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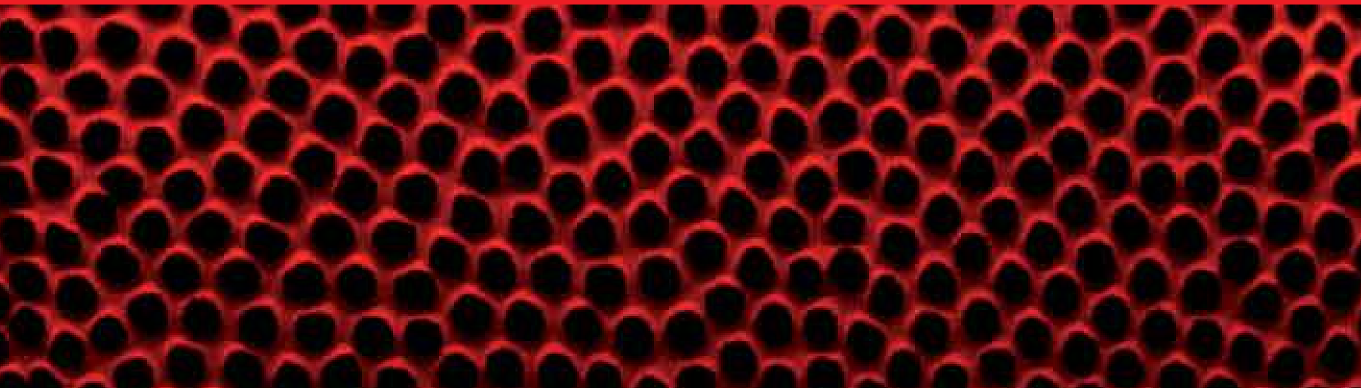

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http://dx.doi.org/10.5772/intechopen.69756
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Notice

First published in Croatia, 2018 by INTECH d.o.o.
eBook (PDF) Published by IN TECH d.o.o.
Place and year of publication of eBook (PDF): Rijeka, 2019.
IntechOpen is the global imprint of IN TECH d.o.o.
Printed in Croatia

Legal deposit, Croatia: National and University Library in Zagreb

Additional hard and PDF copies can be obtained from orders@intechopen.com

Sport and Exercise Science
Edited by Matjaz Merc
p. cm.
Print ISBN 978-953-51-3794-8
Online ISBN 978-953-51-3795-5
eBook (PDF) ISBN 978-953-51-4089-4

Meet the editor

Matjaz Merc is an orthopedic surgeon at the Department of Orthopedics in UMC Maribor, Slovenia. He also started working as an assistant at the Faculty of Medicine in Maribor. He graduated in 2008 from the Faculty of Medicine in Ljubljana, Slovenia, and completed his PhD degree in 2015 from the Faculty of Medicine in Maribor. He was a visiting fellow at the Department of Orthopedics at University Clinic in Basel, Switzerland; Speising Spital, Vienna, Austria; and KBC Šalata, Zagreb, Croatia, where he got subspecialized. His clinical work is based on foot and ankle surgery, pediatric orthopedics, and sports medicine. His research interests are mainly based on the application of rapid prototyping technology in orthopedics.

Contents

Preface

Professional and semiprofessional sports as well as excessive amateur exercise inevitably lead to some degree of musculoskeletal injury once in a sportsman's career. Some injuries are represented as chronic injuries, which can result in irreversible long-term tissue changes and deformities. Furthermore, even if no obvious pain and disability have been experienced, overuse can induce early degenerative tendon, cartilage, and bone changes. The subject of this book is to represent the up-to-date knowledge about etiology, pathogenesis, diagnosis, management, and prevention of chronic injuries or sport-related long-term changes in locomotor system. Moreover, topics about presentation of acute injuries that often become chronic are the subject of this book as well.

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Section 1

General Chapters

Chapter 1

Biology of Stress and Physical Performance

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.72425

Abstract

Regular physical training leads to physical capacity and optimal sports performance, and although this relationship is usually linear, the athlete's adaptation is conditioned by multiple factors: environmental, genetic and psychological. Studies have shown that between 70 and 85% of successful and unsuccessful athletes can be identified using psychological measures of personality and mood, a level higher than chance, but insufficient for the purpose of selecting athletes. The research indicates that the mood of the athletes exhibits a dose-response relationship with their adaptation to the training load; This finding has shown potential to reduce the incidence of overtraining syndrome in athletes who undergo rigorous physical training, through early detection using scales of perception of their mood and physiological measures such as the testosterone / cortisol index. Thus, the genetic and epigenetic modifications of the factors that regulate the hypothalamic-pituitary-adrenal axis and, therefore, the response to stress, have recently been associated with a detrimental effect on physical performance and early manifestations of the overtraining syndrome and the abandonment of training and competences.

Keywords: stress, psychopathology, cortisol, anxiety, sports performance

1. Introduction

Physical exercise corresponds to a set of activities of which multiple health benefits have been documented, especially in the prevention of a number of diseases [1]. It is known that regular physical training leads to a physical capacity and a certain sports performance, and in this sense, it is worth mentioning that the physical capacity and sports performance are conditioned by many factors: the intensity and type of training, the energy expenditure of the race (distance, feeding, hydration, climatic conditions, etc.), and the condition of the athlete's health, his anthropometric and morphometric characteristics, and his psychological condition before and during the competition [2]; determining then according to the foregoing that the athlete has a complex phenotype influenced by multiple environmental, genetic, and psychological factors [1, 3].

The effects of anxiety on sports performance have been the main target of study of sports psychology in recent times [4]. Stress is a feeling of physical or emotional stress marked by an increase in the activity of the body's homeostasis systems, and anxiety is a feeling of fear, restlessness, and worry (you are neurogenic); people who frequently present these emotions may have an anxiety disorder within which a series of psychopathological entities are included [5, 6]. Anxiety can have an impact on several aspects of the sport; for example, anxiety is associated with the interruption of sports activities, less pleasure during competition, and deterioration in sports performance [6]. On the other hand, a number of researchers have associated anxiety disorders with dysfunctions of the hypothalamic-pituitary-adrenal (HPA) axis regulatory mechanisms, within which synaptic modulation through neurotransmitters, its receptors, and regulatory mechanisms takes on particular importance. It is in this instance where molecular biology and genetics have marked the understanding of these entities in the last 20 years; so today, the genetic and epigenetic factors that affect the functionality of proteins involved in the neuromodulation of the HPA axis are the target of multiple publications and research projects.

1.1. Theoretical framework

The study of anxiety, its antecedents, its relations with other psychological variables, and its consequences has been the target of theoretical and empirical attention within the psychology of sports for a long time [7]. Alterations in the concentration and the reactivated physiological stress are considered as two components of the anxious response, and an attempt has been made to establish a relationship between the cognitive and somatic consequences of these in sports performance [6, 7]. Stress is a feeling of physical tension (physiological stress) or emotional stress (neurogenic stress), and anxiety is a feeling of fear, restlessness, and worry. People who frequently present these emotions may have an anxiety disorder that includes panic disorder, agoraphobia, social phobia, post-traumatic stress disorder, obsessive-compulsive disorder, and generalized anxiety disorder; each anxiety disorder has different symptoms, but all symptoms are grouped around an irrational and excessive fear or dread [5, 6]. Anxiety is a multidimensional construct that is constituted by two main components: cognitive anxiety (i.e., worrying thoughts about one's performance) and somatic anxiety (i.e., individual physiological changes, for example, sympathetic hyperactivity, respiratory changes, changes in blood pressure, etc.) [5]. In long-distance athletes, the changing situations in the course of training and competition, together with the presence of anxiety disorders, could be caused by maladaptive fatigue syndrome (overtraining syndrome) characterized by anger, hostility, anxiety, confusion, depression, sadness, lack of energy, and apathy, which has as a consequence of a bad performance and/or the abandonment of training and skills [3, 8, 9].

The model of mental health and sports performance suggests that there is an inverse relationship between psychopathology and sports performance [9]. This model postulates that as an athlete's mental health deteriorates or improves performance it must fall or rise accordingly [3, 8].

Studies have shown that between 70 and 85% of successful and unsuccessful athletes using general psychological measures of personality structure and mood can be identified, a level higher than chance but insufficient for the purpose of selection of athletes [10]. Research indicates that responses of athletes' mood states exhibit a dose-response relationship with their training load; this finding has shown potential to reduce the incidence of overtraining syndrome in athletes who undergo rigorous physical training [3]. Other studies show a deleterious effect of stress and anxiety on sports performance in various sports [3, 4, 8, 9].

1.2. Anxiety disorders' neurobiology

The biological foundation of anxiety disorders focuses on HPA axis dysfunction that leads to an increase in axis activity and an exacerbated response mediated by the neuroendocrine system of cortisol and catecholamines [11]. An important regulator of this axis is the serotoninergic system that would play a key role in the regulation of the HPA axis, regulating its function at least in two levels: on the one hand, by activating neurons that release CRF and, on the other, by regulating the activity of CRF and cortisol at the synaptic level [12]. In this setting, the serotonin reuptake (SERT, 5-HTT) regulates the serotonin (5-HT) levels at the synaptic level [13]. More than 12 different features of human behavior and other systemic pathologies have been associated with variations of the SERT gene (SLC6A4) [13, 14]. The reduced expression of the gene and the function derived from a significant variation in the region of its transcriptional control (serotonin transporter gene-linked polymorphic region; 5-HTTLPR) are linked to multiple psychopathological conditions, including anxiety disorder [15, 16]. Serotoninergic neurons are located mainly in the dorsal and middle raphe nuclei (DRN and MRN) of the brain stem; the projections of these neurons release 5-HT through the entire forebrain and brainstem modulating a variety of neuronal activities [17]. The largely neuromodulatory effects of 5-HT are mediated through 14 subtypes of receptors that are grouped into subfamilies according to their primary signaling mechanism, within which is the 5-HT1A receptor, which in studies in humans and rodents it has been suggested that it would participate in the etiology of anxiety and depression disorders and their treatment [18]. The 5-HT1A autoreceptor is a G-protected coupled receptor (GPCR) and is located in the soma and dendrites of the serotonergic neurons in the raphe nuclei; its activation induces neuronal hyperpolarization and therefore a lower release of 5-HT. The 5-HT1A postsynaptic receptor is expressed mainly in pyramidal neurons and in GABA (gamma-aminobutyric acid)-releasing interneurons [18]. The reduction of levels of autoreceptors and postsynaptic 5-HT1A receptors has been reported in patients with social phobia, as well as in the cortical regions of patients suffering from panic disorder [18, 19].

Another important mechanism of regulation of the HPA axis occurs in the release of corticotropin-releasing factor (CRF) and its binding to its specific receptors CRF1R and CRF2R (corticotropin-releasing factor receptor-1 and receptor-2), which regulate and modulate the activity of the HPA axis [20]. The release of CRF from the periventricular nucleus of the hypothalamus induces the release of adrenocorticotrophic hormone (ACTH) from the anterior pituitary and the consequent activity of this on the adrenal gland to initiate the release of cortisol [21]. Scientific evidence shows that central regulation of CRF release is mediated by the CRF-binding protein (CRF-BP), a protein that binds to CRF and binds to the CRF2R receptor, producing an additional feedback to modulation of the HPA axis [20–22]. Several studies show an increase in the expression of CRF-BP in the amygdala, anterior pituitary, and portal circulation after an increase in the release of CRF [21]. In addition, in CRF-BP knockout mice, an anxious behavior and an increase in the concentration of CRF and therefore the levels of ACTH and cortisol were demonstrated [21]. CRFR2 is suggested to play a fundamental role in recovery from the state of stress to calmness; is abundantly distributed in the raphe nuclei of the midbrain, in those that regulate serotonergic neuronal activity; and has been shown to regulate behavioral consequences of stress [23]. It is suggested that the CRF2 receptor is necessary for the proper functioning of the 5-HT1A receptors in the raphe nuclei, and they are the key to a successful recovery of tension. This altered serotonergic function in knockout mice - / - for the CRF2 receptor probably contributes to its phenotype sensitive to stress and anxiety [23, 24].

Two molecules that participate in the regulation of the HPA axis and that have been reported as factors that can be therapeutic and observational targets in the pathophysiology of stress deregulation and anxiety disorders are substance P (SP) and enzyme-converting angiotensin (ECA). SP has been an important target in the study of the pathophysiology of pain; however, in the last time, it has been shown to be involved in the regulation of mood states, and studies using antagonists of its neurokinin-1 receptor (NK1R) show antidepressant effects in humans [25]. In rodents, treatment with NK1R antagonists has been shown to increase the release of 5-HT from the dorsal raphe nucleus (DRN), suggesting local interactions between SP and serotonin in the desensitization of 5-HT1A receptors. This interaction represents a new element in the complex neuronal circuits proposed in mood regulation [26, 27]. Angiotensin-converting enzyme (ACE) has been one of the main molecular markers associated with physical performance in humans, especially insertion/deletion polymorphism; in recent studies it has been associated with hyperactivity of the HPA axis and increased secretion of cortisol in patients under stress [28, 29]. The presence of this polymorphism has been recently implicated with various behavioral disorders and increased mortality in patients with cardiovascular disease who present with depression [28, 30]. The proposed model for neuroendocrine regulation of the HPA axis is observed in **Figure 1**.

1.3. Genetic polymorphisms as factors associated with stress and anxiety

The 5-HTTLPR polymorphism of the SLC6A4 gene coding for 5-HTT corresponds to a genetic variant in which an insertion/deletion of a fragment of 44 base pairs (bp) occurs in the gene, where the short variant or deletion (short allele or S) results in less transcriptional activity and greater vulnerability to affective disorders (**Figure 2**) [31].

Another important study target of the serotonergic system is the 5-HT1A receptor, which plays an important role in the self-regulation function of the central serotonergic system [32]. Studies of the -1019C > G variant of this gene show an association between this polymorphism and the risk of suicide, not being associated with depression. The dysfunctions of this receptor observed in 5-HT1A - / - knockout mice show an increase in anxious traits and stress sensitivity in these animals [33, 35]. The presence of the -1019C > G polymorphism of this gene increases the inhibitory feedback tone of the 5-HT synapse, by increasing 5-HT1A autoreceptors in the raphe nucleus

[36, 37]. Studies in animals and cell culture show that the increase in activity of the HHA axis goes hand in hand with a decrease in the expression of the postsynaptic 5-HT1A receptor [36].

The polymorphism rs1875999 (also known as CRF-BPs11) of the CRF-BP gene is produced by the exchange of nitrogenous bases in the 3′UTR position of the gene, where a T (thymine) is exchanged for a C (cytokine). The TT genotype for this variant is associated with substance dependence, alterations in eating behavior, and mood disorders [22, 38, 39]. Another polymorphism associated with stress regulation is the variant rs2267717 of the CRF2R gene located on chromosome 7, which has been linked to anxiety and mood disorders in men and women [40].

The activity of substance P in the brain as a stress modulator is carried out through its interaction with NK1R, a protein that is densely distributed in brain regions that modulate the stress response. Antagonists of this receptor have been shown to be effective for the treatment of anxiety and depression [41]. The NK1R gene is located on chromosome 2p13.1 and contains five exons. The polymorphism rs6715729 (G > A), a silent mutation located in exon 1 of the NK1R gene, has been associated with substance dependence and stress hyperactivity [42, 44].

The I/D polymorphism (rs1799752) of the ECA gene corresponds to an insertion or deletion of a 287 bp fragment in intron 16 of the gene. The presence of the deletion allele (D) has been associated with increased levels of angiotensin II and release of plasma cortisol. On the other hand, the insertion allele (I) has been related to greater resistance to fatigue. Multiple studies

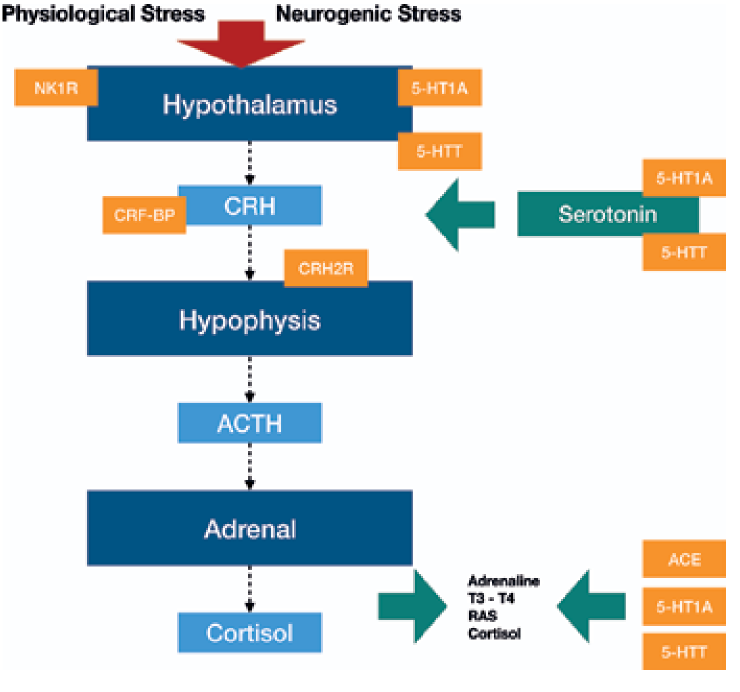

Figure 1. Hypothalamic-pituitary-adrenal (HPA) axis and proposed regulatory model for substance P (NK1R) receptors, serotonin reuptake (5-HTT), serotonin type 1a receptor (5-HT1AR), receptor corticotropin-releasing factor type 2 (CRF2R), angiotensin-converting enzyme (ACE), and corticotrophin-releasing factor-binding protein (CRF-BP), triiodothyronine (T3), tetraiodothyronine (T4), renin-angiotensin-aldosterone system (RAAS).

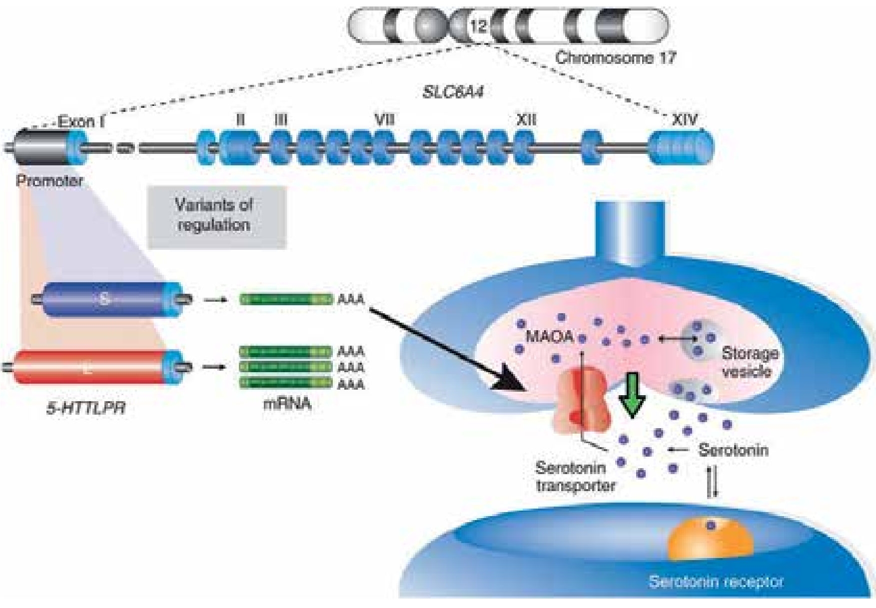

Figure 2. Effect of allelic variation of the serotonin transporter. The 5-HTTLPR (purple) short allele of the SLC6A4 gene reduces 5-HTT expression, as indicated by the green arrow leading to higher concentrations of serotonin in the synaptic cleft. The S allele is associated with personality traits related to anxiety disorder. MAOA, monoamine oxidase type A; L, long allele (red) (Adapted from Canli & Lesch (2007)).

associate RCT with sports performance, and ACE has recently been proposed as an important regulator in the secretion of cortisol and regulator of the HPA axis [29, 45]. The genotype I/I is associated with a lower activity of the ACE in plasma and tissues and the presence of the D/D genotype with a higher concentration of ACE in the plasma and a greater cardiac activity of the enzyme and also with an improvement in performance in sprint sports [46, 47]. The I allele has been associated with greater physical endurance in elite long-distance runners, rowers, and mountain runners [48]. It has been proven that the presence of the D allele increases the ejection fraction and the pulmonary systolic blood pressure [47], in addition to increasing the CRF and ACTH levels of the HPA axis [45]. Recent evidence shows that triathletes who competed in the ironman of South Africa who had higher levels of plasma ECA had a lower performance on the cycling and jogging tests [49].

1.4. Epigenetic modulation

The complex mechanisms that modulate gene expression are the focus of study at present, with epigenetics being one of the main sciences of analysis and observation. The term epigenetics has been defined as "heritable changes in gene expression that occur without an alteration in the nucleotide sequence of DNA." Thus, an epigenetic mechanism can be understood as a complex system to selectively use genetic information, activating and deactivating various functional genes. Epigenetic modifications may involve the methylation of cytosine residues in DNA and/or changes in the structure of chromatin that regulate gene expression [47]. Methylation and histone modifications induce transcriptional changes in DNA. Along with their susceptibility to external influences, epigenetic patterns are highly specific to the individual and may represent an important avenue of analysis to understand the predisposition toward high or low physical performance capabilities. In this context, epigenetics combined with classical genetics could broaden our knowledge of the genotype-phenotype interactions of athletes [48]. It is suggested that epigenetic effects may also play an important role in determining athletic potential and athletic performance, and in the future, they will be of importance in determining the characteristics of an athlete [48]. Currently, in addition to methylation and modification of histones, the activity of microRNAs (miRNAs) and their role in the regulation of gene expression have been included in the study of epigenetic control mechanisms. The miRNAs are small noncoding ribonucleic acids (RNAs), which play a vital role in the regulation of gene expression. They play an important role in posttranscriptional regulation through direct binding with messenger RNAs (mRNA). Currently, several reports relate the regulation exerted by miRNAs on the phenotypic characteristics of skeletal muscle and their participation in the conditioning factors of athletic performance in athletes who practice long-distance sports [49].

There are few reports of epigenetic modifications in the genes associated with stress and anxiety, and there are no precedents that link genetic and epigenetic factors with anxiety and sports performance.

2. Conclusion

The relationship between sport and mental illness in any athlete can occur in one of the three ways: firstly, sport can somehow cause or worsen a mental illness; secondly, the athlete's psychiatric symptoms can somehow attract him to sports, maybe as a way to deal with the symptoms or because the symptoms are somehow adaptable for the sport; and, thirdly, there may not be an obvious relationship between sport and mental illness. A low prevalence of psychiatric disorders in athletes was assumed for a very long time, both by health professionals and by the general public. This bad assumption could have come from a general cultural inclination to idealize the athletes and their health, which excludes the possibility of having psychiatric illnesses. Athletes were taught to be tough and to focus on physical performance and physical signs that interfere with optimal ability at the expense of mental symptoms. On the other hand, mental disorders in general, and in particular among high-level athletes, are stigmatized, and this situation is perpetuated by the general public and the media, as well as sports clubs and health professionals. This has led to a lack of research and an underdevelopment of specific psychiatric treatment facilities for athletes.

Finally, it is important to mention that several authors have tried to establish the association between genetics and sport. However, previous reports only report associations between genetic variants and anxiety disorder, with no information regarding the association between genetics, anxiety disorder, and sports performance. Our data demonstrate, in an unprecedented way, that sports performance and behavioral disorders, with genetic and epigenetic variations as markers, constitute an important factor to be taken into account when assessing the athletic performance of an athlete.

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Chapter 2

Biokinetics: A South African Health Profession Evolving from Physical Education and Sport

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.73126

Abstract

This chapter describes the South African profession of Biokinetics, which operates within the pathogenic and fortogenic health paradigms. Biokinetics is an exercise therapy profession that exclusively prescribes individulaised exercise and physical activity for rehabilitation and promotion of health and quality of life. Biokinetics differs from physiotherapy primarily due its management of injuries, illnesses and disabilities within the final-phase of rehabilitation. A brief history of the profession and its scope of profession and its alignment within the South African National Health statutory and professional bodies will be presented. The two pedagogic models adopted for the teaching and training of Biokinetics will also be discussed. Interprofessional collaborative partnerships within the medical-rehabilitation fraternity, sport, health and fitness industries and educational employment opportunities will be reviewed. Finally, the idea of internationalisation of the profession of Biokinetics to similar exercise therapy professions such as Clinical Exercise Physiology and Athletic Training will be presented.

Keywords: Biokinetics, exercise therapy, rehabilitation, health promotion

1. Introduction

The profession of Biokinetics is a specialised discipline of exercise therapy (ET), which emerged from the South African Physical Education Programme. In the 1920s a medical and physical conditioning surveillance report surfaced, which identified South African boys to be in poor health and physical condition [1, 2]. This prompted the South African Defence Force (SADF) to establish the *Physical Training Brigade* in 1934 [1–3]. This specialised interprofessional medical and rehabilitation collaborative unit addressed the poor medical and physical condition of the boys joining the SADF, via the expertise of medical doctors, dentists, nurses, physiotherapists, occupational therapists, social scientists and physical education instructors. The focus of the South African Physical Education at that time was ergogenic in nature and the research involved was to evaluate and subsequently prescribing performance enhancing exercise or physical activity to improve the physical conditioning of children. This research focused continued until, the late 1960s when a new additional therapeutic focus emerged. The clinical rehabilitative research of Strydom (the salutogenic effects of exercise therapy among coronary heart disease patients) and Buys (the salutogenic effects of exercise therapy among diabetic patients) sowed the seed for the establishment of the profession of Biokinetics [4, 5]. At the Potchefstroom (the PU for CHE, now North-West University), a module on the salutogenic effects of exercise was taught, which was called Kinetiotherapy. The philosophy behind this term reflected the therapeutic benefits of bodily movement (*kinesis*) and the recognition should be sought from health professionals.

Concerted endeavours began in 1969, by the heads of the South African Human Movement Science departments that produced a formal communiqué in 1973, to the then South African Medical and Dental Council to include Kinetiotherapy on its register. However, the registration of this new exercise therapy profession (Kinetiotherapy) was not forthcoming due to resistance from the professions of Physiotherapy, Occupational Therapy and Exercise Science [6, 7]. The initial name of the new exercise therapy profession created considerable tension among its distractors. Biokinetics comprises of two Greek words: "*Bio*" meaning *life* and "*Kinesis*" meaning *movement* [8]. The literal interpretation of Biokinetics is "*life through movement*". Professor Gert Strydom's persistent efforts with the South African Medical and Dental Council (SAMDC), finally culminated with the official announcement of the registration of the profession of Biokinetics as a health discipline within the South African Government Gazette on the 9th of September 1983, acknowledged as a profession on the professional board of medical sciences of the South African Medical and Dental Council (SAMDC), which was later renamed the Health Professions Council of South Africa (HPCSA) [7].

2. The scope of profession of Biokinetics

The HPCSA describes Biokinetics as a final-phase functional therapeutic health related profession concerned with enhancing the physical and physiological health status of patients through personalised evaluation and subsequent exercise and human movement prescription in the context of chronic clinical and orthopaedic pathologies and performance enhancement (pathogenic health paradigm) [9]. Biokinetics is also dynamically involved with health and wellness campaigns and the prevention of orthopaedic injury and hypokinetic diseases, advocating salutogenic effects of exercise (fortogenic health paradigm) [10]. The health and wellness campaigns promote the salutogenic effect of exercise to combat non-communicable diseases (NCDs) and their predisposing risks. At this point the biokineticist is working within the pathogenic health paradigm (illness and illness prevention healthcare dimensions). Further biokineticists also promote an active lifestyle as a protective mechanism to prevent the occurrence of NCDs among healthy individuals, working from the fortogenic paradigm.

The orthopaedic rehabilitation focuses primarily on final-phase functional rehabilitation, which entails enhancing muscle strength and endurance, cardiorespiratory fitness, range of motion of joints, neuromuscular proprioception, functional movement patterns and patient education [9]. Muscle strength and endurance have a strong isokinetic and isotonic foci inter alia on both global and local muscles. Range of motion includes enhanced muscle and ligament extensibility, thereby dissipating contractures through passive, active and resisted movements [9].

Clinical rehabilitation of NCDs entails structured rehabilitative programmes aimed to enhance cardiorespiratory fitness, cardio-metabolic profile, range of motion, neuromuscular proprioception thereby improving the patient's quality of life. The following section will describe the interaction of biokineticists within the health dimensions and paradigms (**Figure 1**).

2.1. Health dimensions and health paradigms

The pathogenic paradigm is inclusive of both the ill care dimension (whereby the pathology is present) and/or illness prevention dimension (the elevated intrinsic risk of prospective pathology) (**Figure 2**) [11]. Both health dimensions require clinical interventions by the medical discipline, which include general medical practitioners, nurses, medical specialists (such as cardiologists, endocrinologists and orthopaedic surgeons) and physiotherapists [12]. The fortogenic health paradigm involves the individual, who is apparently healthy, having no elevated intrinsic risk of pathology, but is interested to adopt physical activity regimes to prevent risk of illness and/or illness and increase quality of life. The health dimensions actively intersect each other, and such the respective medical practitioners. This dynamic trespassing between the health paradigms encourages interprofessional collaborations. **Figure 2** provides a graphic representation of the dynamic overlapping of the different health dimensions and the respective healthcare practitioners. The following scenarios describe the potential trespassing among health dimensions and paradigms and practitioners.

i. Area A displays the intersection of the pathogenic and fortogenic health paradigms, known as the *final-phase rehabilitation,* or *post medical phase* (**Figure 2**). During this phase rehabilitation consists exclusively of physical activity and condition as the primary therapeutic modality. A popular example would be a cardiac patient who is on prescribed

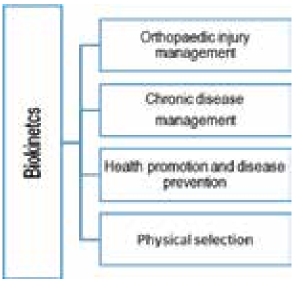

Figure 1. Scope of profession of biokinetics.

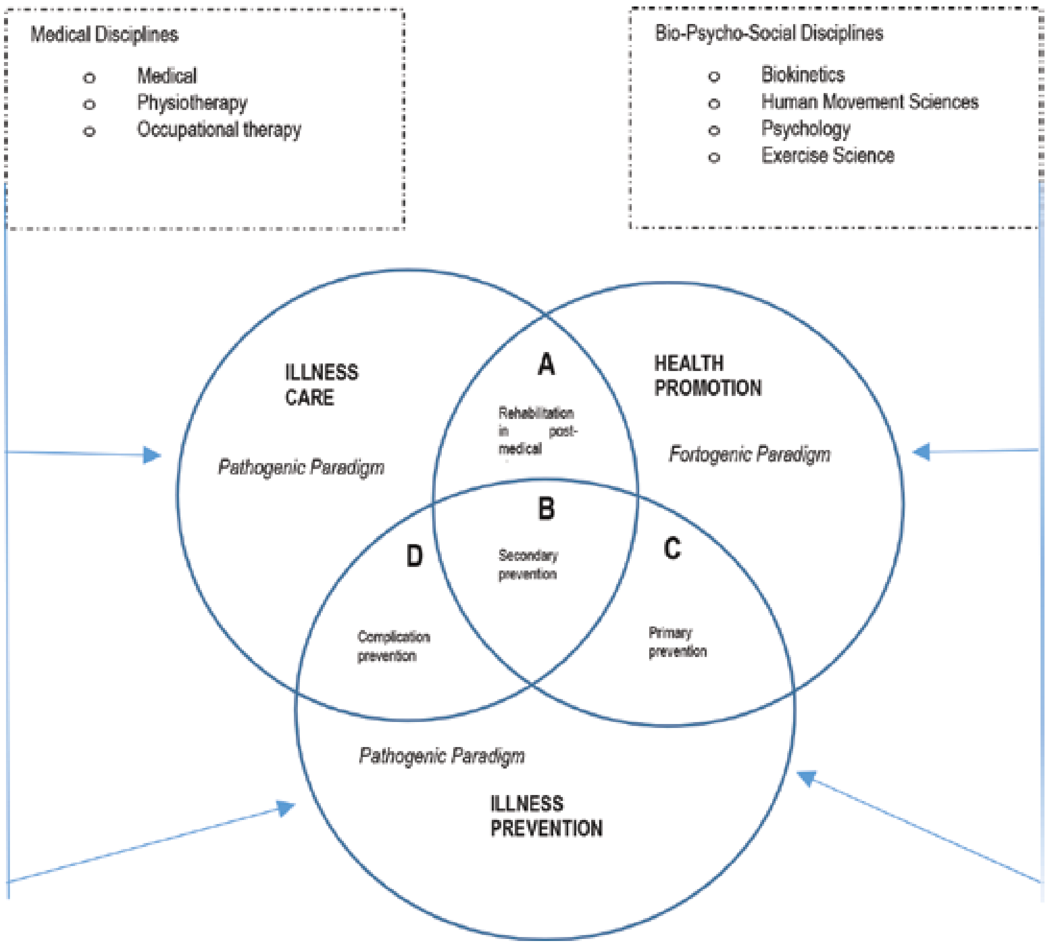

Figure 2. Articulation of the health dimensions in the health paradigms [10].

medication, undergone physiotherapy and lastly is referred to biokineticist [11]. The biokineticist aims to enhance the patient's cardiorespiratory function, quality of life and encourage independent living through structured exercise and physical activity.

ii. Area B is known as *secondary prevention*, where the patient has a pathology, who has underwent medical treatment and/or surgical intervention and has since engaged in final-phase functional rehabilitation (Area A) to prevent the predisposing pathology from deteriorating and/or developing co-morbidities. Referring to the previous example of a cardiac patient who has successfully undergone cardiac surgery, followed by physiotherapy and then the subsequent referral to a biokineticist. The objective of the biokinetic rehabilitation would be to encourage the patient to maintain a physically active lifestyle (within safe guidelines) to avert the recurrence and/or development of co-morbidities. Many cardiac patients are keen to live physically active lifestyles, through the pursuit of enjoyable physically active games and sport (*recreational therapy)* [11]. Biokineticists functioning as recreational therapists prescribe enjoyable games, sport and physical activity regimes to engage the patient in enjoyable movement simultaneously gaining the health benefits that they would have received from a rigid clinical rehabilitation programme [10]. These patients would need to have regular cardiorespiratory evaluations to determine the status of their cardiorespiratory function and whether the exercise therapy is effective. This interaction forces interprofessional collaboration between cardiologists and exercise therapists.

iii. Area C refers to instances when a person is healthy, illness free, neither having any predisposition to risk of pathology and wants to use physical activity as a proactive protective mechanism against illness and risk of illness (primary prevention). Such individuals seek the expertise of biokineticists to prescribe a physical activity programme to increase their physical conditioning and quality of life.

iv. Area D known as *complication prevention* occurs, when a patient has no pathology, but is at high risk of developing a pathology due to an unhealthy lifestyle (**Figure 2**). Such a patient would require the prescription of physical activity to diminish the predisposing risk profile. People are subjected to modifiable (excessive alcohol consumption, smoking, diet, physical inactivity and stress) and non-modifiable (age, gender, genetic disposition) risk factors which adversely influence their cardiorespiratory status and cardiometabolic profiles. The salutogenic effect of exercise and movement helps to lower the modifiable risk factors, improves quality of life and prevents premature morbidity and mortality [12]. The patient falls within the illness prevention dimension, which is an extension of the ill care dimension of the pathogenic paradigm. This patient requires the interprofessional collaborative expertise of medical discipline (general practitioners, nurses, medical specialists (such as cardiologists, orthopaedic surgeons and endocrinologists) and physiotherapists) and the bio-psych-social discipline (biokineticists, dieticians and psychologists) [13, 14]. Diabetic patients are common examples of patients who adopt a therapeutic exercise programme to prevent the further metabolic deterioration [15].

3. National statutory and professional bodies

In this section the HPCSA and Biokinetics Association of South Africa (BASA) affiliations of the profession will be reviewed.

3.1. Health Professions Council of South Africa (HPCSA)

The profession of Biokinetics is a health related discipline, which is affiliated to the HPCSA formerly known as the SAMDC. In the late 1990s, the then SAMDC underwent reorganisation, resulting in the formation of 12 health professional boards that are intended to guide the various health professions, as the motto of the HPCSA is *to protect the public and guide the profession* [8, 16]. Health professions with a related scope of profession were congregated under a specific health professional board. In 1998, the Professional Board of Physiotherapy, Podiatry and Biokinetics (PPB) was formulated to safeguard and serve the interest of the public and chaperon the aforementioned professions consequently [16]. Subsequently, in 1999 the SAMDC changed its name to the Health Professions Council of South Africa (HPCSA) [7, 8, 16].

3.2. Biokinetics Association of South Africa (BASA)

On 17th October 1987 in Potchefstroom, the South African Association of Biokinetics (SAAB) was instituted, with its inaugural office bearers being elected. These office bearers were Prof. G.L. Strydom (President) (Potchefstroom University for Christian Higher Education), Prof. J.M. Loots (Vice-president) (University of Pretoria), Prof. M.F. Coetzee (University of Zululand), Dr. J.F. Cilliers (South African Defence Force), Dr. D. Malan (Potchefstroom University for Christian Higher Education), Ms. M. Delport (Potchefstroom University for Christian Higher Education) and Mr. H. Daehne (University of Pretoria) [7]. Subsequently, the nomenclature of the SAAB was transformed to the present BASA [8]. The principal purpose of BASA is to serve its constituent biokineticists, intern biokineticists and the student biokineticists-in-training [16]. Annually HPCSA registration of biokineticists is compulsory to gain eligibility to practice. Without HPCSA registration it is a criminal offence for biokineticist to practice. However membership of BASA is optional and the professional can practice, without annual registration but does not enjoy any benefits of the professional association (BASA).

4. Education and training

In this section the two pedagogic models, tertiary training institutions and academic curriculum is presented. Presently, there are two pedagogic models adopted by the 12 South African universities that provide biokinetic training.

4.1. The twin pedagogic models of training

There is the former model (3 + 1 year model) and the new 4 year professional degree. The former Biokinetics degree entailed a three-year undergraduate degree in Human Movement Science or an equivalent (such as Human Kinetics and Ergonomics) followed by a post graduate honours degree specialisation in Biokinetics (3 + 1 year model). During the post graduate year of study, being the student's 4th year, the incumbent begins their 2 years of professional clinical internship [8, 16]. During the post graduate honours year, students are obligated to affiliate with the HPCSA and BASA as a *student biokineticist-in-training*, providing admissibility to commence their professional clinical internship. A student *biokineticist-in-training* is in the process of completing a Biokinetics degree. During the fifth year, the *student biokineticist-in-training* must then affiliate himself/herself with BASA and the HPCSA as an *intern biokineticist* [10]. An *intern biokineticist* is a post graduate student biokineticist who has successfully completed his/her academic university requirement of the Biokinetic degree, but is presently concluding the ultimate year of professional clinical internship. An intern-biokineticist must secure professional clinical internship at either private Biokinetics practices or biokinetics training institutions (universities and SADF), which are endorsed by HPCSA and BASA. Presently, professional clinical biokinetic internship is not accessible in the South African public healthcare sector. During this year, the *intern biokineticist* may receive a salary as per the incumbent's negotiation with the biokineticist providing the clinical internship opportunity.

4.2. Tertiary training institutions

There are many South African Biokinetics tertiary training institutions viz.: the North-West University, University of Venda, University of Johannesburg, University of Free State, University of Pretoria, Tshwane University of Technology, University of Zululand, University of Kwa-Zulu Natal, Nelson Mandela Metropolitan University, University of Stellenbosch, University of Western Cape and the University of Cape Town. The Nelson Mandela Metropolitan University, University of Venda, University of Johannesburg, North-West University and University of Free State have already instituted the new professional 4 year degree, while the other seven tertiary institutions are preparing to follow suit [8].

5. Academic curriculum

Figure 3 illustrates academic curriculum of the 3 + 1 year model.

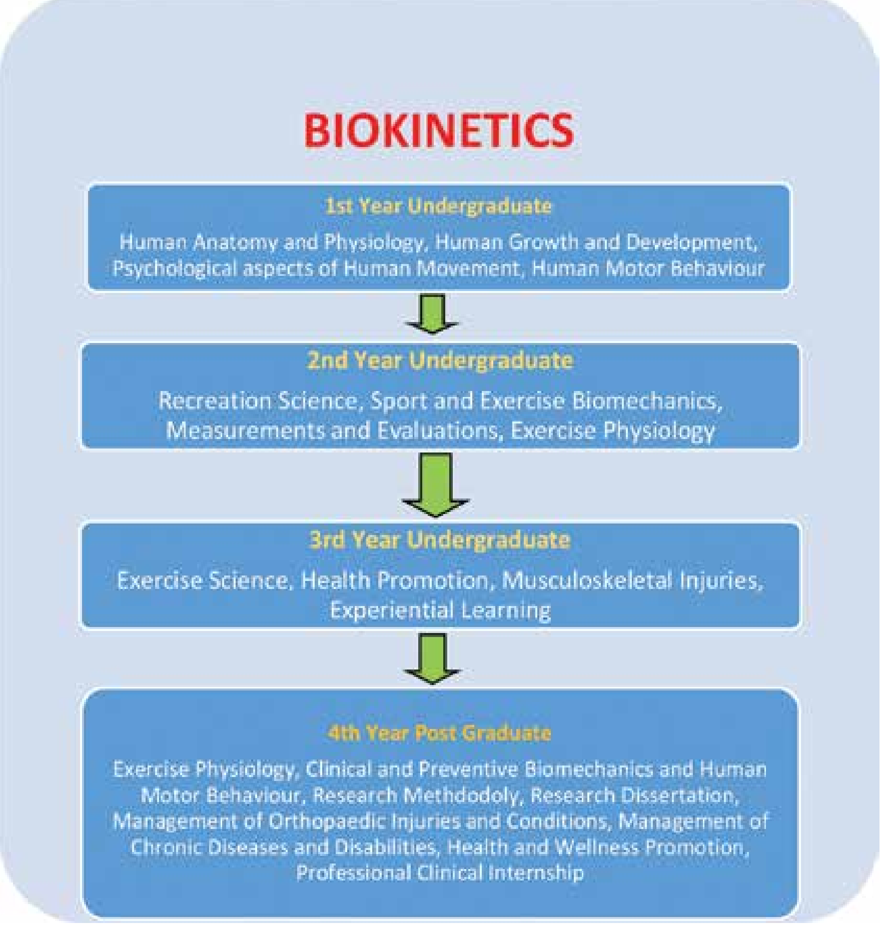

Figure 3. An illustration of the academic curriculum of the Biokinetics: 3 + 1 year model [17].

6. Occupational career opportunities

In the discussion of biokinetic career opportunities national and international prospects will be reviewed.

6.1. National career opportunities

Presently biokineticists are only eligibility to practice in the South African private healthcare sector. There are on-going negotiations for biokineticists to be allowed entrance into the public healthcare sector. Despite this challenge, Moss and Lubbe have reported that there is a viable private healthcare biokinetic patient market [18]. South African biokineticists predominantly operate in private biokinetic practices, corporate wellness programmes, private school and the SADF. Private biokinetic practices and biokineticists employed by SADF generally mange the orthopaedic and sport injuries, clinical rehabilitation of NCDs and disabled patients and feverously campaign the salutogenic effects of exercise. Many private schools employ biokineticists to rehabilitate and guide their sport teams, physical educators and sport co-ordinators.

Prominent South African corporate companies have engaged the expertise of biokineticists to manage the health status of their employees, as part of a multidisciplinary medical rehabilitation team [19]. The multidisciplinary team includes medical doctors, nurses, dieticians, occupational therapists, speech and hearing therapists and biokineticists. Large South African companies and their medical insurers have developed medical schemes such as the Med Benefit and Discovery Vitality assessments, aimed towards health and wellness campaigns, which mutually benefit the employers (company), employees (patient) and the medical insurer. Employees receive expert nutritional, exercise and health advice to empower them to adopt a healthier life. The company benefits healthier employees, who are absent less thereby increasing productivity [19, 20]. The medical insurers lessen their financial numeration to employees/patients who receive biokinetic and occupational rehabilitation to manage NCDs and occupational musculoskeletal related injuries due to the enhanced health of their patients. Large South African companies such as inter alia BMW, ABSA Bank, First National Bank, SASOL, Mondi Unlimited, have established multidisciplinary health and wellness centres at work residence to inspire employees to live healthier lifestyles. These corporations have embraced the salutogenic effect of exercise.

6.2. Present international collaborative relationships between biokinetics and other exercise therapy professions

The following section demonstrate the capability of biokineticists to practice as exercise therapists in other countries, adding value to the health and well-being of society [20, 21]. International career opportunities for biokineticists currently exist in Namibia, Australia, New Zealand, and the United Kingdom as clinical exercise physiologists. Further many biokineticists practice as personal trainers in South Africa, United States of America, Namibia, United Kingdom, Australia and New Zealand.

http://dx.doi.org/10.5772/intechopen.73126

6.2.1. Namibia

At this time Namibia is the only other country that allows biokineticists to practice as biokineticists. The biokineticist requires a work permit and registration with the Allied Health Professions Council of Namibia (AHPCN) and Biokinetic Association of Namibia (BAN) (AHPCN, 2017, Act 55 of 2004: RN 105 & 106) and completing a compulsory Council examination [22]. These Namibian biokineticists practise in the private sector, among corporate businesses, private practices, health and fitness centres, and schools. Their eligibility to practice in the public healthcare sector is also not yet forthcoming [23].

6.3. Clinical exercise physiology (CEP)

International biokinetic career opportunities exist for biokineticists to practice as *clinical exercise physiologists* in Australia, New Zealand and the United Kingdom. Biokineticists need to attain recognition of prior learning and then complete the respective national entrance board examination. However a clinical exercise physiologist's scope of profession includes the following health care services: (i) chronic disease rehabilitation, (ii) the management of predisposing chronic disease risk factors, (iii) the propagation of an active and healthy lifestyle, (iv) enhancing the ease of elementary daily activities, and (v) fostering continued physical, social, and economic independence [24, 25]. There is no professional biokinetic association in the USA, United Kingdom, Australia or New Zealand, nor is the profession of Biokinetics registered with the respective national health and medical statutory bodies. Ellapen et al. reported that although CEP and Biokinetics share similar educational curricula and management strategies, CEP focuses on the management of NCDs while Biokinetics rehabilitates both clinical pathologies and orthopaedic injuries in the pathogenic paradigm and enhances the quality of life in the fortogenic paradigm [25]. While the scope of profession of CEP is more limited than that of biokineticists, the ability to practice as a CEP nevertheless presents a lucrative opportunity, allowing biokineticists to practice internationally.

6.3.1. Botswana and India

While biokineticists practice in Botswanan private hospitals and corporate businesses, there is however no professional body governing the profession of Biokinetics nor registration with the Botswana Ministry of Health [26]. Marias reported that there is a need for biokinetic rehabilitation in Botswana in order to improve the country's quality of life [27]. Anecdotal reports of Indian and Botswanan universities expressing interest in the profession of Biokinetics have circulated, but no firm steps have been initiated. Collaboration between BASA and the interested universities need to be undertaken so as to create an undergraduate degree in Biokinetics, which, it is hypothesised, will pave the way for the establishment of Indian and Botswanan Biokinetic professional bodies. The registration of these bodies with the respective national health and medical statutory bodies coupled with the formalisation of a national Biokinetic undergraduate programme will in turn create better career opportunities for biokineticists in Botswana and India.

7. Conclusion

Table 1 provides a synopsis of the profession of biokinetics, adopted from Paul et al. [28].

BIOKINETICS	
Professional description	Therapeutic exercise scientist
National emblem of BASA	BIOKINETICS SA LIFE THROUGH MOVEMENT
Teaching and Learning	
Duration of professional degree	Former model: 4 years (3+1 year model) New vocational model: 4 years
Academic curriculum	Human Anatomy and Physiology, Kinesiology, Biomechanics, Statistics and Research Methods, Rehabilitative Exercises, Administration and First Aid, Aetiology and Rehabilitation of Orthopaedic Injuries, Pathophysiology and Rehabilitation of Hypokinetic Disease, Epidemiology and Salutogenic effects of Exercise
Professional Clinical Internship	
Professional clinical internship	Conducted under the supervision of a registered biokineticist/physiotherapist/medical doctor. In the former model: post graduate honours year (4th year) and the 5th year of mandatory professional clinical internship. New vocational model: starts in the 3rd and 4th year of the degree.
Clinical internship	Orthopaedic, geriatric, cardiac, neuromuscular, muscular rehabilitation, health and wellness campaigns, fitness programme prescriptions and physical ability assessment for workers who undertake hard labour.
Professional and Statutory Affiliations and Requirements	
Statutory and professional bodies	HPCSA (statutory body) BASA (professional body)
Conference	Life through Movement (biennial)
Mandatory CPD	Yes
Career Opportunities	
National	Corporate wellness programmes, South African military, private schools and practices, biokinetic training institutions and high performance centres.
International	Namibia In USA, United Kingdom, Canada and Australia as CEP once the incumbent pass the entrance board examination.

Table 1. Synopsis of the profession of Biokinetics.

Acknowledgements

The authors would like to acknowledge the support, encouragement and funding from the North-West University, South Africa.

The authors would like to thank Proff. Awie Kotze (Dean of the Faculty of Health Science, North-West University) and Hans De Ridder (Director of the School of Human Movement Science, North-West University) for their tremendous support and encouragement.

Conflict of interest

There is no conflict of interest.

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Chapter 3

Diagnosis of Motor Habits during Backward Fall with Usage of Rotating Training Simulator

Andrzej Mroczkowski and Dariusz Mosler

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.71463

Abstract

There are jobs with high risk of a fall. It seems reasonable to create a device for diagnosis and improving safe fall skills for workers. The aim of the present study was a verification of usability of a rotating training simulator for assessing motor habits during a fall caused by an external force by conducting validation procedure. Material and Methods: the participants were chosen from a group of 128 students of physical education of the University of Zielona Góra. Predictive validity was determined by comparing results of immediate fall test (IFT) to forced fall test (FFT). Repeatability was determined by conduction test/retest conditions. Reliability was also determined by comparing grades given by two observers with those given by an expert. Results: the acquired results show that there were no significant differences between results of IFT and FFT tests conditions and also no significant differences between test/retest conditions separetly for IFT and FFT, alongside with moderate correlation of its results. Good and excellent reliability ICC values were obtained for observers and experts (from r = 0.853 to 1.00). Summary: the obtained results show that the rotating training simulator is a valid and reliable tool for diagnosing motor habits during a fall caused by an external force.

Keywords: accidental falls, safety, biomechanical phenomena, validation studies, ergonomics

1. Introduction

Motor safety of people is important in terms of protection of health. A person can lose his/her health as a result of hitting an object that can mechanically damage his/her body [1]. Falls are very frequent reasons of mechanical injuries to a human body from the youngest one [2] to the elderly [3]. According to the WHO definition of a fall, it is a result of a sudden loss of balance and changing a body position from vertical to horizontal [4]. The loss of balance can be a result of involvement of an external force, for example, pushing or hitting [5]. The loss of balance by an external force, for example, a centrifugal force in a curvilinear motion, can be facilitated by a slippery surface [6]. Even trained people from special services may fall. Up to 20–30% of injuries of firefighters, around 10% of EMS employees, 20% of policeman nonfatal injuries are caused by a fall [7, 8]. A consequence of balance loss can be a fall, which does not necessarily lead to an injury. When falling, trained people can control their body activities adequately to the fall direction [9] and proper reaction of the body during a fall can be practiced, which is shown in numerous research results [10, 11]. After several training courses in safe fall techniques, which are most frequently based on martial arts methodology, human susceptibility to injuries during a fall can be improved. Thus, through an adequate training, we can increase motor safety of a person. Kalina and Barczyński defines motor safety of a person as consciousness of a person undertaking to solve a motor task or consciousness of a subject who has the right to encourage this person to do this or even enforce it, who will be able to do it without the risk of losing life, injuries, or other adverse health effects [11].

The most dangerous are falls performed backward [12]. If a person's front is moved to the direction opposite to the direction of the motion, then this person is unable to see the circumstances that cause a fall. Very often, the reason of falling backward is a slip [13]. As some authors report, slips or trips account for 50% of all falls [14].

There is a non-apparatus test measuring susceptibility to body injuries during a fall designed by RM Kalina [15]. By assessing a way to lie down, he determined probability of occurrence of an injury when falling backward. He puts scores based on committing errors while lying down, which determine which body parts are most prone to injury in real life situation. This idea was a point of reference to process of its evaluation.

1.1. Biomechanical aspects of backward fall

One of the first attempts of biomechanical analysis of a men's fall on the ground were presented by Jaskólski and Nowacki [16, 17]. The mechanical energy of moving man consists of kinetic energy $E_k = mV^2/2$ and potential energy $E_p = mgh$. If center of gravity of a man is lowered because of a fall, it results in increase of kinetic energy due to lowering potential energy

$$mgh_2 - mgh_1 = mV^2/2 \tag{1}$$

If the man has a certain velocity of V_0 before a fall, then the formula for kinetic energy of the movement while hitting the ground takes form of:

$$mV^2/2 = mV_0^2/2 + mgh_2 - mgh_1 \tag{2}$$

where m is the body weight, h is the height of the man's center of gravity (h_2—before the fall, h_1—after the fall), and g is the gravitational acceleration.

From biomechanical point of view, that segment of a body part model is a velocity, which specific body segments are gaining during a fall depends on their initial height. Velocity acquired by head's center of mass V_g will be higher during a fall than for trunk's center of mass V_t (**Figure 1**).

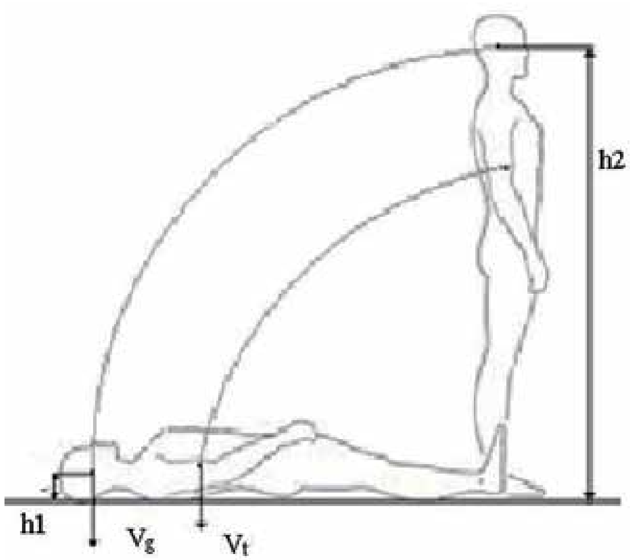

Figure 1. Changes in velocities of body segments during a backward fall.

Jaskólski and Nowacki analyzed the deformation energy of a human body during a fall. They assume that body surface is homogenous and resilient. They assumed that all of kinetic energy of a faller comes from deformation energy. They established a formula for deformation energy per volume unit of human body.

$$e = \frac{k}{t^2 S^2} \tag{3}$$

where *S* is the surface affected by the force during collision with the ground, *t* is the time of deceleration during the collision, and k the values a man does not have any influence on during a fall.

Obtained formula (3) justified that deformation energy per the volume unit of the human body could be reduced during a fall by increasing area of contact with the ground, as well as time of this contact. Similar conclusions were formulated by Reguli and coauthors [18], pointing out necessity of distribution of the forces during a fall to the biggest possible area and suppressing a fall in possibly longest time.

Biomechanical analysis of a fall presented by Jaskólski and Nowacki does not include analysis of deformation energy of human body while performing a rotational motion on the ground.

In sport disciplines, where falls are on daily basis, this pattern of movement is very common. Biomechanical analysis of falls performed by rotational motion on the ground was conducted by Mroczkowski [17], who compares human body during rotational motion to a rolling wheel. He gets the following formula:

$$mV_0^2/2 + mg(h_2 - h_1) = mV^2/2 + Iw^2/2 + s\, f_t N/R \tag{4}$$

where m is the body weight, h is the height of the man's center of gravity (h_2—before the fall, h_1—after the fall, g—gravitational accelerations, V—velocity of the center of a man's gravity (V_0—before fall, V—after fall), f_t is the sliding friction coefficient, N is the contact force, R is the radius of the circle on which the subject is moving, and I is the moment of inertia and w is angular velocity.

Analysis conducted by author (or rather its summary) results in conclusion that during such fall, deformation energy of human body per body part volume contacting with the ground may be reduced by lowering time of contacting of the body with the ground and extending area of contact of body parts with the ground. Lowering the time of contact with the ground could be achieved by increasing velocity in certain limits. Increasing circle's radius on which fall is performed is a factor, which increases a contact area with the ground. I causes lesser friction force of rolling faller, which is responsible for inelastic deformations of the body. Velocity of a faller in such manner, compared to fall without movement is lesser, which states in formula 2. It happens due to change of potential energy not only by rotational movement, but also by its progressive aspect. Adopted movement model in formula 4 assumes that person performing a fall did not fight for maintaining a balance. His movement model is similar to a ball thrown from a certain height, which is rolling on the ground afterward. But it is common for humans to defend from falling by activating muscles accordingly. In that case, formula 4 needs to be completed, by including a certain kinetic energy, which person gains before a fall. Then, we get this formula:

$$mV_0^2/2 + mg(h_2 - h_1) = mV^2/2 + Iw^2/2 + s\, f_t N/R + W \qquad (5)$$

where W is the work done by a muscles, which suppress a fall.

1.2. Techniques of backward falls

Techniques of falling, thought in certain sport disciplines, could be put into two kinds:

1. First one: fall performed in a way similar to gymnastic backward roll (**Figure 2**)

Habit of such fall could be obtained during teaching backward roll in a program of physical education classes in a school or in gymnastic-related disciplines. In a rolling phase through the head, it is necessary to perform dynamic extension of upper limbs, which will result in elevating shoulders and trunks upward. Line of performed roll is indicated in an end phase by the head. There are forms of performing a fall, where rolling is performed by shoulder line, not by the head and extending upper limbs. This form could be seen in handball or volleyball players.

2. The second one: fall performed backward with side aligning of the body

Rolling is starting from more retracted leg, which is aligned to the side. This leg was bend accordingly, in a way that will form a circle with the line of contact. Body movement imitates a rolling ball. Whole line of a body contact with the ground forms a circle. From **Figure 3**, it can be seen contact begins with, e.g., left leg, then on a buttocks goes to the right shoulder

http://dx.doi.org/10.5772/intechopen.71463

and ends up on right upper limb. Upper limb forms a bow, so line of contact of the body with the ground may remain as a circle. This method of falling is often described in martial arts [19–21].

This way of performing fall is commonly used during a training of defend kind of special forces, football players, speedway riders, etc.

There is no empirical studies comparing those two methods of falling in a biomechanical aspect in terms of sustaining possible injuries of the body during a fall.

Figure 2. Fall backward by rolling over.

Figure 3. Side positioning in a backward fall.

Mroczkowski [17] highlighted importance of length of line of contact with the ground, so the first contact will not be collision at the same time. It is better to start movement in a manner, which allows falling with a bigger radius R, which explains formula 4. Going beyond the line of circle with specific body parts may result in hitting the ground and increasing strains on them. For example, hitting with the pelvis griddle at the beginning of a fall may result in occurrence of inertia forces on specific body parts. These forces are especially dangerous for the head and may result in its hyperextension.

While side falling, circle's radius R is bigger than in the other way of falling, because it starts at the feet. The bigger a radius of the circle is, the lesser is the rolling friction, as well as deformation energy per volume unit. With this kind of fall, it is required to retract one leg. In a case when this movement is delayed, it may result in a fall on the pelvis griddle causing unsymmetrical distribution of forces while hitting a ground.

For the first kind of fall, contact with the ground begins with buttocks. In a moment of contact with the ground, the pelvis griddle's strain is distributed evenly. The problem is a big knee flexion, to avoid big strain on the buttocks while hitting the ground.

While conducting biomechanical analysis, it is important to include a direction of velocity, with which foot hits a ground [17]. If part of vertical velocity is significantly bigger than horizontal one, for example during fall from height, it is important to land on both foots evenly. It follows that forces, which put strain on hip joints, need to be similar. Only after fulfilling these criteria, one can perform rolling in a circle-like movement.

This case could occur in for example falls during jumps on trampoline. In that case, it is strongly advised to apply first kind of falling technique. After landing, there is no time for additional lower limb movement.

On the other hand, when there is a big value of horizontal velocity component compared to vertical one, it is important to align body as fast as it is possible, so a contact with a ground will be proceeded by rolling over, forming a circle [17]. In such condition, there will be no harm to a pelvis griddle due to unsymmetrical load of hip joints, because vertical velocity component during a fall will not be big. We can conclude from this analysis that in such case, it is recommended to use techniques based on falling on the side, with assumption, that foots are not blocked during a movement of the body.

In both methods of falling, practitioners of martial arts or combat sports often obtain a habit of hitting a ground with hand with proper angle. Hitting a ground could reduce kinetic energy, with which human body segments hit the ground [22, 23].

But for people untrained in falling techniques, it is common to extend and arrest hands during backward fall, which is considered as error [24]. It may result in fractures or serious joint injuries in upper limbs. This reflex is especially dangerous during jumps on trampoline.

During a competition in martial arts and combat sport, it is not always possible to roll over in a circle movement back to vertical position. During fight between two judo competitors, they try to restrict opponent movements, which is a reason why during a fall, they try to disperse collision energy by hitting the ground. During backward falls (koho-ukemi) and side falls (yoko-ukemi) [22, 23] taught in judo, it is crucial of proper performance, to contact the ground with the biggest possible area alongside with properly hitting the ground with a hand to reduce collision energy.

Competitors in martial arts hit the ground with their hand automatically, even if there was possibility to make full rolling over movement, to reduce collision energy. They cannot be certain if opponent allows them to perform full rolling movement and regain vertical stance, because they might be for example held. However, it is important to notice, that fights and hits are performed on mattress, and not, e.g., on concentrate floor. Theoretical considerations described above require empirical verification.

1.3. Rotating simulator as an device for training of rotational motion

For practicing of falls for experiment participants, rotating training simulator was applied (patented) [25]. The rotating training simulator includes an induction three-phase motor driving simulator base in rotational movement. Replaceable additional platforms and vertical bars could be installed to simulator base. Rotating simulator allows to improve motor habits connected with performing rotational techniques. While performing rotational techniques, it is important to adopt sense of balance to changes in angular velocity during rotational movement and acceleration affecting the body alongside that. Rotating training simulator could be a tool for improving sense of balance of a competitor, who is preparing to apply techniques, which involves greater physical abilities [26].

Rotating training simulator can teach how changes in body position may affect acquisition of different angular velocity during rotational movement of a man. It could indicate moment of inertia for determined positions while performing rotational techniques. This way of experimental explanation of laws of rotational movement mechanics might result not only in faster understanding in physics education, but also enhanced process learning process of motor actions qualified as rotational techniques. These assumptions were made while teaching specific rotational techniques of aikido [27, 28]. Rotating training simulator is a device that can be used for training of falls by creating centrifugal force.

Mroczkowski states [17] that one of the important factors increasing forces that may cause a fall is that which causes sudden change in direction of movement. Transfer from a rectilinear movement into a curvilinear movement increases the effects of external forces that are responsible for a fall. At the moment of changing a movement direction, a force of inertia occurs.

The person in such a movement is affected by a centrifugal force, with which a small friction force of a surface can result in slipping. Besides that, while being in curvilinear movement of body segments, especially during rotational movement, inertia forces affect internal organs. Angular accelerations affect sense of balance, forcing men to certain reactions. Slowing these reactions for sudden changes in rotational movements—for example in sports—could lead to a fall.

Rotating training simulator could be used to scientifically observe ways of controlling the body during loss of balance and fall of a man, who stays in relative immobility. These simulations did not only refer to situation when person is sitting in a stopped car and someone hits it with another car, but also bus passenger who stays during ride and bus hits something. In certain simplification of reasoning, falls from rotating training simulator could be simulation external forces, which cause a fall of anybody (being hit by running animal or person, sudden landslide, etc.). Rotating training simulator, applied in training of safe falling, could intensify effects of learning and lead to improving of motor safety of training people.

This device could greatly contribute in expanding our knowledge about phenomena of rotational movements of the human body and adaptations to motor action with frequent occurrence of certain situations. Probability of being in such situation unwillingly concerns especially soldiers, policemen, firemen, etc. That is why rotating training simulator could find its application value as a device enhancing a training of employees of such services.

1.4. Description of rotating training simulator during fall exercises

Figure 4 presents application of the simulator for the needs of the author's experiment. The rotating disc has a board fixed to it, which is at least 2 m long. The rotating disc can be accelerated to a chosen rotational frequency.

Near the rotating disc, there were two locks placed (**Figure 4**). After switching the drive off and displacing the end of the board on which a subject was standing, a locking pin was released, sticking upward. The board is also provided with rubber bumpers into which the sticking out pin bumps when the board is in move. The first pin causes an abrupt stop of the board motion, whereas the other limits its motion in the opposite direction after it hits the bumper (**Figure 5**). A braking switch is on the control panel.

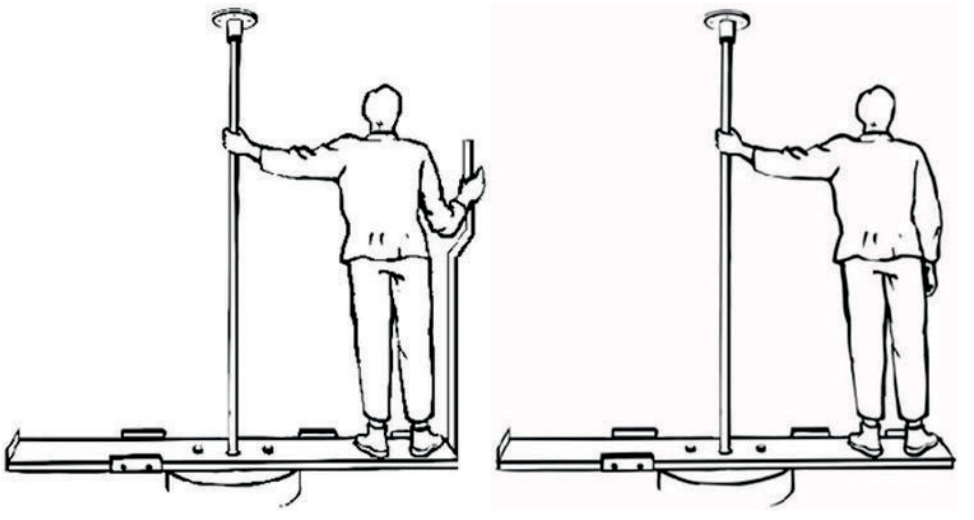

Figure 4. Method of setting the position by a student at the moment the board bumps into the first pin (version with and without the additional pipe).

Its activation causes transfer of voltage onto the motor, which stops the rotary motion of the disc with the board. This switch played an important role in the experiment, especially when participants lost their balance and jumped down when the disc was being driven into the desired frequency. The switch stops the board. The additional factor causing a fall was the fact that after the board bumped into the first pin, it moved in the opposite direction to the person's fall (**Figure 5**). The electrical system applied with an encoder made it possible to measure the frequency of rotations and the angle of the platform rotation on the control panel as well as to record data on a PC [26].

To provide safety of the students exercising on the platform, mats were placed around the apparatus. The subjects fell off the board on two layers of the mats. The bottom layer was composed of 7 cm thick hard mats, whereas the upper layer consisted of softer mats, 10 cm thick.

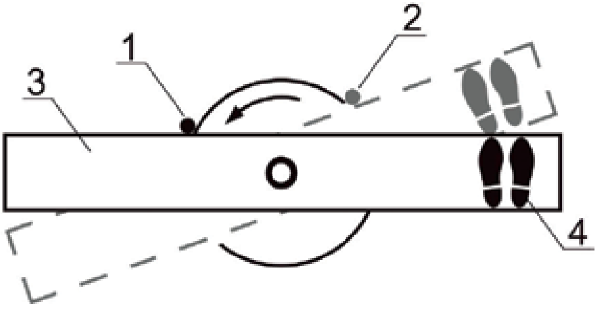

Figure 5. Method of stopping the board as a result of bumping into the pins. Key: 1—first pin, 2—second pin, 3—board, and 4—place where subject's feet are put.

Participants exercising on rotating training simulator were wearing protective headgear similar to that used in combat sports. Additionally, in the first tests on the rotating simulator, the participants were wearing shin protection gear. If the expert supervising the test concluded that the subjects' behavior did not involve any risk, they were allowed to use shin protectors if they wished. Maintaining balance by a subject while on the rotating disc was simplified by constant and relatively low acceleration of the disc. The value of acceleration was selected in a way that would not cause any balance disruptions or eventually its loss.

While the board was being accelerated, the participants were allowed to hold on to two pipes (**Figure 4**). Using the second pipe was not necessary, as shown in the "relative immobility" movie attached to the article, which explained the mechanism of the rotary trainer [26]. If the balance of a person was uncertain, the second pipe was attached upon the subject's request. The participants signed a formal consent for participating in the tests of this experiment.

A subject assumed the position as shown in **Figure 4**. After reaching the required rotational frequency and after the first pin acted, the subject let go of the pipe. There was a sound signal to release the pipe at the moment the first pin was activated. During the first pin activation, the inertial force worked on the tested person. At the same time, the board moved away in the opposite direction to the direction the person was moving until it bumped into the second pin (**Figure 5**). This caused additional balance disturbances of the tested person. As a result of the collision, the angle of the board displacement depended on the place where the second lock was fastened to the surface. The outside leg (**Figure 5**) moved approximately 40 cm away. Such a board move can be a good simulation of a foot slipping when walking on a slippery surface.

1.5. Analysis of the force causing a fall

When the board with a person exercising on it stops abruptly, there acts a resultant of the inertial force, as presented in **Figure 6**.

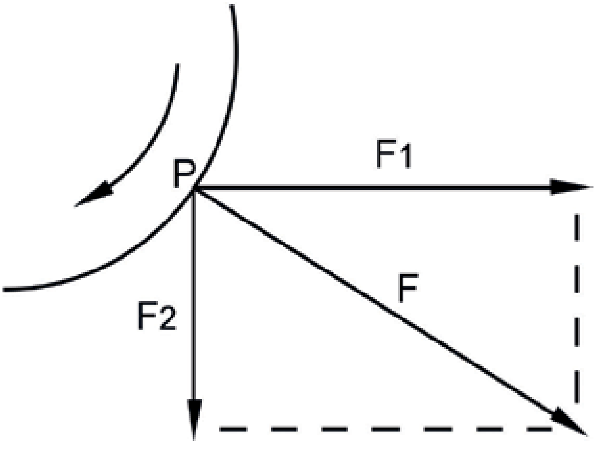

Figure 6. Distribution of forces causing a fall of a person exercising on the rotating training simulator.

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Inertial force F_1 is a centrifugal force acting on the tested person and it is calculated with the formula:

$$F_1 = \frac{mV^2}{r} \tag{6}$$

The force F_2 resulting from the sudden decrease in the linear velocity value V of the tested person due to the board bumping into the first pin is calculated following the formula:

$$F_2 = -ma \quad \text{or} \quad F_2 = -\frac{m\Delta V}{\Delta t} \tag{7}$$

The resultant force F is calculated as follows:

$$F = \sqrt{\left(\frac{mV^2}{r}\right)^2 + (ma)^2} \tag{8}$$

The bigger change resulting from changes in the frequency of rotations is brought about rather by the force F_1 than F_2, because after the formula transformation, we find that its value depends on the rotational frequency f squared

$$F_1 = m\omega^2 r \quad \text{or} \quad F_1 = m4\pi^2 f^2 r \tag{9}$$

Thus, the resultant force F acting on the tested person increases significantly as a result of an increase in the rotational frequency. The total inertial force that acts on the person making a fall is difficult to calculate because human body is not a uniform rigid body. A change of the human body's linear velocity depends on various factors. However, it is easier to analyze an increase in the centrifugal force value along with an increase in the rotational frequency. The formula referred to herein (9) shows that with an increase in the rotational frequency as presented in the experiment, namely from 0.2 to 0.26 Hz, this force increased by 70%, whereas with an increase to 0.3 its value rose by 125%.

The present chapter shows a validation procedure of the rotating simulator as a tool for testing motor habits of a man during a fall, as well as balance maintenance after a fall. Preliminary results of the validation procedure were presented at the first World Congress on Health and Martial Arts in Interdisciplinary Approach, HMA 2015 [29]. In the study, the authors expanded experimental methods by including simulations of falls that are similar to those occurring in real life situations. The purpose of this study is to show its usability by presenting validation procedure of rotating training simulator device.

2. Material and methods

2.1. Participants

The participants were chosen from a group of 128 students of physical education of the University of Zielona Góra. Participants were divided into two groups. First group of 96 students were randomly selected for test conducted in 2014 and 2015. Second group was composed of 32 participants, selected for conducting studies in 2016 and 2017. Due to criteria of validation procedure, two students performed task correctly, but in different manner regarding determining angles in knee joint. This factor excluded them from the overall analysis due to impossibility of comparison conditions. The students were physically active, often practicing a particular sport discipline with the mean age of 25.4.

In the first group, among all participants, 59 students agreed to participate in forced simulation fall test. Second group included those students, who fall in the first attempt for all applied circumstances, so they were qualified for test-retest circumstances.

There was a formal consent granted by the Bioethical Committee of the Regional Medical Council in Zielona Góra for conducting this research under the number 4/55/2014. The experiment was conducted in 2014 to 2017.

2.2. Assessment procedure

Falls were performed with certain frequencies; f_1 = 0.2 Hz, f_2 = 0.23 Hz, f_3 = 0.26 Hz, and f_4 = 0.3 Hz. In the experiment, the selected frequencies correspond to an average line velocity of a subject's center of gravity: V_1 = 1.0 m/s, V_2 = 1.15 m/s, V_3 = 1.3 m/s, and V_4 = 1.5 m/s, acquired after application of the following equation:

$$V = 2\pi f r \tag{10}$$

The velocity was determined basing on the reports of other authors, who tried to define peak slip velocity which would definitely result in a fall. Strandberg and Lanshammar suggested that a slip over a distance of 10 cm with peak slip velocity above 0.5 m/s could result in a fall [30]. Other authors report that a fall will occur at a peak slip velocity above 1 m/s [31] and even 1.44 m/s for young people [32]. That is why a board run on a longer distance can be compared to loss of balance on, for example, ice or oil spill.

For a subject to have an inertial force act on him properly, it was necessary to assume, after releasing the grip, the posture as shown in **Figure 1**. It was forbidden neither to move feet on the board before it hit the pin nor to lean the body forward. Otherwise, the trial was repeated. All the falls performed by the trainees were recorded by cameras. The positions of the cameras made it possible to view the motor activities both from the left as well as from the right. The way a particular fall was made was assessed by analyzing successive frames.

First task in immediate fall test (IFT) test begin with command "fall immediately." This condition is applied to situations in some sports. For example, football players may decide to fall immediately after action of external force, without fight to maintain balance. This strategy may lower the risk of injury. After tested person perform this task, three body parts were assessed. Errors performed by "head" (hitting a ground), "hands" (supporting while landing), and "hips" (correct is to bend the knee in a value higher than 90°). The same criteria of assessment were applied for IFT and FFT tests. Assessment of knee flexion was performed with commonly used manner in physiotherapy standards [33]. Each body parts were given scores: 1 point for "hip" or "head" error and 2 points for "hands" error, depending supporting on one or both hands. When performing a fall from the rotating training simulator, the participants first jumped off on one foot. Jumping off with both foots was impossible because of a sudden disc movement in the opposite direction after it bounced from the first pin. That is why for assessing body control during a fall, the criteria from the first STBIDF task were taken, counting from the moment when after landing a subject started to loose balance while trying to stand on one leg.

In the same way as in STBIDF test, tested person always entered room of testing separately, to avoid seeing each other during performing exercises on rotary trainer. Experiment was divided into two phases. Firstly, IFT test was performed. Tested person, executed command "fall immediately" directly after desk was stopped and they lose balance due to action of external force. If tested person committed serious "head" and "hips" errors on the lower velocities, they were not permitted to perform on higher velocities because of safety reasons. That is the reason why number of tested subjects decreases alongside with the increased velocity. Secondly, tested persons performed forced fall test (FFT). Same exclusion criteria as in IFT were applied. If tested person maintains balance after landing, such result was not included for specific velocity. After a week, there was retest for the same individuals with the same conditions (test (t1)–retest(t2)) validation procedure.

In order to compare the test results, subjects must perform a fall backward in such a way as to make the positioning of particular body parts properly visible on a freeze frame on XY plane, both from the left as well as from the right. This analysis is possible when the position of the body is similar to the one in a gymnast's back flip (**Figure 3**). It was possible for 98% of the experiment participants. However, some people can perform a fall backward with a lateral body position (**Figure 4**). Such a fall method is used in some combat sports, e.g., aikido, which was presented by Mroczkowski in the film "relative immobility" [26]. Comparing results of tests performed with the above-mentioned body position would be difficult, especially in terms of defining the knee joint angle during a fall.

2.3. Validation procedure

Construct validity is determined by test conditions itself. During the test, tested person falls as a result of losing balance due to action of external force, which is the same reason why people fall in real life situation. People can fall in a different manner, revealing their own motor habits during loss of balance and contact of the body with the ground. For fulfilling predictive validity, two possible responses of tested people were considered. In a first option (IFT), in a moment of balance loss, tested person immediately started to control body movements to eventually lie down safety. In the second option (FFT), tested person falls only if they cannot maintain balance. In a real life situation, people mostly are trying not to fall and they decided to do so in last resort. In those two different options, occurrence of similar motor habit is expected. Readiness to fall immediately or fighting for maintaining balance should not affect a way, how someone is controlling his body movement during collision with the ground. Fall is understood as unintentional balance loss; however, lack of difference between decisions of tested persons regarding undertaken strategy will allow to determine predictive validity. For that purpose, T Student for dependent samples was computed for results of IFT and FFT. Because conditions of FFT did not require, that person have to fall if he can maintain balance, there should be an increase in number of tested persons alongside with the increase of force that causes fall. Increase of fallers alongside with increase in velocity will additionally confirm validity, which simulates real life situation, where forces causing falls are different, and probability of fall is increased when causing force is bigger.

Validation procedure requires confirmation, if test conducted on the device is reliable, so if there is repeatability of results. Comparison of results in a procedure of test/retest condition in a 1 week period was performed, to avoid significant changes in tested persons behavior and experiences. Comparison was performed separately for IFT and FFT. Each of four applied velocities were compared separately. For determining reliability of tests, T Student for dependent samples was applied because of pointing criteria applied in tests. For head and hips errors, there are only 0 or 1 point, where lack of differences between results needs to be done to determine repeatability of results. Additionally, for both test, correlation between results of both test in test-retest conditions were conducted.

For confirming reliability of tests on the device, it was resolved if applied assessment criteria is repeatable by independent observers. Two students of physical educations conducted independent assessment of tested subjects and then, it was compared with an expert evaluation. For revealing such correlation of assessment, intraclass correlation coefficient was computed.

Moreover, presenting a proportion of quantity of participants who falls, to all who participate during FFT, will indicate probability of fall after application of specific force. Participants, who fall at lower velocities, are more likely to fall than people who maintain balance even at higher velocities. Differences in number of fallers will confirm that testing on rotating simulator can not only diagnose motor habits during a fall, but also ability to maintain balance in a moment of its loss during action of external forces.

2.4. Ethical considerations

Ethical points including conduct and reporting of the research, contributions, authorship as well as declaration of Helsinki on ethical principles for medical research involving human subjects were considered.

3. Results

3.1. Predictive validity

For all applied variables for specific velocities, there were no significant differences between points acquired by tested people in IFT and FFT (for first assessment). Alongside with the increase in velocity, there is increase of fallers from 23 people for lowest velocity (v1) to 43 for highest (v4). There is a slight difference between v3 and v4. The lowest difference was revealed for hand errors, while the highest was for hip errors (**Table 1**).

Velocity	Variable	N	Difference	Standard deviation difference	t	Degrees of freedom	p-value	Confidence −95%	Confidence +95%
v1	Hands	23	0.00	—	—	22	—	—	—
	Head	23	−0.087	0.417	−1.000	22.000	0.328	−0.267	0.093
	Hips	23	0.130	0.344	1.817	22.000	0.083	−0.018	0.279
	Sum	23	0.043	0.562	0.371	22.000	0.714	−0.200	0.287
v2	Hands	34	−0.029	0.171	−1.000	33.000	0.325	−0.089	0.030
	Head	34	−0.029	0.171	−1.000	33.000	0.325	−0.089	0.030
	Hips	34	0.029	0.171	1.000	33.000	0.325	−0.030	0.089
	Sum	34	−0.029	0.300	−0.572	33.000	0.571	−0.134	0.075
v3	Hands	42	0.024	0.563	0.274	41.000	0.785	−0.152	0.199
	Head	42	−0.071	0.463	−1.000	41.000	0.323	−0.216	0.073
	Hips	42	0.119	0.395	1.952	41.000	0.058	−0.004	0.242
	Sum	42	0.071	0.973	0.476	41.000	0.637	−0.232	0.375
v4	Hands	43	0.000	0.488	0.000	42.000	1.000	−0.150	0.150
	Head	43	0.023	0.556	0.274	42.000	0.785	−0.148	0.194
	Hips	43	0.093	0.426	1.431	42.000	0.160	−0.038	0.224
	Sum	43	0.116	0.956	0.797	42.000	0.430	−0.178	0.411

Table 1. Test T for dependent samples between IFT and FFT for each variable and all velocities ($p < 0.005$).

3.2. Repeatability

In test-retest conditions in IFT, tested persons did not reveal significant changes between results of repeated assessment. For v3 velocity, number of tested person decreased. The lowest difference was for hand errors. Tested people did not reveal any difference between sum of points for v4 velocity (**Table 2**).

For specific errors of body control, tested people did not reveal significant changes between results of repeated assessments. However, for most of situations (v1,v2,v4), sum of point was statistically significant. For two velocities (v1 and v4), there were no differences between committed hip errors. Revealed difference for hand errors was higher than in IFT. Firstly, at the beginning of increase in velocity, number of qualified person increased, but at velocity v3, it stabilized (**Table 3**).

For sum of all velocities (v1-v4) for both test, all correlations were statistically significant. In IFT, highest correlation was revealed for hip errors ($r = 0.818$). Correlation for IFT had moderate level for hand and head errors ($r = 0.651$ and $r = 0.652$, respectively) and high for hips errors. That is why there is high correlation between sum of point acquired by tested

Velocity	Variable	N	Difference	Standard deviation difference	t	Degrees of freedom	p-value	Confidence −95%	Confidence +95%
v1	Hands	94	0.021	0.206	1.000	93.000	0.320	−0.021	0.064
	Head	94	0.064	0.353	1.751	93.000	0.083	−0.009	0.136
	Hips	94	−0.011	0.274	−0.376	93.000	0.708	−0.067	0.046
	Sum	94	0.074	0.513	1.407	93.000	0.163	−0.031	0.180
v2	Hands	94	0.000	0.388	0.000	93.000	1.000	−0.079	0.079
	Head	94	−0.043	0.357	−1.157	93.000	0.250	−0.116	0.030
	Hips	94	−0.032	0.177	−1.751	93.000	0.083	−0.068	0.004
	Sum	94	−0.074	0.553	−1.305	93.000	0.195	−0.188	0.039
v3	Hands	85	0.012	0.244	0.445	84.000	0.657	−0.041	0.064
	Head	85	−0.012	0.393	−0.276	84.000	0.783	−0.097	0.073
	Hips	85	−0.024	0.308	−0.705	84.000	0.483	−0.090	0.043
	Sum	85	−0.024	0.654	−0.332	84.000	0.741	−0.165	0.118
v4	Hands	83	0.000	0.312	0.000	82.000	1.000	−0.068	0.068
	Head	83	0.012	0.247	0.445	82.000	0.657	−0.042	0.066
	Hips	83	−0.012	0.247	−0.445	82.000	0.657	−0.066	0.042
	Sum	83	0.000	0.584	0.000	82.000	1.000	−0.128	0.128

Table 2. Results of IFT for test(t1) to retest (t2) using T Student for dependent samples.

persons (r = 0.711). For FFT test, tested person revealed very high correlation for hand errors (r = 0.843), but low correlation for hips and head errors (r = 0.373 and r = 0.218, respectively). Still, sum of points acquired for both assessment is strongly correlated (r = 0.774) (**Table 4**).

Values of intraclass correlation coefficients between two student observers (ob1, ob2) and between them and an expert for different circumstances were at good or excellent level. It is a proof of a very high reliability of the test (**Table 5**).

T1, T2–test and retest attempts in IFT; N–number of participants; ob1,ob2—student observers.

While performing first attempt of FFT, for velocities v1 and v2, there were more participants who maintain balance after precipitation. For velocities v3 and v4, there were more fallers than those who maintain balance. There was slight difference between fallers for velocities v3 and v4 (**Figure 7**).

Velocity	variable	N	difference	standard deviation difference	t	degrees of freedom	p-value	confidence -95%	confidence +95%
v1	Hands	14	0.214	0.426	1.883	13.000	0.082	-0.460	0.032
	Head	14	0.071	0.267	1.000	13.000	0.336	-0.226	0.083
	Hips	14	0.000	0.392	0.000	13.000	1.000	-0.226	0.226
	Sum	14	0.286	0.469	2.280	13.000	0.040	-0.556	-0.015
v2	Hands	25	0.200	0.577	1.732	24.000	0.096	-0.438	0.038
	Head	25	0.080	0.277	1.445	24.000	0.161	-0.194	0.034
	Hips	25	-0.040	0.351	-0.569	24.000	0.574	-0.105	0.185
	Sum	25	0.240	0.663	1.809	24.000	0.083	-0.514	0.034
v3	Hands	30	0.133	0.434	1.682	29.000	0.103	-0.295	0.029
	Head	30	0.100	0.403	1.361	29.000	0.184	-0.250	0.050
	Hips	30	0.033	0.183	1.000	29.000	0.326	-0.102	0.035
	Sum	30	0.267	0.521	2.804	29.000	0.009	-0.461	-0.072
v4	Hands	29	0.172	0.468	1.983	28.000	0.057	-0.351	0.006
	Head	30	0.067	0.450	0.812	29.000	0.423	-0.235	0.101
	Hips	30	0.000	-	-	29.000	-	-	-
	Sum	30	0.233	0.568	2.249	29.000	0.032	-0.446	-0.021

Table 3. Results of FFT for test (t1) to retest (t2) using T Student for dependent samples ($p < 0.005$ marked as red).

variable	IFT (n=356)	FFT (n=99)
hands	0.651	0.843
hips	0.818	0.218
head	0.652	0.373
sum	0.711	0.774

Table 4. R Spearman correlation results for sum of velocities (v1–4) for results of test-retest of both IFT and FFT ($p < 0.005$ marked as red).

	V1					
	T1			**T2**		
	ob1–ob2	**ob1–expert**	**ob2–expert**	**ob1–ob2**	**ob1–expert**	**ob2–expert**
	N = 94	**N = 94**	**N = 94**	**N = 94**	**N = 94**	**N = 94**
Hands	0.951	1.0	0.951	1.0	1.0	1.0
Hips	0.941	0.941	0.882	0.934	0.931	0.939
Head	1.0	1.0	1.0	0.934	0.966	0.967
	V2					
	T1			**T2**		
	ob1–ob2	**ob1–expert**	**ob2–expert**	**ob1–ob2**	**ob1–expert**	**ob2–expert**
	N = 94	**N = 94**	**N = 94**	**N = 94**	**N = 94**	**N = 94**
Hands	0.853	0.853	1.0	0.827	0.827	1.0
Hips	1.0	0.934	0.937	0.965	0.962	0.925
Head	1.0	0.968	0.968	0.943	0.972	0.972
	V3					
	T1			**T2**		
	ob1–ob2	**ob1–expert**	**ob2–expert**	**ob1–ob2**	**ob1–expert**	**ob2–expert**
	N = 80	**N = 80**	**N = 80**	**N = 83**	**N = 83**	**N = 83**
Hands	1.0	1.0	1.0	1.0	1.0	1.0
Hips	1.0	1.0	1.0	1.0	1.0	1.0
Head	1.0	0.958	0.958	0.919	0.96	0.96
	V4					
	T1			**T2**		
	ob1–ob2	**ob1–expert**	**ob2–expert**	**ob1–ob2**	**ob1–expert**	**ob2–expert**
	N = 78	**N = 78**	**N = 78**	**N = 78**	**N = 78**	**N = 78**
Hands	1.0	1.0	1.0	1.0	1.0	1.0
Hips	1.0	0.962	0.960	1.0	0.963	0.963
Head	1.0	1.0	1.0	1.0	1.0	1.0

Table 5. Intraclass correlation coefficients between scores given by students (ob1, ob2) and those given by an expert for different tested circumstances in first attempt of IFT. All correlations are significant ($p < 0.05$).

In test-retest conditions, number of participants were lower (n = 32 instead of n = 59). For velocity v1, more than half of participants managed to maintain balance. Between v1 and v2, there was significant increase in number of fallers. For velocities v3 and v4, almost all participants fall, with no difference in number of fallers (**Figure 8**).

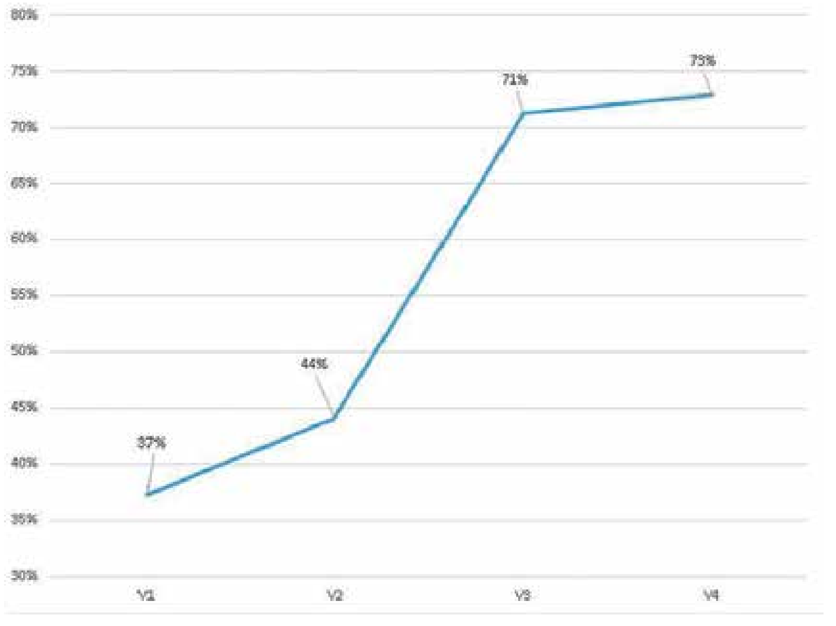

Figure 7. Proportion of fallers to all participants during first attempt of FFT (t1) (n = 59).

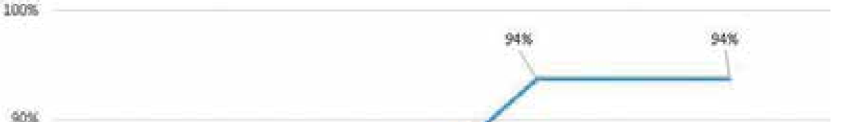

Figure 8. Proportion of fallers to all participants in FFT for test-retest conditions (t1/t2) (n = 32).

4. Summary

Data presented in **Figure 6** confirm that alongside with increase in velocity on which fall occur, there was increase in number of fallers. In formula 8, it states that alongside increase in linear velocity, there is increase in inertia force affecting practitioner and causing a fall. Therefore, increase in a force causing a fall is connected with bigger probability of fall, which is confirmed by obtained results. At the same time, among randomly chosen group of 59 people, which participate in FFT, 73% fell for highest velocity (43 participants). Therefore, 27% of tested people have sufficient balance skills, which allows them to maintain balance after action of external forces during experiment. For the lower velocities, there were more participants who maintain balance. This phenomena confirm construct validity of tests on this device, as this device is creating proper circumstances accordingly to definition of a fall.

Entry studies of authors indicate that there is correlation between probability of fall occurrence in FFT and level of coordination in rotational motion by nonapparatus tests.

For FFT in test/retest conditions, only those participants who fell for all velocities during first attempt were included. The retest results indicate improvement in maintain balance for some individuals (**Figure 8**). Some of participants did not fell for specific velocities, and there were more of nonfallers for lower velocities, when precipitating force is lower.

This process indicates that there was improvement because of acquired motor experience. We can conclude that rotating simulator could be used as a tool for improving balance after its loss during action of external forces as in circumstances created in FFT.

Immediately, there appears a suggestion for a coach, who trains athletes in a specific sports discipline where a risk of a fall is high, to apply a safety fall diagnostics in his work. The diagnosis should be done before the contestants are allowed to compete at a level, where the risk of injury is raised for players without proper abilities of body control during a fall or collision [34].

Application of the apparatus of that kind would be of special importance to people, who in their work may encounter forces responsible for a fall. Such people may, for example, include firemen, soldiers, policemen, stuntmen, or athletes of various sports disciplines. Simulated falls, for example, in full equipment might expose unconsidered disturbances in motor control because of carried equipment or specific uniform. Proper defensive mechanism during extreme situation will work only if trained persons had met similar situations in the past. Acting accordingly during a duty is more like trained habits. The same situation is when someone is exposed to fall, especially in critical situation, like firefight. Moreover, because most of nonfatal injuries caused by falls occur when worker is tired due to prolonged action [8]. Therefore, rotating training simulator would be perfect during their training as supplementary element of training course to improve their competence.

In comparison of IFT and FFT, there were no significant differences between test results (**Table 1**) for errors during control of specific body parts as well as there were no significant differences between conditions of test/retests for both applied tests (**Tables 2** and **3**). Obtained results may justify suggestion, that motor actions of a man during a fall are not random. For tested students, we can conclude that during a fall, there is a motor habit. Improving that habit could lead to reduction of body injuries during a fall. It is right to say that "sustaining injury" is not an unavoidable consequence of fall [24]. Performing certain movements during a fall is possible in certain limits of precipitating forces values [17].

Formula 4 explains that for fall performing during IFT test, that energy during a fall changes into kinetic energy of the motion and rotation and energy connected with rolling friction. For FFT analysis, formula 5 should be applied. While performing FFT, a participant tries to protect himself from falling by proper muscle contractions. As a result, mechanic energy during a moment of a fall is reduced because of work „W" done by muscles, which inhibit a fall. By this work, there is deceleration of fall. This could result in different numbers in "head" errors, as in some cases, kinetic energy of movement may be insufficient to fully roll the body over a head. Although, results of IFT and FFT did not reveal significant differences between committed errors, there is a clear difference in strength of correlation between IFT and FFT for both "hips" and "head" errors (**Table 4**). Because each time value of "W" could be different, as work performed by muscles differs as person fights to maintain balance. From the moment of balance loss due to a slip, a human has around 200 ms to start motor operations leading to an effective control of the body during a fall [35]. A variety of body motor control abilities and changes in reaction speed due to a changing spatial body orientation lead to taking various actions and strategies in order to prevent the body from an injury. An untrained person, in a real life situation, would try to maintain balance at all costs, that is why precipitated, and he would try to regain balance as long as he can [36]. An untrained person would fall if the force applied would be too strong for him to maintain balance [37].

The obtained results (**Tables 2** and **3**) demonstrated, that the rotating training simulator is a reliable assessment tool used for diagnosing susceptibility to injuries during a fall caused by external forces, showing repeatability of the acquired scores. The results demonstrated in **Table 5** show a big application value of the test. Scores given by observers having been instructed about assessment criteria are sufficient to make a reliable judgment about susceptibility of certain body part injuries during a fall of a tested person. A possibility to verify the trainees' performance assessment on the recorded footage and presenting their mistakes to them plus the possibility to rate people's motor control progress both in a point scale and in a visual manner makes rotating training simulator applications corresponding to the idea of complementary health-related training [11].

The presented method of evaluating susceptibility of body injuries during a fall by using the rotating stimulator could be upgraded and expanded by applying proper biomechanics motion capture devices. That kind of gear could allow to measure acceleration of specific body parts during a fall or to analyze changes of angles between joints in a specific moment. Using a mattress during tests reduces accelerations, which occur when the body contacts the ground. Reducing the size (thickness) of mattress might improve accuracy of measurements. But on the other hand, it might be dangerous for inexperienced participants or those with bad motor habits. An advantage of using adequate sensors, like XSENS system [38], would be a possibility to measure accelerations and angles among particular body segments in XYZ dimension. Further analysis will allow to gather knowledge about other body configurations during a fall and check, which is the best for minimizing potential injuries.

In the methodology of a safe fall, it is said that a fall should not take longer than 1/3 of all training session time [39]. Application of rotating training simulator during a training session and elaborating a proper training methodology will be a goal of future studies. We need to take into account the fact that using apparatus assessment tools requires more funds and a special training ground. Advantage of rotating training simulator is the fact that none of the tested people was injured and that the test was carried out by a qualified person who applied the right rotating frequency causing that external forces were not too strong for subjects to cope with and that might result in an injury. Further studies might involve accepting different types of body configuration during a fall, such as the mentioned side configuration (**Figure 3**). This might require changing the assessment criteria of susceptibility to injuries during a fall. Teaching safe falls is given little attention in physical education curricula or treating them as supplementary exercises in sport. Authorities ignore this injury factor for young population and pay no attention to developing practical motor competences that can increase people's safety. It is proved that even children from 10 to 12 years old have a high level of injury risk [40]. Therefore, it seems advisable to take a proper action to teach kids proper motor habits, which will reduce risk of injuries, rather than taking care of them in hospital after accidents.

Acknowledgements

I wish to thank Andrzej Kacprzak for making most of the figures included in the paper.

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Chapter 4

The Missing Science: Ethics in Practice

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.71883

Abstract

The Greeks argued that philosophy was the most important science even though it was a science that studied no things. Their science, philosophy, focused on the meaning of life and death, life after death, existence, knowledge, knowing the good and bad, as well as the application of right and wrong. We argue that what is right and what is wrong should underlie the development of the current book *Sports and Exercise Science*. The stated purposes of the book, "to present the up to date knowledge about etiology, pathogenesis, diagnosis, management and prevention of chronic injuries or sports related long term changes in locomotor system. Moreover, topics about influence of sports activities on growth and development in pediatric population and presentation of acute injuries that often develop to chronic…as well," are topics that should be addressed through science in sports and exercise science—philosophy and ethics. Ethics should govern all science, including the growth and development of sports and exercise science. Injury often occurs because of poor coaching, poor training, or overtraining. The problem exists because of unethical practice of either coaches, parents, leaders, trainers, or a combination of all of them. This chapter focuses on ethical education for professionals, educators, practitioners, and coaches.

Keywords: ethics in sports, coaching ethics, athletic training ethics

1. Introduction

The Ancient Greeks argued that philosophy was the original and most important science even though it was a science that studied no things. Rather, their science, i.e., philosophy, specifically focused on the meaning of life and death, life after death, existence, knowledge, knowing the good and bad, as well as the application of right and wrong. We argue that one of the important questions from the Greeks, what is right and what is wrong, is a philosophical question that should underlie the development of the current book: *Sports and Exercise Science*.

The stated purposes of the book, "to present the up to date knowledge about etiology, pathogenesis, diagnosis, management and prevention of chronic injuries or sports related long term changes in locomotor system. Moreover, topics about influence of sports activities on growth and development in pediatric population and presentation of acute injuries that often develop to chronic…as well," are topics that should be addressed through the lens of the most important science in sports and exercise science—philosophy and ethics. Ethics governs or should govern all aspects of science none more so than the growth and development of sports and exercise science for all populations.

Injury often occurs because of poor coaching, poor training, or overtraining. In all the above cases, the problem exists because of unethical practice of either coaches, parents, leaders, trainers, or a combination of all of them.

Therefore, this chapter will focus on the importance of ethical education for professionals, educators, practitioners, and coaches. We will address specifically:

A. Youth sports practices, the lack of professional preparation of coaches, and the result of over-practice of children in youth sports.

B. The current sports science and kinesiological curriculums that focus almost entirely on "science" and do not address motor skills training, education, or application for preprofessionals.

C. The lack of philosophy and ethics education in preprofessional programs which focus almost entirely on the science.

D. Overzealous parents who focus on youth sports monetarily, physically, emotionally, and socially support it over all other activities, including education.

2. Youth sports practices, the lack of professional preparation of coaches, and the result of over-practice of children in youth sports

A positive youth sports environment is based around an athlete-centered approach that focuses on the growth and development of young people [1]. When administrators and coaches conduct their youth sports programs with an athlete-centered philosophy, youth sports can provide a safe place where a young person can develop skills, learn to compete, and overcome limitations. In any context, including youth sports, the coach has the most influence on the type of learning environment they create with their team [2]. Thus, the training and experience of the coach or lack thereof are paramount in the coach's ability to create a positive youth sports environment.

Various resources are available to assist coaches in creating a situation where the best interests of young athletes are at the center of the youth sports experience, most notably, the National Standards for Sports Coaches (NSSC) and the International Sports Coaching Framework (ISCF). Both documents cover key areas of sports across all contexts, addressing the need for coaches to be skilled at or trained in conducting practices; managing competitions; building relationships; teaching communication, safety, injury prevention, and evaluation techniques; providing a vision for the program, and role-modeling ethical practice [3, 4]. (*Note: At the time of this publication, the National Standards for Sports Coaches are being updated to include new information on key areas previously mentioned*).

Established standards provide the framework for youth sports programs to ensure that coaches are trained and equipped to teach, lead, and develop young people through sports. However, the challenge in implementing the standards and/or specific training programs to develop youth sports coaches is complicated by the number of volunteer coaches. In the United States, over 45 million youth aged 6–18 participate in organized sports [5], and it is estimated that a majority of youth sports coaches are volunteer coaches [6]. Lacking time and likely experience as a coach, the volunteer is thrust into a coaching role they may be unprepared to fill. In a study of volunteer coaches, less than 1 in 5 are trained to effectively communicate with youth, and only 33% have been trained to teach sports skills or tactics [7].

With a large percentage of coaches giving their time and many more working part-time, administrators of youth sports will streamline the training process for coaches or provide no training at all. Furthermore, even though the National Standards for Sports Coaches exist, coaches are not required to demonstrate knowledge or implementation of the standards to become a coach or stay in coaching. In other words, at the youth level, the management and oversight of coach training and education are often limited to the youth organization running the program. With inconsistent training and education for coaches, young athletes are potentially exposed to poor teaching and improper training procedures which can lead to overuse injuries. For example, it has been reported that 46–50% of all athletic injuries are a result of overtraining [8]. In addition, the cause of many youth sports injuries is often the result of minimal rest between competitions due to overscheduling by youth program administrators and coaches [8]. In 2016, the NBA and USA Basketball released youth sports participation guidelines. Broken down by the age level, the guidelines include practice length, game length, number of practices/week, number of games/week, and number of games in 1 day [9]. Beyond a lack of understanding on best practices, an untrained coach may struggle to provide instruction on the skills related to the activity and lack of knowledge on how to teach effectively [10]. More importantly, coaches may not be aware of what constitutes ethical practice when working with young people.

This problem has not gone unnoticed; there are a variety of resources (i.e., books, courses, web sites, workshops, clinics, etc.) for coaches covering an assortment of topics related to teaching and working with athletes that include, but are not limited to, tactical skills, technical skills, psychology, risk management, and program management. Unfortunately, youth programs often provide minimal training on ethical leadership and ethical decision-making. This might be because seeking continued education on ethical leadership and ethical decision-making is a long-term approach to getting better and developing as a coach. Even at the youth level, coaches feel pressure to meet expectations driven by results on the field of play and therefore are more likely to seek resources on how to teach technical and tactical skills of sports to achieve short-term results. In addition, coaches do not always equate this type of information as pertinent to their role as a coach. Because they may believe that they are already morally competent or they lack an understanding of how this type of training or information provides results on the playing field.

Based on a variety of factors including organizational leadership, time, expectation of results related to winning, and a lack of adherence to national standards, the youth sports coach will likely not receive proper training regarding ethical leadership. However, the importance of ethical education for coaches cannot be understated, as coaches have an opportunity to recognize "teachable moments" where character development can occur. The ability of coaches to identify "teachable moments" rests in their knack to pinpoint universal core ethical values [11]. An understanding of character development and universal core values can be developed from a combination of past experience (i.e., environment), moral role models (i.e., teachers, coaches), and formal education. If coaches fail to receive training on ethical leadership (i.e., formal education), they may lack the ability to recognize "teachable moments" and be limited in their ability to serve as a moral role model in the character development of the young people on their team. They may also misunderstand the importance of ethics within coaching practice, training, and game play.

2.1. Solutions

Proper ethical training for sports coaches would involve formal education on ethical decision-making procedures involving the understanding of social and moral character values displayed in sports and the importance of reflective practice.

2.2. Value-based decision-making

A great exercise for a coach in a formal setting is to complete a three-step value audit. Following a discussion on the types of values (i.e., moral, nonmoral, social, etc.), a coach can reflect on what is important to them and develop a list of values. After constructing the list, the coach can give meaning to each value by providing an action statement [12]. In this second step, the action statement describes what the value means to the coach. For example, an action statement for responsibility (a moral value) might read, being accountable for my actions and holding others to the same standard. Once an action statement is added to each value, the third step is to prioritize the value list. The coach must list the values that are important to them. It is important to take a "winner take all" approach, as the coach needs to meet the challenge of placing each value in order to better understand how values guide daily action. By reflecting on their values and completing a value audit, the coach is identifying and evaluating how and what they value guides individual actions each day.

2.3. Reflective practice

Serving others requires hard work, and one aspect of hard work in improving and growing as a leader is reflective practice. Reflective practice is more than evaluating a recent scenario and making adjustments for the next time. It is a deliberate attempt at critical self-evaluation to improve coaching practice. Furthermore, a reflective practitioner will often, either consciously or subconsciously, engage in a reflective behavior. Purposeful, conscious reflective practice may involve R-cards [13], journaling [2], think-aloud [14], reflective conversation, [2] or a personal leadership narrative [10]. In utilizing one of these activities, the coach is aware of the reflective task, and the effort is deliberate to improve his or her understanding of interactions with their followers. In coaching, by reflecting on our actions when we engaged with others, we increase self-awareness and have a better understanding of how our actions impact others [14], and through the use of reflective practice, techniques over time may develop specific reflective habits.

One of the key components of reflective practice is perspective-taking. In other words, the coach uses reflective practice techniques, often subconsciously to understand what others are thinking and what their needs are. Therefore, the concept of perspective-taking is essentially a reflective exercise demonstrated by the coach. Although purposeful reflective practice techniques can be learned and implemented in learning to lead and improve leadership skills, a coach demonstrating the characteristics of a reflective practitioner may be predisposed to this approach based on personality and their ability to show empathy. Having an empathic mindset toward others likely drives the coach to consider the perspective of those they lead.

The problem that is addressed above is only one issue of the many. The second problem that affects overtraining and injury rates of youth also lies in the science underlying the field of kinesiology.

3. The current sports science and kinesiological curriculums that focus almost entirely on "science" and do not address motor skills training, education, or application for preprofessionals

Fundamental motor skills (FMS) are movement patterns that involve smooth, sequenced patterns of the feet, legs, hands, arms, trunk, and head [15]. These movement patterns (running, hopping, skipping, gliding, jumping, galloping, leaping, and walking) are the building blocks of movement and provide the foundation of physical literacy. These purposeful movement patterns require that an individual be able to feel or sense what one's muscles are doing and know where one's body and body parts are in time and space. More importantly, fundamental movement skills are a prerequisite for individuals to develop good sports skills safely [15–18]. Children who have high levels of FMS are more likely to participate in physical activity, have higher levels of self-esteem, are generally more healthy, and are more likely to remain active throughout their lifespan [19, 20]. Inadequate fundamental movement skills can have a major negative impact on an individual's motor performance and activity later in life [21].

Physical education programs where FMS are the foundation positively impact children developmental growth and physical movement. These programs focus on the skills needed to move and integrate increasingly more complex patterns into sports skills. For example, a hop is springing from one foot and landing on that same foot, while a leap is springing from one foot and landing on the opposite foot which causes the body to travel through time and space. Not only are the feet required to move in a fluid pattern, but the trunk, arms, and head must also be sequenced to the pattern in order to keep the body upright and smooth. Some fundamental movement patterns such as galloping incorporate alternate actions. Galloping involved stepping forward and pushing off of one foot while the other foot follows, with the individual landing on the trailing foot. Again, this action requires a sequenced movement of the trunk, arms, and head. Sliding is similar; however, one foot slides sideways across the floor, while the other follows. Sliding is the basis of sports skills such as skating and skiing. When the trunk, arms, and head are out of position in the locomotor pattern, an awkward, jerky movement occurs, and the child may lose balance and be unable to move in a predetermine direction. In early childhood physical education classes, children practice each of these skills as individual movement patterns until they become fluid movements.

Gallahue et al. [16] state that FMS is composed of three different constructs: locomotor such as running, hopping, skipping, jumping, leaping, and so forth; control of objects such as striking, and throwing, catching; and non-locomotor (stability) skills such as bending and twisting. The ability to sense shifts in body movement and alter balance to compensate through locomotor skills allows one to know body orientation and become physically competent across complex sports skills. These fluid movement patterns become the foundation of the more complex movement patterns involved in sports skills development [22]. Sequenced together, these fluid movements require large muscle groups to control the body in various situations where one integrates sports skills such as agility, balance, coordination, and strength in smooth body actions.

The developmental progression for children starts at birth and is generally linear [23]. As a 4 year-year old, children should be able to stand on one foot for 5 seconds, stand on tip toes for 3 seconds, without moving the feet, jump forward 3 feet, jump onto a step approximately 8 inches high with two feet, jump over a small hurdle, and while running, be able to change direction and stop easily without losing balance. Early physical activity and education activities should take a developmental approach and foster a strong sequence of fundamental motor skills. Over time, activities should include multiple motor skills that allow children to progress into more complex motor skills movement thus allowing the body to adapt and learn safe movement patterns. These FMS activities should be mastered in early childhood as they are the basis of all physical and sports activities. Moreover, playing sports activities, dance, and other recreational activities safely all require a good command of fundamental movement skills. Inadequate fundamental movement skills in early childhood may have a negative impact on the motor performance in later life [16]. As children mature, the complex nature of sports skills movement requires good balance, flexibility, agility, coordination, and strength [17].

Unfortunately, in today's sports culture, for several reasons, young children are not developing the span of FMS, locomotor, and stability skills as has occurred to a greater extent in the past. First, schools have cut back and/or eliminated structured physical education programs with certified physical education teachers. Second, there has been a concomitant reduction in the number of majors in physical education teaching programs. Therefore, few trained physical

http://dx.doi.org/10.5772/intechopen.71883

education teachers provide sound FMS practices with young children. Third, university and college sports studies programs have reduced or completely eliminated courses where FMS relative to sports skills progressions have been taught. Thus, sports studies majors have little-to-no knowledge of the importance of FMS and how to teach progressive skills. Fourth, the huge growth in the number of children and youth participating in AAU and other club sports (over 30 million) as early as 4 years old has radically changed how children develop skills. Instead of the large foundation of FMS being taught at an early age, children are learning complex motor skills without the foundational locomotor, non-locomotor, and stability patterns firmly in place. Interestingly, there appears an assumption that because an athlete can play a particular sports they thus must have good FMS.

Yet, coaches at the youth sports level (typically parents), as well as many coaches in junior high, high school, and college, have little-to-no background in any sports education, much less FMS training. Without the understanding of the importance of FMS to all skills development, these coaches teach children sports skills as if they are miniature adults. Finally, the lack of FMS in any kind of a foundational capacity has more than likely impacted the number of injuries (catastrophic and otherwise) among young children and youth, over 3.5 million injuries per year [24, 25]. The most common injuries include sprains and strains of knees, ankles, elbows, and shoulders. A large number of these injuries (sprains and strains) occur in children 5–12 years old, the primary time for FMS development. Oftentimes, these injuries lead to lifelong joint issues.

3.1. Strategies for positive change

3.1.1. FMS skills training should be part of all university sports studies curriculums

Regardless of the focus (pre-physical therapy, strength and conditioning, athletic training, physical education) of a sports studies curriculum, focus should be spent on FMS training strategies. The Society of Health and Physical Education (SHAPE), the American College of Sports Medicine (ACSM), the American College of Pediatricians (ACPeds), and other associated organizations should push for policies which ensure that coaches (physical, psychological, cognitive, emotional, and so forth) in all levels of sports are appropriately trained and certified. And, sports programs should be developed with the appropriate developmental growth of children in mind.

3.1.2. FMS skills training should be part of all coaching education programs

The National Alliance for Youth Sports, AAU, National Federation of High School Activities Association, and other organizations should incorporate FMS skills within their coaching models. Parents and others in coaching capacities at the local levels should be required to become certified through sound coaching education programs. These coaches should know how to demonstrate, analyze, and correct movement of FMS patterns as prerequisites for any sports program.

3.1.3. Work with the local area physical therapists to develop dynamic FMS skills programs for athletes of all ages

Given the significant number of injuries in children and youth between the ages of 5 and 12, a significant need exists for young athletes to be trained in FMS as an integral and ongoing aspect of any sports program. Sports studies professional working with physical therapists can have a positive impact on proper development of FMS in young children [26]. SPARQ (strength, power, agility, reaction time, and quickness) programs that include FMS as the foundation provide youth an opportunity to develop more mature and safer movement patterns while building sports skills.

Why do preprofessional programs have such a dearth in preparation of coaches and what philosophy is driving the issue at hand which brings us to issue C?

4. The lack of philosophy and ethics education in preprofessional programs which focus almost entirely on the science

Once a long time ago, philosophy and ethics were required courses for every university student either in the normal course of events within a department or college of letters [27], and most programs often concluded with a "capstone" class taught by the university president. These capstone courses were directed toward a philosophy of living well and serving well [28]. These courses in toto often were part and parcel of a liberal arts tradition, and one learned that there was such a thing as right and wrong, good and bad, and even what was beautiful and what was not. However, such is not the case today, especially in the field of kinesiology and exercise science, which lies at the root of education for sports, coaching, and teaching [29].

Interestingly, there are very few institutions[1] that have an active, publishing, and researching philosopher of sports or ethicist in the kinesiology discipline. With so few institutions with professors who are trained, educated, and published in the field, there can be no faculty teaching in the subject matter field with merit. We find that interesting [29, 30]. No kinesiological faculty would place a non-exercise physiologist in an exercise science course—but the faculty has no issue with placing an instructor in a philosophy of sports class who has no credentials.

All of this is important in relation to the study within the science of kinesiology. All medical schools require study in medical ethics. Schools of physical therapy require study in medical ethics. However, in the study of kinesiology, there is no general requirement in the study of ethics, period. Such little regard for the importance of ethics speaks volumes about what a student is learning.

A Google search of unethical coaching behavior in sports provides 342,000 hits including numerous academic articles on the lack of ethics as well as many academic texts written by

[1]Penn State University, R. Scott Kretchmar (major professor), has the only degree offered in PhD in History and Philosophy of Sports. Other scholars work in ancillary fields. At the University of Idaho, we offer a PhD degree in Physically Active Lifestyles, with an emphasis in moral reasoning and moral development in sports.

nonphilosophers. Unethical behavior appears to be common, and unethical behavior that directly affects the health of children is very common [5, 31].

The question then is why do we value our children and their sports experience so little that we do not train, educate, or inform coaches about the important of ethical education? Why? Perhaps, much of this has to do with the love of science and the lack of appreciation for ethics and ethics education [30]. As noted in this chapter, coaches are neither trained nor educated in ethics, and that is a pity because children suffer from overspecialization, overtraining, and poor coaching.

4.1. Strategies for positive change

The long-term strategies for the problem of no-required ethics education in sports education or coaching education are highly problematic. A few textbooks do exist [32, 33], and curriculums for coaches somewhat exist on coaching ethics but nothing of substance. The strategy depends on a reworking of the basic undergraduate education and coaching education to focus on coaching ethics as the fundamentally most important aspect of sports education [30, 34]. Therefore, we recommend not only courses in sports ethics but also an overarching umbrella where the concept of ethical practice becomes part and parcel of all that is taught [35]. That is no easy solution and not something that can be covered in a few pages in this book. However, administrators need to start the dialog for the health of our children who depend on it.

5. Overzealous parents who focus on youth sports monetarily, physically, emotionally, and socially support it over all other activities, including education

"Participation in sports by children and adolescents is associated with a range of documented physical, emotional, social, educational, and other benefits that can last into adulthood" [7]. However, youth sports participation rates have been on a consistent decline. "In 2008, 30.2% of youth ages 6 to 12 were active to a healthy level through sports, organized or unstructured; by 2015, that number had dropped to 26.6%, according to SFIA. Among 13- to 17-year-olds, the rate fell from 42.7% to 39.3%" [7]. Overall, "70% of children are dropping out of organized sports by the age of 13" [36]. A driving question continues to be why?

O'Sullivan [36] attributes this marked decline to multiple reasons, all of which center around a discrepancy between how adults and children understand and expect to experience sports engagement. Shields et al. [37] assert that "parents play an important role in their children's development and value formation." Parental involvement itself is not the issue. Rather, a child's perception of parent involvement is impactful [37].

The feedback and behavior of a parent can affect how long a child stays involved in a sports as well as how a child perceives his or her abilities. The outcome a parent emphasizes and reinforces, such as winning or improving skills, can have a major effect on what a child deems as success in sports. Moreover, how a parent acts before, during, and after a practice or game can cause a great deal of anxiety in the child. As a result, a child's performance and enjoyment can be impacted [37].

O'Sullivan [36] argues that organized sports have become too heavily structured by adults. Because of this, the activity is less influenced by what kids find fun—noncompetitive activities or activities by children, and more impacted by how adults believe that activities should be played. For example, kids like and want to play which means that kids will have more fun if they have an opportunity to participate. However, an overemphasis on winning influences some coaches to only play the most highly skilled athletes. Additionally, some adults utilize a communication style which focuses on mistakes rather than skills attainment and improvement. A focus on errors and being fearful that making an error will result in less playing time can create an environment where kids become driven by fear, not by fun. Once the activity becomes unenjoyable, O'Sullivan argues that children are likely to seek out other opportunities in which they have more autonomy to create a fun, interactive, positive environment.

Identifying problematic sports parent behaviors is a necessary first step to begin to establish a more positive youth sports participation environment. Smoll et al. [38] identified that parents/guardians who do not engage with their youth's sports experience are overly critical or are overprotective and/or scream and coach from the sidelines can be negatively perceived by his/her child. The frequency of such behavior was measured by Shields et al. [37]. A survey including 803 athletes, 189 parents, and 61 coaches revealed that 14% of parent/guardian respondents "acknowledged having loudly yelled at or argued with a ref or sports official, with fathers apparently more verbally aggressive than mothers" (p. 55). Additionally, 13% […] "acknowledged having angrily criticized their child's sports performance."

5.1. Strategies for positive change

5.1.1. Remember that not all sports parents exhibit negative behaviors

Not all parents/guardians have difficulty providing healthy levels and types of support to their children. Coaches and athletic administrators need to be careful to avoid making general statements or policies which could feel punitive to those who are not contributing to the problem. Additionally, engagement in sports can be a source of positivity for families [38].

5.1.2. Develop an understanding of the purpose and objective of youth sports

Youth sports, while competitive, are not collegiate or professional sports. As such, their purpose differs. Youth sports are a means for kids to learn a variety of skills that can transfer to other phases of their life. Pursuit of victory is less important than pursuit of physical, social, and emotional skills improvement [38]. Understanding this difference is critically important before appropriate behaviors can be agreed upon.

5.1.3. Develop an understanding of the role and responsibility of a sports parent

Not all children wish to play sports [38]. For those that do, Perhaps it is time for parents to turn their child over to the sports. Doing so ensures that the experience is the child's, not the parent's. Doing so also ensures that kids play because they want to and that if the experience is not fun, positive, and/or healthy, the child can opt not to play with less fear of disappointing their parent(s).

5.1.4. Develop an understanding of appropriate conduct of a sports parent

Smoll et al. [38] recommend the following rules for appropriate parent conduct:

1. Do remain a spectator during the event.
2. Do not interfere with the coach. Parents must be willing to give up the responsibility for their child to the coach for the duration of the practice or game.
3. Do express interest, encouragement, and support to young athletes. Be sure to cheer good effort as well as good performance. Communicate repeatedly that giving total effort is all that is expected.
4. Do not shout instructions or criticisms to the children.
5. Do lend a hand when a coach or official asks for help.
6. Do not make abusive comments to athletes, parents, officials, or coaches of either team.

5.1.5. Develop sound and comprehensive coaching education/training programs

Youth sports coaches need sound, comprehensive training to effectively prepare to coach youth safely and effectively. Skills development, teaching progressions, mental performance enhancement techniques, and effective communication strategies for communicating with youth participants and their parents/guardians are needed. Additionally, youth sports organizations could benefit from creating mandatory parent/guardian training that must be successfully completed prior to children being allowed to begin a sports season. The training could focus on expected conduct.

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Section 2

Disorder Specific Chapters

Chapter 5

Overuse Injuries in Professional Ballet

Francisco J. Sobrino and Pedro Guillen

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.72428

Abstract

Ballet is an athletic activity with a marked artistic component, that need a highest technical requirement and repetitive movements. In this way, Overuse injuries, as we have been able to demonstrate in our studies, will be the most frequent injuries in ballet. The technical requierements of ballet will influence both injury specificity for each discipline and for both sexes, usually with higher technical requirements among women and higher athletic requirements among men. The patellofemoral syndrome is the most frequent overuse injuries in ballet, related to decompensating mechanisms to increase a naturally weak in turnout or dehors. This injury and others as the snapping hip, are more common among women, with higher technical requirements than men, and in the more technically demanding disciplines such as classical ballet. Other important injuries in ballet are Achilles tendinopathy, the mechanical low back pain, or the Os trigonum Syndrome. It will be very important to know about, the biomechanic and pathomechanic of the Ballet specific technical gesture, the intrinsecal and environmental risk factors involved in ballet injuries, the injury-based differences among ballet disciplines and among age and professional seniority, as well as the most important preventive measures in ballet.

Keywords: overuse injuries, ballet injuries, ballet disciplines, ballet injuries prevention

1. Introduction

We can define ballet, without fear to fail, as an athletic activity that incorporates similar movements to the ones of other athletic activities called sport. From our point of view the most notable difference is the marked artistic component that carries ballet practice, what makes this more important than the competitiveness in itself. Actually, all the authors define the professional dancer like an elite athlete [1].

Nevertheless, there are some important factors that differentiate the classical ballet of other athletic activities. Between others:

- The five classical ballet postures in *dehors,* that require a maximum external rotation of the lower limbs
- The work of the women in *tip or points*
- The requirement of a high number of repeated movements often in extreme positions.
- The ancient design of the ballet footwear unlike the constant changes that in this regard they exist in other sports [2]

In any case, in ballet just like in sport we are going to find two types of musculoskeletal injuries, **traumatic injuries** with acute features which are generally caused by accidents, and **non-traumatic or overuse injuries** which appear slowly and progressively and are caused by repetitive motion or microtrauma and/or accumulative actions [3].

The first contributions about Overuse injuries, are all refer to the work world. This is easy to understand since the physical activity related with the sport like such, is much more recent. To find the first historical antecedents of these disorders in the sport, we might situate in the 19th century, when it was already recognized by *Verneuli, Bardeleben and Erichsen*, the possibility that an injury is produced by exaggeration of a physiological function." Already in the 20th century, in 1936, *Batzner*, coined the concept of functional injury, which could be possibly the base so that later it described by *Allman* the principle of *Specific Adaptation to Imposed Demands- SAID*, which establishes that the body answers to a physical demand given with a predictable specific adaptation [1, 4].

In spite of, was not until 1968, when *Slocum & James*, in a study on tibial periostitis in runners, coined the term **"overuse injury"** [5], to describe a class of organic injuries from the inside, which were different from those caused by trauma and were the result, among other factors, of poor planning of training sessions or rehearsals, deficient technical execution or repetitive movements performed for long periods and/or with insufficient recovery time.

These injuries are going to differ from the traumatic sharp ones, in which in its appearance there are going to be involved a few intrinsic risk factors to the dancer or athlete and other extrinsic risk factors derivatives among others, of the technic or of the environment.

Regarding to epidemiologic criteria, the prevalence or incidence of these overuse injuries in the sport, will change in which it is on individual athletic activities in which contact is the main risk factor, or of more individual athletic activities the main factor will be the alteration of the biomechanical conditions of the exercise, and that usually need an accurate technique and repeated movements [6].

Therefore, we could say about the last ones, on which ballet is paradigm, that an adequate technique will be one of the best ways to prevent these injuries, being conversely, an insufficient technique, one of the main factors involved in its appearance.

People sustaining these injuries tend to underestimate their significance and/or fail to allow for recovery from fatigue, a key factor in understanding the root cause behind these disorders,

http://dx.doi.org/10.5772/intechopen.72428

which are often diagnosed by the presence of pain, and whose prevalence is particularly high in technical and individual sports [4].

So, whereas in the contact sports (football, basketball, handball…) the prevalence of these disorders is around the 30%, in the most technical sports (cycling. Tennis, athletics…), the prevalence of these disorders is around the 70%. In this latest sports, the majority of the injuries are produced in Lower limbs and lumbar spine [1].

The Scientific literature regarding ballet is very heterogeneous, dating back many of the studies 20 years ago or more. In addition, the vast majority of the studies on ballet-related injuries are based on surveys, being difficult to find studies that contribute specific diagnoses. However, in some studies and in those we have recently published, we obtain specific clinical diagnoses based on clinical history and clinical examination [7–12].

These studies, indicates overuse injuries as the most common ones in ballet, with published prevalence rates around 65–80%, being the most affected the lower limbs, especially the ankle and foot's anatomical complex, followed by the spine and knee, with the patellofemoral syndrome being the most frequent overuse injury in ballet [1, 3, 13–15].

We could say that these overuse injuries in ballet will appear as a consequence of the disorders in the biomechanical conditions undergone by a dancer when executing different exercises, giving way to what is known as pathomechanics of ballet [1]. Additionally, other influencing factors have proven to be the ballet discipline in practice, sex and the presence of various individual risk factors which predispose dancers to the onset of specific injuries as well as environmental risk factors which would lead to their appearance [1, 2, 6, 13, 16–21].

Considering the fore-mentioned, and although a good physical condition is a must in any sports activity, we should think about the importance of a good technique adapted to each dancer's biomechanical characteristics, as one of the best ways of preventing these injuries, while the opposite—an insufficient or inadequate technique which goes beyond these biomechanical conditions- would be considered a factor favoring the appearance of such injuries.

In ballet, will be crucial not to lose sight of the importance of factors such as each dancer's individual anatomical characteristics and their exposure to different environmental conditions, which have been analyzed by several authors [2, 7–9, 11, 13, 17, 20, 22–25], highlighting the hard floor, and above all the changes of choreography, where the repetitive technical maneuvers are the most frequent, above all in the rehearsals [1]. The possibility that a practitioner may lack adequate physical training should not be underestimated either [1, 9, 21, 26–28]. Even the eating disorders, more frequent in women and related to stress fractures, between others, could be considered [23, 27].

In connection with the above, it is also necessary to take into account the differences between males and females and those relative to the type of ballet under consideration. Thus, while males are usually expected to meet tougher athletic requirements, demands on females relate more often to their technical requirements [1, 10]. In addition, there are technical gestures typical of women (*points, forced dehors*) or men (*portées, jumps* more repeated and wider), which will also justify gender-based gender differences, and that will can produce biomechanics changes involved in the pathomechanic of the ballet.

The most currently acknowledged disciplines in ballet are classical ballet **Figure 1**, neoclassical ballet **Figure 2** and contemporary ballet **Figure 3**, with Spanish ballet **Figures 4** and **5** a leading discipline also in Spain. It’s technical characteristics, will influence injury specificity

Figure 1. Spanish National Dance Company. Choreography William Forsythe. Photograph Jesús Vallinas.

Figure 2. Victor Ullate ballet company. Photogrph Pedro Arnay. Dancers Marlen Fuerte and Josue Ullate.

http://dx.doi.org/10.5772/intechopen.72428

Figure 3. Spanish National Dance Company. Choreography Sharon Fridman. Photograph Jesús Vallinas.

Figure 4. Antonio Marquez dance company. Photograph Francisco Ruiz.

Figure 5. Spanish National Ballet. Choreography Antonio Najarro. Photograph Jesús Vallinas.

for each discipline. However, even though professional dancers practice a major ballet discipline, it is not uncommon for a performance of some other discipline throughout the season.

So knowing these differences, it is easy to understand that will may exist injuries differences in the execution of these ballet disciplines and also in terms of gender.

Finally, it's important to consider overuse injuries as really specific of each athletic activity in which they produce, in this case of the ballet, and those that more go to benefit of a suitable prevention, the main measure of treatment and also the most effective in this injuries.

2. General etiology of overuse injuries

In the etiology of Overuse injuries in the sport and ballet, it must be considered the presence of intrinsic or individual risk factors, own of each dancer or athlete and that they will be predisposing for his apparition, and extrinsic risk factors, derived from the technique itself and from the environment, triggering the appearance of these injuries [1].

2.1. General intrinsic or individual risk factors

- Age: Age condition the presence of the different injuries.
- Examples are the degenerative changes in the joint among the oldest, or the osteochondrosis among the youngest. In the latter, highlighting the Osgood Schlatter Syndrome, 10–16% of overuse injuries in these ages.
- Gender: it Is known the gender relation with determinate injuries. Example, the hormonal modifications that become more frequently in women.
- Vascular, Metabolic or Degenerative previous illnesses
- Previous deformities.
- Previous surgeries.
- Anatomical variations
- Extremities Misalignment, particularly important in the Lower limbs.
- Insufficiencies, retractions or muscular imbalances.
- Structural weaknesses of the human anatomy
- Psychosocial factors of predisposition
- Stoicism of the subject: Individual who decide to ignore the pain, that is the first sign of alarm and the first symptom in overuse injuries. This goes to aggravate by the greater concentration of endorphins related with the usual practice of physical exercise, and that will favor that it diminish the perception of the pain.

2.2. Intrinsic factors related with ballet

The intrinsic factors are very general and will not going to exist differences between the different sports or athletic activities.

Nevertheless and considering the previous, an essential appearance that have to have always present, is related with the study of those anatomical risk and/or functional risk factors, that in case to be present will favor determinate injuries in different anatomical locations.

Like this in the ballet would stand out:

- Joint hyperlaxity
- Lower limbs misalignment.
- Muscle imbalances.
- Scoliosis
- Lumbar spondylolisthesis
- Rigidity of the Psoas muscle
- Femoral anteversion.
- Short hamstrings
- Dysfunction of the maximum external rotation of hip.
- Trochlear or patellar dysplasia.
- Knee recurvatum
- Hyperpressure patellar Syndrome.
- Achilles shortened
- Os-trigonum.
- Morphological and/or functional imbalances and deformities of the ankle-foot.

2.3. Extrinsic or environmental risk factors

The 60-70% of overuse injuries in sport and ballet, are due to errors in the training, outstanding:

- Bad teaching or application of the technique.
- Unsuitable coordination
- Errors of the program of training in the volume, intensity and length.
- Maladjustment of the training program to the biological characteristics and physical preparation of the dancers or athletes.
- New training techniques.

- Absence of previous warming.
- Absence or bad technical and indication of stretching.
- Tension sustained on a same muscle, producing prolonged contractions that increase the intramuscular and tendinous pressure, hampering the blood flow and diverting the energetic metabolism to the anaerobic road.
- Maximum muscular contractions.
- Shortening of the recovery time between the repetitions, the series and the rehearsals.
- Climatic extremes factors.
- Surfaces of unsuitable sportive practice, like the hard floor or irregularities or inclinations of the terrain.
- Unsuitable sportive clothes
- Deficiencies of the footwear. Or his absence, as it occurs in some ballet disciplines.
- Doping No frequent in ballet

2.4. Extrinsic or environmental factors regarding ballet

In ballet, these factors have been object of deep literature review [13, 17, 20, 21, 29], being triggers in a lot of cases of the apparition of different injuries. Then, we would have:

- Inadequate temperature
- The hard floor

One of the most important environmental factor related to ballet, together the changes of choreographies.

So, there are different studies that justify the injuries in the dancers by repetitive impacts on a hard and inflexible surface. Whereas the athletes use devices of absorption and leveling in his shoes, the dancers use shoes without these devices or even dance barefoot, what contributes to increase the potential of injuries, especially in the spine and lower limbs [1, 19, 30].

In addition to the hardness of the floor, the irregularity or unsuitable floor inclination, are important too.

- Unsuitable footwear

The classic ballet shoes, especially if they are damaged, with inadequate floor, are also a risk factor related to these injuries.

On the other hand, we have already seen the importance that has the absence of footwear, as it occurs in some ballet disciplines such as the contemporary or modern ballet.

- Process of work

It is important to stand out, the contributed by some authors that indicate that although the traumatic injuries are used to be more frequent in representations, overuse injuries, the most

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frequent in ballet, are most frequent in the rehearsal, where the complex technical actions of the ballet are repeated until they are brilliant in their execution. This will be more frequent with the changes of choreography, being this factor, the most frequently involved in the appearance of overuse injuries in ballet [17, 20], more with bad physical condition, if there is no balance between strength training and flexibility, and if the recovery time is insufficient [13].

- Period of season

The ballet is characterized by demanding work and rest cycles throughout the season, this being a factor favoring of injuries and the psychological pressure, especially in the small private companies with lower structure [1, 13, 28].

These considerations describes that this injuries are more frequent in the periods of incorporation to the activity after a prolonged rest [15], suggesting other authors, that this lesions appear more frequently in the transition from inactivity to maximum activity [1, 17].

- Technician peculiarities

We have already seen how the bad teaching or application of the ballet technique, might be an essential factor in the appearance of injuries, causing alterations in the biomechanics of the technical ballet gestures and giving place, beside the intrinsic factors of predisposition, to the presence of changes involved in the pathomechanics of ballet.

So, although "the process of the jump," understanding this such as the action to elevate the twists or movements associated in the flight and the reception, is most frequently involved in the appearance of traumatic injuries in ballet, the technical gestures most involved in overuse injuries in ballet, are *dehors*, *relevé* action, the tips or points in women, and the portées in men.

3. Main technical gestures in ballet. Biomechanical and pathomechanical condition

We can define ballet, without fear to fail, as an athletic activity that incorporates similar movements to the ones of other athletic activities called sport. From our point of view the most notable difference is the marked artistic component that carries ballet practice, what makes this more important than the competitiveness in itself. Actually, all the authors define the professional dancer like an elite athlete [1].

Nevertheless, there are some important factors that differentiate the Ballet of other athletic activities. Between others: the five classical ballet postures in *dehors;* the work of the women in tip or points; other specific technical gestures as *pliée* or *portée;* the requirement of a high number of repeated movements often in extreme positions; or the ancient design of the ballet footwear unlike the constant changes that in this regard they exist in other sports [2].

When we refer to pathomechanics of any athletic activity, we are talking about the pathological modifications of the biomechanical conditions produced by the execution of different exercises or specific technical gestures of each one of the activities or athletic disciplines, that gives as a resulted the appearance of different injuries.

Besides, the pathomechanical changes will result secondary to the presence of some anatomical or functional predisposing factors and to other environmental factors including the technique alterations, that will be a triggers factors of the overuse injuries appearance [1].

By the way, first to indicate the important paper of the true training of the ballet, which beginning around the 8 years in girls and a little bit later in boys. This will increase progressively regarding intensity and efficiency, checking that with the step of the time and in a big majority of the cases, the unsuitable use of the technical, will be a trigger factor of this musculoskeletal injuries.

Regarding to the Main technical gestures in ballet and it's Biomechanical and Pathomechanical condition, being different studies in the Ballet international scientific literature about [1, 13].

In this way, we highlight the study of *dehors, points, pliée and portée*:

3.1. Dehors (turnout)

Related to the 5 classical ballet positions, is the maximum external rotation of the lower limb, that will want to reach 90° of external rotation with each tip. It should be at the expense of a hip's natural rotation, which should reach between 60° and 70° as well as 5° outside of knee rotation and 25° of external rotation of the foot.

However the *flat-dehors* 180°, is not readily available, and much less on learners fans, being easier to reach around 70° of external rotation with each tip.

However the demands of some teachers, or even the self-requirement of the own dancer, who wants to have a greater *dehors* which can actually reach, favors decompensating mechanisms to increase it, that are going to start with the pronation component of the feet, and then transmitting it through the chain kinetics of the lower limbs, lumbar spine and pelvis, that also will be affected.

So pronation of the foot, will facilitate:

- Initially In foot and ankle:

The emergence of a sesamoiditis, mostly associated with repetitive jumps, and more if it's on bare feet, and also on the anatomical region of the ankle, that will cause stretching of the posterior Tibial tendon as well as a weakness of the tendons peroneal ankle, and even a stretching of the tendon Achilles weakening it, and favoring the injury of the tendon weakened with jumps and relevée plantar foot repeated.

Whereas the pronation of the foot aim will be trying to increase forced external rotation of the lower limbs, this aim will be achieved at the expense of a stretch of all of the lower limbs, shifting body weight back, and forcing in this way:

- In knees:

The stress of the medial structures, and a "high pseudopatella" with a tendency to the knee hyperextension (recurvatum).

As consequence, it will produce a great strain on the femoropatelar joint and even the patellar tendon, especially these changes are associated with repetitive jump, being the origin of the so-called dancer Knee.

- In lumbar spine:

Could favor lumbar hyperlordosis, with clamping of the joint facets and an anterior tilt of the pelvis.

- In Hip, pelvis and thig:

Further, It will favor tension in the anterior capsule and soft tissues of the hip, favoring, between others, the presence of Snapping Hip, also weakening the psoas tendon.

Psoas and adductors muscle, can be considered the main stabilizers of the pelvis in ballet, above all in support on one leg. Adductors also weaken when the center of gravity delayed.

- In leg:

If in addition, all these *dehors* decompensating mechanisms, are associated with repetitive jumps, could appear in addition, stress phenomena in tibia.

3.2. Points or tips

Point position, is a technical exercise in ballet, being specific to women who practiced classical and neoclassical Ballet.

It is characterized by the passage of the foot in the plane of the floor to the most anterior support on toe full tip.

This is done by the *relevée* move which allows the carrying of the foot on the plane of the floor to the concerning support to half or full tip. The *relevée* is one of the most frequent technical gesture in ballet, in both sexes as in the different ballet disciplines.

Full tips require good balance and postural control as well as a good transmission of weight.

Before starting dancing on tips, dancers might reach a sufficient skeletal maturity which will allow a stable joint structure and also a good active of the intrinsic muscles of the foot control.

These are the muscles that help us keeping the transverse arch and also the length of the fingers in this maintained position.

Points are associated with different pathologies, and by a biomechanical point of view, they are characterized by the increasing in the load of the inner side of the metatarsal phalangeal hallux joint, and also, on the inner and outer face of the interphalangeal of this hallux, which will also produce foot pronation.

For this reason, the tips maintained position could produce or even aggravate all pathologies related to the *dehors* decompensating mechanism, and also others such as the posterior ankle impingement Syndrome or Os trigonum syndrome, that are also related to the *relevée* action without full tips.

The foot pronation during *points*, will produce a Knee recurvatum, a increase of the tension in the rear knee face, a high pseudopatella, and different cumulative disorders and weakness of lower limbs structures. The stress phenomena in tibia, is even associated to these repeated gestures, torsion forces and repetitive jumps.

The recommended age for starting dancing on tips is approximately the age of 12. It will depends on the moment when the skeletal maturity allows a joint stable structure and also the intrinsic muscles of the foot control.

3.3. Plie

It is another critical exercise in ballet. It is characterized by the flexion of the knee with the foot on the floor plane, emphasizing the analysis of the knee forces in the sagittal plane.

So, the resulting force from the strength of the quadriceps and patellar tendon will increase progressively according as increases the knee flexion. This could corresponds to three times body weight when it reaches 90°, moment in which the patella will be embedded in the femur.

It is easy to understand that in the case of: axels changes of the lower limbs, the *dehors* compensating mechanism, repeated plies and more with *portées* or rise of the partner; could eventually lead to injuries in this femoropatelar joint, that are very common in ballet.

3.4. Portée

The carrying or lifting of the companion is also present in all the ballet disciplines and it is another characteristic element of ballet exercise.

Broadly speaking could be related with shoulders pathology, mainly subacromial syndromes or cuff rotator affections, as well as the lumbar spine, mostly of the lumbar L5 S1 segments, being this more frequent in contemporary ballet where these *portées* are produce out of axis.

4. Ballet disciplines

The word ballet appears for the first time in *Cornazzano of Piazenza's* book in 1465, in the Italian Renaissance [1].

Although in 1588, *Thoinot Arbeau* described the technique of external rotation of the legs in ballet *(dehors)*, it was not until 1661 when the academic classical dance is described through the principles of *Bescham and Gulli* which is what reaches our days. Also highlighting the figure of *Maria Taglionni* as the first dancer who at least structured stood on tiptoes in 1832, in The Sylphide representation at Paris Opera House [1].

In the 19th century appeared a new trend, the neoclassicism that followed the Enlightenment's principles that affected the rest of the branches of culture in Europe during the eighteenth century. This new trend adopted the technique of academic classical dance, although ballet achieved a less corseted expressive dimension but fluently in torso and limbs.

Subsequently highlighting, in the early as the 20th century, the figure of *Isadora Duncan*, dancer that will revolutionize the world of dance with their ideas, complete freedom of movement, no rules and limitations and starting to dance barefoot. It was from this point that the so-called contemporary ballet began [1].

Actually, the most currently acknowledged ballet disciplines are classical, neoclassical and contemporary ballet, with Spanish ballet a leading discipline also in Spain.

These four disciplines establish their foundations in the knowledge and perfect performance of classical ballet technique, which additionally makes up a great part of its structure. Nevertheless, they have been known to show technical differences for quite some time [1, 13].

So, classical ballet has the most structured discipline of all and shows the highest technical requirements, being typical of this discipline, among other features, the use of pointes by female dancers and half-pointes by both males and females.

In contemporary ballet, there is a greater freedom of movement, with fewer rules and hindrances, commonly finding both male and female dancers to either dance with half-pointes or bare footed. In this discipline, women do not use tips.

Neoclassical ballet is midway between the well-structured organization of classical ballet and the freedom of movements of contemporary ballet, thus allowing dancers to wear the corresponding alternatives concerning footwear. Being not uncommon that in some representations of the neoclassical ballet, there are women using tips simultaneously to others who may be half-tip shoes or even barefoot.

As for Spanish ballet, it shows to have the classical ballet structure joined to Spanish folklore, with the bolero school or the Spanish classical dance being predominant variables and having faster movements and more frequent jumps than classical [1]. Footwear with a higher heel is used in Spanish dance and a "heeling" technique used in some performances.

The fore-mentioned technical features will influence both injury specificity for each discipline and for both sexes, usually with higher technical requirements among women and higher athletic requirements among men [1, 10].

Considering the fore-mentioned, and although a good physical condition is a must in any sports activity, we should think about the importance of a good technique adapted to each dancer's biomechanical characteristics, as one of the best ways of preventing these injuries, while the opposite–an insufficient or inadequate technique which goes beyond these biomechanical conditions- would be considered a factor favoring the appearance of such injuries.

5. Epidemiology of ballet. Lesions most frequent

The vast majority of studies on ballet-related injuries, indicate overuse injuries as the most frequent ones in ballet, as pointed out in our studies where a statistically significant prevalence of these lesions was observed (75%).

In addition to, all the authors are agree than 65–80% of ballet injuries affected Lower limbs, being the most frequent the ankle-foot complex followed by spine and Knee.

Although some studies [29] show that the prevalence of ballet-related injuries tends to increase with proficiency, years of training and professional experience, others demonstrate, as reported *by Solomon* [21], that younger dancers display a high prevalence of injuries 6, a finding that is in line with our own studies. Indeed, as shown in our studies, the higher prevalence of overuse injuries was observed, overall, among the younger dancers, especially women.

The great majority of the studies on ballet-related injuries are based on surveys, being difficult to find studies that contribute specific diagnoses. However, in some studies and in those we have recently published, we obtain specific clinical diagnoses based on clinical history and clinical examination [7–12].

So, the most common overuse injury in our studies and in the historically known studies about ballet [31, 32], is the Patellofemoral Syndrome or anterior knee pain, related in ballet with decompensating mechanisms to increase a naturally weak in turnout or *dehors* [1, 25]. With respect to the knee, mention must be given to patellar tendinopathy, pathology even described in some studies [2] as the most prevalent pathology in the ballet knee.

Related to vertebral column, mechanical low back pain, represented special mention in our studies, being more frequent in more athletic disciplines such as contemporary ballet and related to disorders of the Mobile Segment [1]. Decompensating mechanisms in turnout or *dehors* will also play an important role in low back pain which, together with extension movements of the trunk when performing arabesques and *cambreés*, would cause an anterior pelvic lean increasing lumbar lordosis and an overload of posterior joints, making these technical gestures responsible for cervical and even dorsal back pain, both considered common aches among *"flamenco dancers"* [33, 34].

Our prevalence for low back pain in Spanish ballet will be much alike that mentioned in other studies indicating a value of 15.3% [35]. As a general comment, our results will appear to be well below those mentioned by other authors using surveys [36], which indicate values of up to 70–80%.

Regarding the hip, the snapping hip stands out in our study, especially the lateral snap with respect to the anterior one, being more common among women who practice those more technically demanding disciplines such as classical ballet. As has been mentioned for other pathologies, forced external rotation of the full kinetic chain in the lower limbs may give way to the presence of these snapping hip [37–40].

Among ankle overuse injuries, we must point out, undoubtedly, the Achilles tendinopathy, frequent in sport and athletic activities such as ballet which demand to a large extend jumping and running movements.

It is also worth mentioning the importance in our research studies of the hallucis longus flexor tendinopathy, both as an isolated injury or associated to an Os trigonum Sd [41, 42], which, however, in German dance companies [7], was more prevalent than the Achilles tendinopathy. This injuries are related to *relevée and points* [39, 43].

With respect to the foot, the pathology due to mechanical overload of the 1st MTTF joint plays an indicative role in our studies [1], being more frequent among male dancers and in contemporary ballet, as well as being related in ballet with repetitive dorsal flexion movements of the first toe, an essential action for the *relevée* technique [44].

Also in the foot, point out stress fractures which affect the base of the second metatarsal, which turn out to be the most representative in ballet according to most authors [27, 45], and with a notable increase based on gender, in this case women showing higher values and especially in classical ballet due to the use of tips or points [45].

5.1. Injury based differences among age and seniority

Entities such as Patellofemoral Syndrome, stress fractures of the base of the second metatarsal or lateral snapping hip, which in our studies display a significantly higher prevalence in junior professional dancers, are especially frequent in the more technical disciplines such as classical ballet, characterized by tougher technical demands and more repetitive actions [14].

In contrast, the prevalence of other conditions such as chondral injury of the knee or lower-back disc disease, more prevalent in more athletic disciplines such as contemporary ballet, augments with increasing age and years of professional practice and reaches a peak in senior dancers [14].

It would therefore seem that while at a younger age it is the more technically demanding disciplines that favor the development of overuse injuries, in the more physically demanding disciplines, which generally allow a greater freedom of movement, most overuse injuries result from a mechanical overload that intensifies with the passage of time. In this connection, the case of neoclassical ballet is of special interest. Indeed, that discipline could be considered intermediate in terms of technical and athletic demands and, its prevalence is also significantly higher in the intermediate age group of our sample [14, 15].

Surprisingly, many of the overuse injuries resulting from pathomechanic alterations, such as patellofemoral Syndrome, stress fractures of the base of the second metatarsal and lateral snapping hip, not only had a higher prevalence in the more technical disciplines like classical ballet and among junior professionals; they were also highly prevalent in women dancers, who are usually subject to greater technical demands than men. On the other hand, many of the pathologies derived from tough physical demands, such as chondral injury of the knee and lumbar disc disease, were more prevalent not only among senior dancers and in the more athletic disciplines, but also among men, who are usually subject to more athletic requirements than women [14, 15].

A certain number of the pathologies described are good examples of these considerations. Thus, stress fractures of the base of the second metatarsal and mechanical overload of the Lisfranc joint are clearly related to the use of tips shoes in women, whereas rotator cuff pathology is more connected with the performance of *portées* by men. Also, patellofemoral syndrome and the lateral snapping hip showed themselves to be related to an effort to increase the external rotation of the lower extremities by dancers wishing to improve their *dehors* or turnout technique [1, 22].

Moreover, the possibility exists that for junior professional dancers, and specifically for women practicing the more technical ballet disciplines, the higher number of injuries may occur in the less talented and/or technically accomplished dancers who usually require more repetitions of each movement to achieve their goals.

6. Prevention of injuries in ballet

As it gives off the contributed by different authors in the scientific literature related overuse injuries, there is agreement about the prevention as the best form of treatment and also the most effective for these disorders.

Like this, and although the injuries can not avoid of the all, as the own sport carries implicit the risk that they produce, if it can reduce the risk of it's appearance [33]. Actually supported a proposal of sport injuries prevention [39], based in a sequence of four steps that would include: know the amplitude of the problem, identify the factors and injured mechanisms, incorporate measures of prevention and evaluate his efficiency.

With these considerations, we are going to describe below, a general prevention protocol for the overuse injuries in ballet, as well as some specific Prevention measures. Nevertheless, it will be to carry out research studies with a sufficient scientific methodology, allowing to compare the efficiency of the preventive measures in ballet.

6.1. Prevention protocol

The Prevention Protocol it will be based in the knowledge of the epidemiology, etiology, biomechanics, and pathomechanics, of the most notable injuries in ballet [1].

In addition to, it will be important the teamwork of the professionals related with the dancer, including the medical service, physiotherapist, and also the teacher technical team.

Of this form, would direct his performance to two levels that would have to be near at hand of any dancer interested or professional, independently of the structure of the Academy or Company to which belong:

- 6.1.1 Prevention phase: before the apparition the symptomatology.
- 6.1.2 Clinical phase: performance when this self-evident

6.1.1. Prevention phase

The prevention is more useful, profitable and with better results. It would have to establish the coordination of the different professionals involved. In general, and to reach this aim we would owe:

- The knowledge of the etiology and general clinic of overuse injuries.
- Identify the risk factors about the injuries appearance.
- The Knowledge of the Ballet biomechanics and pathomechanics.
- The knowledge of the anatomical and functional characteristics of the dancer.
- The learning of the technical ballet demands and it's different disciplines.
- The control of the materials employed, including the environmental factors related to the floor, temperature and also on the footwear among other.
- The inclusion of the preventive culture in the management and organization of companies
- Training and advice of teachers, physical coaches and others professionals related with the dancers.
- Training of dancers about the prevention of the musculoskeletal disorders
- Suitable warming methodology
- Balanced work of flexibility and strength
- Eccentric work, showed his efficiency in the prevention of muscular injuries and in the prevention and treatment of tissue injuries and joint reinforcement
- Proprioceptive Work

http://dx.doi.org/10.5772/intechopen.72428

6.1.2. Clinical phase

Once the symptoms appear, the fundamental objective will be the early diagnosis and treatment. Once treated, it will be important a progressive reincorporation to the activity and the medical follow-up, being important the direct relation between the doctors, physiotherapist, teachers and physical coaches, if it exists.

Considering the importance to avoid the tendency to chronicity of these injuries and avoid recurrences, it will be essential before starting the activity, to recover the complete mobility of the damaged joint or area, as well as, to recover progressively the coordination, proprioception and workload, recommending the work in water in the initial phases.

Once initiated the activity, it will be advisable the following general algorithm of performance: "REST—Warming- stretching - progressive adaptation to the maximum work load—maximum Load—progressive reduction of the maximum workload—stretching—ICE (except tendon)—REST."

6.2. General and specific measures of prevention in ballet

Concerning preventive measures in ballet, we would highlight [1]:

6.2.1. General measures

6.2.1.1. Control on the predisposing conditions and triggers of injury

- Anatomical variations.
- Bad education of the technician.
- Deficiencies in the methodology of the rehearsals
- Imbalance in the Training of strength and flexibility.
- Deficiencies in the warming and stretching.
- Insufficient control of the Fatigue and stoicism of the dancer when appear the first symptoms of injury.
- Avoid the tendency to the chronic of the injuries, limiting the activity and rest a time, performing exercises other than ballet with extraneous exercises to the ballet to avoid the overload in the structures damaged.
- Reduce the frequency and length of the repetitive movements, especially during the rehearsals related with changes of choreography.
- Enough recovery time
- Value the performance on the footwear, adapting the new advances with the tradition that marks the Ballet, and on the hardness of the floor and others environmental factors and in some surfaces.
- Suitable physical preparation and diet balanced to reduce the incidence of injuries.
- Minimize the psychological stress

6.2.2. Specific measures

- Although it is usually established the age of 12 years to start getting on *"points or tips,"* the beginning this have to coincide with the foot intrinsic muscles development and with the joint stability of the foot and ankle.
- A good methodology of stretching and flexibility exercises is necessary to improve the *"dehors,"* and to avoid the decompensating mechanisms of this technical gesture to expand the external rotation of the lower limbs.
- Regarding that data, it has to procure besides, a suitable balance between the usual exercises of abduction—external rotation, and with the adduction—internal rotation, like base to try avoid the pain in previous face of hip and lateral face of knee [25].
- It is important that the technique conform to the biomechanical conditions of the dancer, knowing his limits. In this sense, some authors [34], indicate control measures of suitable "*dehors,*" like what during the execution of this gesture, the alignment of the knee should not surpass that of the second metatarsal bone.
- Avoid, especially in precocious ages, the frequent change of the footwear and/or an excessive height in the heel in those disciplines of ballet, like the Spanish, that like this require it [34].
- Considering the recommendation of some authors [26], is necessary the suitable balance of agonists and antagonistic muscles of the thig, and the realization of eccentric exercises in the prevention of the patellofemoral syndrome in ballet.
- Incorporation of eccentric exercises and stretching exercises of the plantar fascia to the programs of training, in the prevention of the plantar fasciitis [46].
- Likewise, will be indispensable a suitable methodology of the warming, including the progressive stretching in this context, and with arrangement to the previously described algorithm, to try to avoid determinate injuries like the lesions of the proximal insertion of the hamstrings [47].

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Chapter 6

Sports Concussion: A Clinical Overview

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.70765

Abstract

Concussion is an injury risk associated with participation in collision sports. It has been identified as a research priority for many contacts and collision sports governing bodies worldwide. However, concussion remains under-researched in terms of clinical translation from both experimental models to clinical understanding, and from clinical studies to sports policy. Currently, the clinical management of concussion is largely guided by the presence or absence of symptoms with recovery indicated once all post-injury symptoms have resolved. Management of concussion includes physical and cognitive rest until acute symptoms resolve, with a graded program of exertion implemented prior to medical clearance and return-to-play. Considering the potential sequelae, the heterogeneity of symptoms, and the lack of an intervention known to prevent concussion, it is not any wonder that concussion is one of the most complex and perplexing injuries faced by medical professionals, and why making the return-to-play decision can be quite challenging. This chapter will provide an overview of the current clinical management guidelines and research literature pertaining to identification and diagnosis of injury, acute and post-acute management, and return-to-play decision-making. The traditional standard assessment process (e.g., symptom reporting, cognitive assessment, balance testing), new methods and advanced technology (e.g., ocular-motor testing, neuroimaging techniques), and biomarkers (e.g., blood plasma and serum, fluid) have led to greater insights into sports concussion and will also be briefly explored in this chapter.

Keywords: concussion, head injury, diagnosis, assessment, management, research, clinical care

1. Introduction

Modern sport is a highly competitive and lucrative commercial product, with the health of its major stakeholders, the athletes, regarded as a vital asset. The status of the athlete's cognitive health is an important factor for maintaining a high level of athletic performance and the greatest risk to an athlete's cognitive health in any contact or collision sport, is concussion [1]. In general, sports concussion is recognised as a major health concern worldwide and the management of such injuries is currently one of the most complex topics in sports medicine. Concussion has been increasingly recognised as a large burden of disease and as such has been identified as a research priority for many collision sports' governing bodies worldwide. Despite this concern, concussion is under-researched in terms of clinical translation. Currently, the clinical management of concussion is largely guided by the presence or absence of symptoms with recovery indicated once all post-injury symptoms have resolved. The international guidelines on concussion management and return-to-play recommendations are open to clinician interpretation and based primarily on expert opinion. Until more recently, the management of concussion included physical and cognitive rest until acute symptoms resolve, with a graduated program of exertion implemented prior to medical clearance and return-to-play. Now, complete rest is only considered to be beneficial in the first few days post-concussion, with relative rest and a graduated program of exertion recommended [2]. Considering the heterogeneity of concussion, the differences in presentation between individual athletes, and the lack of an intervention known to prevent concussion, it is clear why concussion is one of the most complex injuries for medical professionals to manage, and how making the return-to-play decision is challenging.

In this chapter an overview pertaining to the identification and diagnosis of injury, acute and post-acute symptom presentation and management, and return-to-activity decision-making will be provided. Specifically, key aspects including identification, diagnosis, assessment, management and return-to-play, as well as potential long-term concerns that have been associated with concussion will be reviewed.

2. Incidence rates for sport-related concussion

Obtaining reliable incidence figures for sports concussion is challenging due to methodological inconsistencies in epidemiological studies and the under-reporting of symptoms by athletes. Investigators use different data acquisition methodologies (e.g., definition of concussion, definition of injury [time loss versus no time loss], sports, sample sizes, self-report versus physician diagnosed), types of data analysis, and draw different conclusions from similar data. Variable terminology and reporting formats (e.g., injuries per 100-player exposures versus injuries per 100-player hours) also complicates comparisons across studies.

In the United States, the Centers for Disease Control and Prevention (CDCP) reported incidence rates for sports concussion of approximately 3.8 million annually [3–5]. Comprehensive collegiate injury data have been collected by the National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS) since 1982. The NCAA ISS reported 4.2 concussion injuries per 1000 athletic exposures, with football game injury rates at 2.2 injuries per game for a team of 50 athletes [6]. When considering all injuries sustained in NCAA competition, concussions generally account for approximately 4–10% of all injuries [7].

http://dx.doi.org/10.5772/intechopen.70765

3. Identification

The identification of a potential concussion is an important initial step in the management process. Removing an athlete from the potential for further harm is thought to reduce an athlete's risk of more serious or catastrophic consequences associated with a second concussion. Importantly, an athlete does not need to be 'diagnosed' with a concussion in order for them to be removed from play, the mantra *"if in doubt, sit them out"* is quiet frequently quoted and is the conservative approach. In all suspected cases of concussion, the individual should be removed from the playing field and assessed by a physician or licenced healthcare provider [8]. Many sports' governing bodies now have a low threshold for requiring athletes to be removed from play, with 'suspected concussion' providing ample concern that the athlete must be removed from play. Many sporting bodies now apply criteria (identifiable concussion signs) at the elite and semi-professional levels that are considered 'red flags' and require immediate and permanent removal from play, or immediate removal from play and assessment. At all times parents, coaches, and officials need to act in the best interest of athlete safety and welfare by taking responsibility for the recognition, removal, and referral of athletes to a medical doctor.

The Pocket Concussion Recognition Tool™ was created and updated by the Concussion in Sport Group (CISG; a group of international sports concussion experts) to help identify possible concussion. It is a quick reference and brief tool that may be used to identify suspicion of a concussion through providing a short list of visible cues (of suspected concussion), and signs and symptoms (of suspected concussion), in addition to orientation and memory questions.

3.1. Self-reported symptoms

Athletes may themselves report experiencing a single post-concussion symptom, or a cluster of symptoms that may raise suspicion that a concussion has occurred. These symptoms can be covert (not witnessed by others), whereas other signs may be overt (observed by witnesses). Where an athlete has reported any one of the symptoms presented in **Table 1** (see for common concussion symptoms), a potential concussion may have occurred and the athlete should be managed conservatively.

In the Hunter New England Local Health District's Sports Concussion Clinic, the most commonly reported symptoms between 48 and 72 hours post-concussion by the athletes are headache, pressure in the head, dizziness, a general feeling of "not quite being right," and fatigue. Anecdotally, some athletes seem to experience a constellation of symptoms while others do not, which suggests that particular athletes may be more vulnerable to particular post-concussion symptoms than others, and that some symptoms may have an association with others. Many athletes underplay their symptoms in order to return-to-play quicker; this is why objective tests sensitive to post-concussion changes are also an important adjunct to the clinical assessment and certainly to any self-reported symptom questionnaire. Objective measures will be discussed further in sections that follow.

Difficulty remembering	"Do not quite feel right"
Headache	"Pressure in the head"
Confusion	Feeling like "in a fog"
Dizziness	Blurred vision
Sensitivity to light	Sensitivity to noise
Amnesia	Feeling slowed down
Neck pain	Difficulty concentrating
Sadness	More emotional
Nervous or anxious	Fatigue or low energy
Irritability	Nausea

Table 1. Potential symptoms of concussion.

3.2. Overt signs

Overt signs may be witnessed by others such as players, match officials, coaches, managers, other team support staff, parents, and/or fans. Potential symptoms are outlined in **Table 2**. For matches that are televised, the various broadcasters' views are often scrutinised by the expert analysts and the general public at home. The use of video for reviewing a concussion may identify signs of injury that may have been blocked from view or otherwise missed by medical staff. A number of professional contact and collision sports have recently introduced the use of sideline video review for club medical staff to help identify and manage concussions [9]. Numerous studies of video footage have been conducted in a variety of sports; for example, rugby league [10–12], rugby union [13], and Australian rules football [9, 14, 15]. Other sports, such as boxing [16], soccer [17], taekwondo [18], ice hockey [19–22], and lacrosse [23], have also reported on the use of video footage for understanding the circumstances and mechanisms of injury unique to their sports.

Video replay analysis presents a useful tool for sports medicine professionals to identify potential concussions, but it also can be difficult to interpret and presents challenges in identifying those who have sustained a concussion. In a series of work in professional rugby league [10–12, 24–26], the use of video analysis was comprehensively evaluated. Being aware of the combinations of possible concussion signs and the likelihood that various presentations result in a concussion diagnosis can provide a useful addition to sideline concussion identification.

Loss of consciousness	Blank or vacant stare
Gait ataxia or balance problems	Seizure or convulsion
Clutching or shaking head	Vomiting

Table 2. Potential signs of concussion.

http://dx.doi.org/10.5772/intechopen.70765

3.3. Red flags

The signs and symptoms of concussion can sometimes be the same as more severe head injuries. It is recommended that more serious action should be taken in the event that there is evidence of loss of consciousness (LOC) or deteriorating conscious state, severe or increasing headache, neck pain, increasing confusion or irritability, repeated vomiting, unusual change in behaviour, or weakness or tingling/burning in the arms or legs. These signs and symptoms are considered to be *red flags*, and may be an indication of something more serious. If any of these signs/*red flags* occur, the athlete should immediately attend the nearest Accident and Emergency Centre.

3.4. Rugby union's 'Blue Card' system

World Rugby (the international governing body for the sport of rugby union) introduced a trial 'Blue Card' system across a number of nations over the past few seasons to increase efforts in the identification and management of concussion. The Blue Card initiative provides the on-field referee authority to issue a Blue Card to any player presenting signs of concussion during a match. After receiving a Blue Card, the player must leave the field of play for the remainder of the match and cannot return-to-rugby until they have completed a series of steps designed to ensure they make a full recovery before taking the field again (discussed further below).

4. Diagnosis

Despite considerable advancement in the field, there still remains an absence of a perfect diagnostic test or marker that can be used by clinicians for an immediate concussion diagnosis. The CISG Berlin Consensus Statement reports that "*at present there is no perfect diagnostic test or marker that clinicians can rely on for an immediate diagnosis of concussion*" [8]. Because a concussion is an evolving process, it is not possible to rule out a concussion when transient neurological symptoms occur [8]. In order to identify and diagnose an injury, a definition is required. There are numerous, varied definitions, but the diagnosis of concussion should always be a medical decision. The Concussion in Sport Group (CISG; Berlin, 2016) [8] recognises a sports concussion as a traumatic brain injury (TBI) induced by biomechanical forces.

The CISG Berlin, 2016 highlighted that there are a number of features that can be considered in clinically defining concussion:

- Concussion may be caused either by a direct blow to the head, face, neck, or elsewhere on the body with an impulsive force transmitted to the head.
- Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, signs and symptoms evolve over a number of minutes to hours.
- Concussion may result in neuropathological changes, but the acute clinical signs and symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is seen on standard structural neuroimaging studies.

- Concussion results in a range of clinical signs and symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive features typically follows a sequential course. However, in some cases symptoms may be prolonged.
- The clinical signs and symptoms cannot be explained by drug, alcohol, medication use, other injuries (such as cervical injuries, peripheral vestibular dysfunction, etc.), or other comorbidities (e.g., psychological factors or coexisting medical conditions) [8].

The recent consensus statement on concussion in sport [8] clarified that the final determination regarding sport-related concussion diagnosis and/or fitness to play is a medical decision based on clinical judgement.

Traditionally, loss of consciousness (LOC) was perceived by many professionals as a necessary sign for the diagnosis of concussion and many of the concussion grading scales reflected the duration of LOC as an important categorisation value [27]. Despite this, there was never a clear association between the duration of LOC and prognosis for a good versus a poor recovery. In traumatic brain injury more generally, the association has had greater support at the severe end of the severity spectrum. For example, duration of coma appeared to have some impact on both early functional outcomes at time of discharge and long-term level of disability (GOS scores at 5–7 years post-TBI). It was also shown to be a strong prognostic factor in predicting both functional and occupational long-term outcome [28]. The majority of studies reported an association between the duration of coma and outcome (i.e., the longer the duration of coma, the worse the outcome) [29–34]. More recently research has reported that LOC occurs in less than 10% of sports concussion at the high school, collegiate, and professional levels [35].

5. Assessment, management, and return–to-activity

A multimodal approach to the clinical assessment of concussed athletes is strongly recommended given concussion is a multi-dimensional injury. The following section provides a brief overview of some of the approaches to the clinical assessment. In addition, various modalities that are currently being used in a research context that may translate in to the clinic in the future are also briefly presented.

5.1. Clinical history

There are many underlying conditions that can mimic post-concussion symptoms, in addition to disorders and conditions that can prolong recovery. Therefore it is essential to the interpretation of the presentation and any assessment measures used in the clinical setting, to collect a comprehensive and thorough history of the athlete. In addition, it is important to ensure that the presenting symptoms are not readily explained by other neurological or medical conditions or disorders, and therefore may potentially be treatable [36]. Individuals without known developmental or health problems, no known history of concussion, also report some non-specific concussion-like symptoms in their daily lives. These symptoms can be related to any number of issues like stress; depression; sleep problems; chronic pain; drug and/or alcohol

http://dx.doi.org/10.5772/intechopen.70765

abuse; pituitary, thyroid, endocrine, or hormone deficiency; and vascular-related disorders (i.e., diabetes, blood pressure issues, cholesterol problems). Pre-morbid learning disorders, behavioural issues, or mental health problems are all known to be the source of a number of the post-concussion symptoms and clusters of symptoms [37]. For example, athletes with Attention Deficit Hyperactivity Disorder (ADHD) [38–42] or learning problems [39] have a greater lifetime history of concussion, and individuals with a prior history are at increased risk for a future concussion [43].

5.2. Neuropsychological assessment

Over two decades ago cognitive tests were first introduced into the sports context to assist with the assessment and management of sports concussion. This paradigm has continued to develop, from the traditional pencil paper-based measures to the computer-based platform. The CISG (Zurich, 2008) advocated for the use of empirically based measures for the management of concussion, and they identified neuropsychological testing as a "cornerstone of concussion management" [44]. The utility of cognitive testing for the assessment and management of sports concussion was first demonstrated by Barth and colleagues [45], who recognised the inherent variability in individual performance on neuropsychological measures. This resulted in a within-subjects comparison to assess for cognitive change after a concussion. Comparing athletes' baseline (i.e., pre-injury/pre-season) and post-injury performance allows for detection of relative deficits, as athletes serve as their own controls. This serial assessment model has been widely accepted by researchers and adopted by many, if not most, high school, collegiate, and professional sports programs as an effective measure of evaluating cognitive impairment [46, 47]. Conventional paper-based neuropsychological testing poses several limitations for sports medicine practitioners (e.g., the extensive time requirements for administration, scoring, and interpretation; practice effects from serial presentation of a finite number of stimuli; and floor and ceiling effects [1]). Additionally, the traditional tests were never designed nor validated for serial assessment over brief periods of time. Intent on overcoming such important clinical limitations, computerised adaptations of conventional neuropsychological tests were developed. Computer-based test batteries have been recognised as an effective concussion-screening tool because of their ability to be administered simultaneously to a large group, increased timing accuracy, and decreased practice effects [1, 48]. At this point of time there are a number of commercial computerised neuropsychological tests that are available for athletes at all levels of competition. Two of the most commonly used are ImPACT (see: https://www.impacttest.com/) and CogSport (see: https://cogstate.com/featured-batteries/cogstate-brain--injury-battery/).

5.3. Neuroimaging

Computer tomography (CT) and structural magnetic resonance imaging (MRI) are typically unhelpful in athletes suffering sports concussion beyond ruling out a more severe traumatic brain injury—in individuals where it is potentially clinically indicated. However, advanced neuroimaging techniques have increasingly been used in a research context, with speculation that some of these techniques may translate to the clinical setting. Some research in acutely concussed athletes with advanced neuroimaging techniques have demonstrated an association with metabolic and physiological changes in the brain, which correlate with post-concussive symptoms and performance on cognitive testing [49].

A recent systematic review [49] found that all of the 76 eligible studies using neuroimaging and/or electrophysiological measures reported significant effects of concussion. This likely reflects the publication bias in the literature (i.e., positive findings are more often published than negative findings), the numerous output variables of these modalities that are available to the researcher for conducting multiple comparisons (which increases the likelihood of false positive findings), or that these modalities are more sensitive to post-concussion changes. The authors note that there are many issues in attempting to bring the literature together when considering each of these modalities; for example, there are a limited number of studies for any specific marker, varying post-concussion time frames when the data was collected, an absence of any standardised acquisition protocol, or post-processing and analyses. Despite these limitations, the authors identified a number of consistent patterns within certain modalities [49].

The majority of task-functional MRI (*f*MRI) studies use a working memory paradigm, and has resulted in varied findings. Increased [50, 51] and decreased activity in task-related networks (e.g., dorsolateral prefrontal cortex) have been reported [52–55]. The variability in methodology (i.e., the type and number of stimuli used [low versus high working memory 'load']) may explain apparent discordance in hypoactivation versus hyperactivation results reported [49]. In concussed athletes, activity outside of the core task regions have also been reported in a variety of tasks [52–54]. Varying methodology is also a considerable limitation in interpreting the resting-state *f*MRI (rs-*f*MRI) literature. The default mode network (DMN) is the most extensively studied network in the concussion and rs-*f*MRI literature, and results have reported both increases and decreases in connectivity between DMN regions [56–58]. Altered functional connectivity has also been observed relative to executive function, visual, and motor networks [57–60]. Reduced cerebral blood flow (CBF) has been reported during the acute and sub-acute phases (days to weeks) post-concussion [61–63], as well as at more chronic time points (approximately 5 months) [64].

The use of diffusion tensor imaging (DTI) has increased substantially over the past few years. In 2012, a systematic review of the DTI and concussion literature [65] reported on eight studies and raised concern in the literature at the time that there was so much variability in the methodology bringing together the findings of the diverse range of work and attempting to interpret the results was challenging. A more recent DTI and concussion systematic review [49] suggested that the most consistent findings were decreased mean diffusivity and/or an increase in fractional anisotropy in white matter within 6 months post-concussion [66–70], but these findings are not universal (i.e., the opposite patterns have also been reported in other studies) [56, 62, 71]. In addition, reduced radial diffusivity has been reported [68, 72–74], but increase and decrease in axial diffusivity have been described [68, 69].

The magnetic resonance spectroscopy (MRS) and sports concussion literature was systematically reviewed in 2013 [75]. The review included 11 eligible studies. The authors of the systematic review raised concerns regarding the absence of studies examining sensitivity and specificity of MRS for concussion and the lack of longitudinal studies involving a reasonably large cohort of injured athletes. One of the greatest shortcomings, was that there was no way of determining how to interpret reliable or clinically significant changes in neurometabolites in individual athletes, because there were no studies involving test-retest reliability. Unfortunately almost 5 years later, this shortcoming has not been resolved. In addition, there is no consensus pertaining to the ideal methodology, with a variety of methods used to measure metabolite concentrations. The availability of additional metabolites, such as Glutamate (Glu) and myo-inositol (mI), might add to the sensitivity and specificity of MRS measures (as shown in severe traumatic brain injury). Therefore, adoption of short echo time methods or other means of obtaining additional biochemical measures would be advantageous [75]. In general, MRS results have found reduced N-acetylaspartate (NAA; relative to creatine and/or choline) predominately in white matter [64, 76–78], with some evidence of acute reduction with subsequent recovery by 30 days post-injury in the MRS literature [76, 79]. There is also evidence that NAA may be decreased more chronically [64, 80].

Several studies have demonstrated the effects of concussion on electroencephalogram (EEG)/quantitative-EEG (qEEG) at rest or during various task conditions. Measures from qEEG have also been shown to be altered at 8 days post-concussion relative to baseline [81], and have been associated with concussion severity, underlining the potential of electrophysiological measurements in the assessment of concussion [82].

In view of the limitations of the literature (e.g., lack of generalisability due to the inclusion of limited age ranges, male athletes focus and/or limited sample sizes, lack of appropriate control groups, lack of pre-injury enrolment and potential for measurement bias due to limited information regarding the definition/diagnosis of mTBI/SRC), the authors of the systematic review on advanced neuroimaging from the CISG Berlin, 2016 suggested that "*the level of evidence for the role of these neuroimaging and electrophysiological measures in the clinical assessment of concussion is low because the most studies reviewed were not designed to specifically assess clinical potential.*" However, the authors also suggested that "*there is a significant role for neuroimaging and electrophysiological measures in characterising the pathophysiology of concussion*" [49].

5.4. Blood and fluid biomarkers

Blood (plasma or serum), saliva, and cerebral spinal fluid (CSF) have become an increasingly utilised method for analysing various biomarkers post-concussion. Proteomics (the study of proteins) has advanced in such a manner that many researchers and clinicians are becoming increasingly interested in collecting samples from athletes. A recent systematic review [49] reported 11 studies found significant alterations in one or more of the following blood biomarkers that could potentially aid in the diagnosis of concussion: α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid receptor peptide (AMPAR) [83], S100 calcium binding protein B (s100B) [84, 85], total tau [85], marinobufagenin [86], plasma soluble cellular prion protein [87], glial fibrillary acidic protein [87], neuron-specific enolase (NSE) [88], calpain-derived αII-spectrin N-terminal fragment (SNTF) [89], tau-C79, and metabolomics profiling [90].

5.5. Oculomotor and vestibular function

The vestibular and oculomotor systems are important in sensing angular and linear acceleration of the head and eyes, which enables a moving individual to maintain gaze on a stable target or a stationary individual to focus on a moving target. Sports concussion clinical researchers have observed vestibular and oculomotor pathway involvement in the recovery from concussion in certain athletes. As such, many concussion-screening programs now include vestibular and oculomotor testing. Vestibular and oculomotor screening may include an assessment of pursuits, saccades, vestibular ocular reflex, visual motion sensitivity, and convergence via symptom provocation and measurement of near-point convergence. Vestibular and oculomotor impairment and symptoms may be associated with worse outcomes after sports concussion, including prolonged recovery [91]. Identifying clinical profiles may help to inform better treatment and earlier intervention to reduce recovery time after concussion [92]. As such, screening for and subsequent monitoring of vestibular and oculomotor impairment and symptoms are critical to assessing and informing subsequent referral, treatment, and return-to-play. Combining these assessments with others that examine whole-body behavioural output of vestibular, visual, and somatosensory integration (e. g., postural balance) may increase sensitivity and greatly improve concussion management. McDevitt and colleagues [93] reported that using a condensed set of balance, and vestibular and oculomotor tests resulted in the greatest accuracy for detecting concussion.

5.6. Dual-tasks

Not only has a multimodal approach to the assessment of athletes suffering concussion been endorsed, but the assessment of multiple domains simultaneously has been considered to be more sensitive to post-concussion sequelae as a means of stressing the system. As noted above, *f*MRI studies using dual-task paradigms have demonstrated recruitment of many neuroanatomical areas outside of the typical structures known to service certain cognitive functions. In addition, the introduction of a cognitive task while walking has been shown to distinguish concussed from non-concussed athletes and may be used as a paradigm for monitoring recovery post-concussion [94–96].

5.7. Rest

Many of the original guidelines and consensus and agreement statements for managing sports concussion have recommended that athletes rest until they have made a complete recovery (i.e., symptom free) [44, 97–99]. As such, rest has been almost universally recommended as part of the 'treatment' process [100, 101]. However, 'rest' is a misnomer; it is not possible for an athlete to be at complete rest (both physically and cognitively), so it is more accurate to label the recommendation as 'relative rest.' Rest has been assumed to ease discomfort during the acute recovery period by mitigating post-concussion symptoms and/or that rest may promote recovery by minimising brain energy demands following concussion [102]. The most recent systematic review on rest and treatment conducted by a number of leading clinicians and researchers from the Concussion in Sport Group [102] and the consensus statement [8] reported that "*there is currently insufficient evidence that prescribing complete rest achieves these objectives. After a brief period of rest during the acute phase* (*24–48 hours*) *after injury, patients can be encouraged to become gradually and progressively more active while staying below their cognitive and physical symptom-exacerbation thresholds* (*i.e., activity level should not bring on or worsen their symptoms*)." Refraining from engaging in vigorous exertion while an athlete is recovering is

Stage	Aim	Activity	Goal of each step
1	Symptom-limited activity	Daily activities that do not provoke symptoms	Gradual reintroduction of work/ school activities
2	Light aerobic exercise	Walking or stationary cycling at slow to medium pace. No resistance training	Increased heart rate
3	Sport-specific exercise	Running or skating drills. No head impact activities	Add movement
4	Non-contact training drills	Harder training drills, for example, passing drills. May start progressive resistance training	Exercise, coordination and increased thinking
5	Full contact training	Following medical clearance, participate in normal training activities	Restore confidence and assess functional skills by coaching staff
6	Return-to-sport	Normal game play	

Note: This table has been modified from the CISG Consensus Statement (Berlin, 2016) [8]. An initial period of 24–48 hours of both relative physical rest and cognitive rest is recommended before commencing the GRTP process.

Table 3. Graded return-to-play (GRTP).

recommended, however, the extent of exercise and duration of rest, or relative rest, is not yet well defined and requires further study [102].

5.8. The graduated return–to-play (GRTP)

The graduated return-to-play (GRTP) is a six-stage program of increased intensity that is completed over a minimum of 6 days (i.e., each stage should take at least 24 hours). If an athlete who is engaged in the GRTP process experiences a return of any post-concussion symptoms, then the athlete is to return to the previous step. In the 2016 consensus statement, the CISG added clarification regarding athletes who experience persisting symptoms (i.e., symptoms lasting more than 10–14 days in adults or more than 1 month in children), stating that the athlete should be referred to a healthcare professional who is an expert in the management of concussion. The CISG also clarified that resistance training should be added only in the later stages (stage 3 or 4 at the earliest). A summary of the GRTP recommendations for each of these stages is presented in **Table 3**.

6. Potential longer term concerns

Understanding the possible long-term effects of concussions sustained during a career in contact sports has become an area of considerable interest. Repetitive neurotrauma sustained during a career in boxing has been reported to be associated with chronic brain damage in some former athletes since the 1920s [103], but it has only been associated with former National Football League (NFL) players more recently. A review on this issue conducted by Manley and colleagues [104] reported that there is emerging evidence that some retired NFL players have mild cognitive impairment [105, 106], neuroimaging abnormalities [107, 108], and differences in brain metabolism [109] disproportionate to their age. Autopsy cases of former professional football players (among others also in the sample) have revealed diverse forms of neuropathology, including immunoreactivity for hyperphosphorylated tau (p-tau) in a specific pattern (e.g., irregularly distributed in depths of cortical sulci) in which p-tau is not expected to be present through normal ageing or in association with frontotemporal dementia or Alzheimer's disease [110]. For a comprehensive review of this literature see Manley et al. [104], Iverson et al. [111], Gardner et al. [112], Randolph et al. [113], and McCrory et al. [114].

In view of the speculation pertaining to the possible consequences concussion may have on the health of some athletes later in their life, current athletes often raise concerns regarding the issue of retirement. In the clinical setting, athletes are regularly presenting following a single, or in some instances multiple, concussion history with information fuelled by the media's speculative presentation of this topic, concerned that they are at high-risk of long-term issues. It is not possible at the current time to predict or diagnose CTE in-life. The diagnosis is made through neuropathological examination on autopsy. There are a number of research groups around the world currently conducting prospective, longitudinal studies to further understand this disease, but it will take a generation of players (or longer) to fully comprehend the extent of the issue, and the factors that place some athletes at risk versus others who appear to be resilient. Providing athletes with information to empower them to make a well-informed decision regarding retirement is a complex issue. Currently no evidenced-based, scientifically validated guidelines for forming the basis of such a decision exist [115]. In the absence of strong empirical evidence to support recommendations, clinical decision-making must be individualised and should involve a multidisciplinary team of experts in concussion and traumatic brain injury [36, 115]. Involving a multidisciplinary team enables a thorough investigation of all domains, and where clinical indications are present, it enables all possible differential diagnoses to be appropriately considered [36].

7. Conclusion

Sports concussion remains one of the most challenging conditions to diagnose, assess, and manage for the sports medicine professional. The acute effects, but also the potential long-term issues, need to be considered when managing athletes through a safe return-to-activity. A comprehensive clinical assessment of a concussed athlete involves a multimodal approach, but it is critical that the clinician understands what each tool being used is measuring and how to interpret the results. For some measures a pre-injury, post-injury paradigm is appropriate for interpreting the results, but for others post-injury performances can be interpreted with the use of normative data. A conservative approach to the return-to-play is recommended, and the final return-to-activity decision should be made by a medical professional.

8. Links to further material for reviewing clinically related subject matter on sports concussion

The following links provide further detail pertaining to the information presented in this chapter:

World Rugby (WR): http://playerwelfare.worldrugby.org/concussion

National Collegiate Athletics Association (NCAA): http://www.ncaa.org/sport-science-institute/concussion

Consensus Statement on Concussion in Sport—the 5th International Conference on Concussion in Sport (Berlin, 2016): https://bjsm.bmj.com/content/bjsports/early/2017/04/26/bjsports-2017-097699.full.pdf

Sports Concussion Assessment Tool—Fifth Edition: http://dx.doi.org/10.1136/bjsports-2017-097506SCAT5

The Pocket Concussion Recognition Tool™: http://bjsm.bmj.com/content/bjsports/47/5/267.full.pdf

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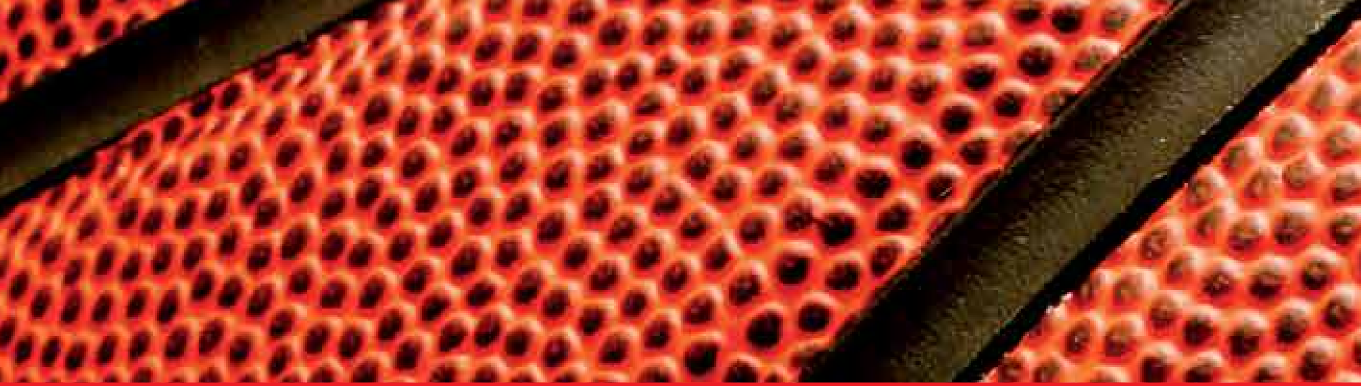

Edited by Matjaz Merc

Professional and semiprofessional sports as well as excessive amateur exercise inevitably lead to some degree of musculoskeletal injury once in a sportsman's career. Some injuries are represented as chronic injuries, which can result in irreversible long-term tissue changes and deformities. The subject of this book is to represent the up-to-date knowledge about etiology, pathogenesis, diagnosis, management, and prevention of chronic injuries or sport-related long-term changes in locomotor system.

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ISBN 978-953-51-4089-4