aerobics or dance are popular among the surveyed girls. In many research works, the general dominance of football, cycling, swimming, running and other sports games is emphasized in the case of boys, while among girls, dominance regards horse-riding, swimming and gymnastics, dance and music as well as running [12, 20, 21, 29, 33–41].

Positive attitudes towards practicing sports by the examined German school students can be demonstrated by the results of the author's research on their opinions regarding their intended sport activity after finishing school education. The vast majority of respondents (81%) declare their intention to practice sport after finishing school. Taking into account these opinions of the surveyed students, it is possible to positively forecast their participation in sporting activities in the future.

10. Conclusions

Based on the analysis of the results of the author's research, the following conclusions can be formulated:

1. Regardless of environmental conditions (large city, small town), the examined German girls practicing recreational sport are guided mainly by esthetic and health reasons, while boys prefer physical fitness and willingness to take risks.

2. German school students, especially girls, prefer more passive activities while sports activities occupy further positions in the hierarchy of favorite free time activities.

3. The gender of the respondents differentiates forms of sports - recreational activity and the place where sports are practiced, such as open areas and public sports facilities, while for the frequency of practicing sports, there are no differences according to gender.

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Sports are very important and help people increase mobility, optimize performance, and reduce their risk of disease. Sporting activities can have beneficial social, cultural, economic, and psychological effects on health, wellbeing, and the environment. As such, this book discusses a range of principles, methods, techniques, and tools to provide the reader with a clear knowledge of variables improving sports' performance processes. Over three sections, chapters consider physical, mechanical, physiological, psychological, and biomechanical aspects of sports performance, sports science, human posture, and musculoskeletal disorders.

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