TITLE:

Injury Risk Factors in Male Youth Soccer Players

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LEAD SUMMARY

Young athletes participating in high intensity sport display an inherent risk of sports-related injury, and this is heightened at various stages of growth and maturation. Recent trends have highlighted a range of injury risk factors and the importance of injury prevention strategies within female soccer players. However, there is a paucity of information pertaining to male youth players. This manuscript provides an overview of the available literature and outlines a range of risk factors that may increase relative risk of injury in male youth soccer players, including: growth and maturation, movement skill, fatigue and previous injury.

INTRODUCTION

Reported injuries in male youth soccer occur mainly in the lower extremities with a higher occurrence of non-contact incidents, and a predominance of ligament sprains at the ankle and knee (Price et al., 2004; Le Gall et al., 2006). More specifically, the medial collateral ligament (MCL) and anterior talofibular ligament are the most commonly reported injuries (Price et al., 2004, Cloke et al., 2009). For young athletes the risk of sports-related injury is heightened at various stages of growth and maturation (67). Specifically, with an increase in a child's age, there is greater exposure to training and competition, which involves high levels of repetitive loading which can increase injury risk (36). Further, a linear increase in injury rates has been reported from 9 to 15 years of age in male players (62), with a marked increase around the age of 13 years (22, 64). Chronologically, these ages coincide with rapid changes in stature and mass as a result of maturational processes. During adolescence, males will experience peak height velocity (PHV) at around age 14, which refers to the time at maximal rate of growth during the adolescent growth spurt (46). Recent research shows that elite male youth soccer players experience more traumatic injuries in the year of peak height velocity (67), which underlines the greater occurrence of sports injuries with later stages of maturation (48).

Recent trends have highlighted a range of injury risk factors and the importance of injury prevention strategies within female soccer players (2, 61). However, there is a paucity of information on male youth players. Due to the physical demands of soccer, the associated injury risk and the number of children and adolescents who participate in the sport, there is a clear need for increased research within male soccer players to identify age and sex specific injury risk factors (3). Specifically, practitioners working with youth male players must be cognizant of a range of modifiable and non-modifiable risk factors that are specific to paediatric populations which may increase injury risk. Hence, the focus of this review is to outline a range of considerations pertaining to male youth soccer players which may contribute to their relative risk of injury.

OPERATIONAL TERMS

For the purposes of this review, *growth* refers to quantifiable change in anthropometrics, body composition, body size, or the size of specific regions of the body (6).

Maturation refers to qualitative system changes, both structural and functional in nature in the organism's progress towards a mature state. The timing and tempo of maturation is variable among bodily systems (6) and while growth and maturation are often used interchangeably, growth should be viewed as a constantly evolving process, whereas, maturation has a definitive end point (i.e. when an adolescent becomes fully mature. *Childhood* is the period of pre-pubescence and extends from the end of infancy to the start of adolescence (46).

Adolescence is more difficult to define via chronological age due to large variation in maturation rates, but can be referred to as the period between childhood and adulthood (46).

THE ROLE OF GROWTH AND MATURATION

One factor which cannot be modified but should be monitored regularly as part of a screening approach is individual growth and maturation. This is highlighted by Michaud et al. (48) who showed that children display an increase in sports related injury occurrence as they mature. Recent data show that there is a heightened risk of injury for youth male soccer players in the year of peak height velocity (67) and that with maturation, there is an increased risk of ligament sprain and a concomitant decrease in bone fractures which are likely due to increased body mass, altered bony lever lengths influencing increased joint loads and greater intensities of play (1, 24, 25). Thus, an awareness of growth and maturational processes is essential for developing an understanding of changes in performance and alterations in motor control at various stages throughout childhood and adolescence (45, 46).

Variability in the growth and development of various physiological systems can be considered a key risk factor for injury, specifically around periods of accelerated growth. For example, with rapid growth in skeletal structures, the muscular system must simultaneously develop both in length (to normalize tension from bone growth), and also in size, so that greater levels of force production are possible to support and move the larger and heavier skeleton (69). However, it should be noted that the preceding growth in skeletal structures provides a stimulus for morphological adaptation of muscle tissue, thus an inherent time lag is present between the rate of bone growth and subsequent muscle lengthening. This has connotations for the incidence of traction apophyseal injuries in youth athletes, particularly prevalent in soccer between the ages of 11-14, with peak incidence occurring in males for the under 13 and under 14 age groups (62). The disproportionate growth rates of bone and the muscle tendon complex result in greater forces experienced by the involved tissues when they are in a relaxed state (previously referred to as tissue preload (11)), and this has been suggested as a contributing factor in the occurrence of traction apophyseal injuries (49). Further, a delay between growth in muscle length and cross-sectional area has also been reported (70). This development lag in cross-sectional area may result in altered neuromuscular control strategies making dynamic stabilization more challenging (23, 24, 34). A reason for this may be the subsequent change in lever lengths, which result in a higher center of mass and concomitant increases in joint torques in order to attenuate forces in the absence of adequate hypertrophy and strength (51, 69). Furthermore, it has been acknowledged that during the peak growth spurt, a differential growth rate exists between the legs and the trunk, whereby, the long bones (limbs) experience peak growth prior to the short bones (trunk) (46). Therefore, the presence of musculoskeletal growth lags following the onset of a growth spurt up to, and around the period of peak height velocity, need to be considered in male youth soccer players to ensure the risk of overuse and apophyseal injuries is reduced during these key periods of growth.

As a consequence of rapid increases in limb length, young soccer players may experience temporary decrements in motor skill performance, which has commonly been referred to as a period of ‘adolescent awkwardness’ (59). While this period of awkwardness does not necessarily affect all youth, adolescents may experience disruption in motor control due to the continual growth of anatomical structures, disproportionate growth of skeletal and muscle tissue and changes in neuromuscular functioning (15). An awareness of the adolescent awkwardness phenomenon is important as it has previously been suggested that acquired skills and movement patterns may need to be re-perfected during this period (18). Cumulatively, literature indicates that periods of accelerated growth may be a key injury risk mechanism and therefore practitioners should adopt an appropriate system of monitoring growth in young athletes.

MOVEMENT SKILL

Precise neural regulation of muscle optimizes human movement and the execution of finely tuned motor skills, in addition to increasing joint stability by dynamic restraint (defined as the role muscles play in joint stability) (33). Frequent stimulation of neural pathways will subsequently enhance motor programming, preparatory muscle activity and reflexive neuromuscular responses, which will contribute to greater levels of dynamic joint stabilization and skill (11). Individuals who lack fundamental movement skill development during the prepubescent period may compromise dynamic stability as they enter puberty and adolescence (5; 34). Therefore, targeted interventions to develop fundamental movement skills during the prepubertal years are deemed critical due to the accelerated periods of neural plasticity associated with pre-pubescence, resulting from the natural development of the neuromuscular system (8). This is further highlighted by suggestions that the optimal age for movement skill development is during the prepubertal period (52), with the ages of 7-11, determined as a 'sensitive period' for sequential development of gross motor skill (27) and movement coordination (35).

The relationship between movement skill competency and injury is not consistent within the available literature. Harmon and Randall (32) showed that skill level does not relate to Anterior Cruciate Ligament (ACL) injury risk across a period of seven years in male and female basketball and soccer players. Further, in female athletes, higher skill levels have been reported as a risk factor for lower extremity and back injury (37). Conversely, in male soccer players, an association between skill level and injury has been reported with low skill players demonstrating a two-fold increased incidence of lower extremity injuries, particularly in the knee and ankle (58, 12). However, it should be considered that in the aforementioned research studies, their classification of 'skill' was determined by sport playing level (i.e. division 1, 2 or 3) and not a reflection of an individual's ability to perform fundamental movement skills. According to Blume (7), seven coordinative abilities provide the key components of skill, including: motor differentiation; motor connection; balance preservation; spatial orientation; motor rhythmitization; speed reaction; and motor transformation. Thus, it should be considered that the ability to compete at a high level in sport is an over simplistic classification of one's skill. This is highlighted by findings that in male subjects, altered movement patterns and deficits in neuromuscular control were able to predict injury (28, 66). Therefore, the ability to perform movements safely in desirable patterns associated with successful performance would be a more appropriate means of evaluation.

Movements that lead to injury in male youth soccer include running, twisting, turning, over-stretching and landing (62), with altered neuromuscular control during such actions a suggested mechanism (2). Neuromuscular control has been defined as the activation of dynamic restraints which occur in preparation for, and in response to, joint movements and forces to provide functional joint stability (63). Deficits in neuromuscular control direct excessive stress to the passive ligamentous structures, exceeding their strength limit, and result in mechanical failure (44). Specific imbalances which have been identified in female athletes include: quadriceps dominance; leg dominance or asymmetry; ligament dominance or knee valgus motion, and trunk dominance or core dysfunction, (34, 50, 51). Further, reductions in fundamental movement skills of injured professional male athletes (42), lower scores on a single leg jump and balance assessment (29), and greater leg asymmetry in dynamic balance tasks (60) have been identified in male and female students as positive predictors of injury. Therefore, it could be argued that the assessment of an athlete's neuromuscular control provides a better indication of their movement 'skill', and if a number of deficits are identified, a greater risk of injury is present. However, despite the growing body of evidence in females, there is a lack of available literature to confirm pertinent injury risk factors for male youth soccer players at different stages of growth and maturation, and thus requires further investigation.

FATIGUE

Heightened fatigue following an acute bout of exercise has been reported to increase known markers of injury risk, which may subsequently effect dynamic joint stabilization (57, 66). In soccer, greater levels of fatigue have been reported to increase injury incidence in both adult male professionals (21) and elite male youth players (13, 62), with injuries occurring more frequently towards the end of the first and second half respectively (62). It is suggested that this timeframe may be indicative of reduced neuromuscular function and control, as evidenced by recent data showing that electromechanical delay increases (17) and feed-forward reflex activity decreases (55) in females and males respectively following exposure to acute soccer-specific fatigue protocols. Furthermore, in a group of male youth soccer player's, fatigue induced changes have been reported during a drop jump task (54). Specifically, the subjects increased landing forces, with a reduction in muscle activity of the tibialis anterior, knee flexors and extensors. Conversely, aEMG of the soleus increased, suggesting that in a fatigued state, young athletes are less able to tolerate ground reaction forces, and due to lower muscle activation, experience greater skeletal loading. Also, youth players may utilize a more ankle dominant landing strategy with reductions in neuromuscular control around the knee. Finally, the measurement of landing kinetics and kinematics in a fatigued state has identified both male and female subjects significantly increased peak proximal tibial anterior shear forces, increased valgus moments, and decreased knee flexion angles (10). Combined, these fatigue-induced neuromuscular alterations lead to an overall reduction in dynamic stabilization upon ground contact (26), thus placing the lower limb at increased risk of injury. Specifically, these high risk landing kinematics increase the risk of injury to both the ACL (Hewett et al., 2005, Padua et al., 2009) and MCL (Gardiner et al., 2001).

Recent evidence shows that paediatric subjects respond to fatigue differently based on age and maturation (16). In this report submitted to U.E.F.A, data showed that pre, circa and post pubertal females experience changes in leg stiffness, electromechanical delay and functional quadriceps: hamstring ratio following an acute simulated soccer fatigue protocol. These changes differed according to age and maturation, with prepubertal and circa pubertal youth showing the greatest decrement in electromechanical delay or functional hamstring: quadriceps ratio respectively, which may negatively impact dynamic joint stabilization. Alterations in the timing and speed of hamstring muscle activation increase the mechanical strain on the ACL due to a reduction in stabilization of the tibia which increases anterior tibial translation (Shulzt and Perrin, 1999). Thus, whilst these responses were measured in female subjects, recent evidence suggests in a fatigued state, altered patterns of neuromuscular control are evident in male youth soccer players (54, 55), and therefore, it is reasonable to assume that differential responses based on age, growth and maturation are also likely in males. Consequently, practitioners should be aware of individualized responses to fatigue and consider implementing more targeted intervention strategies to enhance neuromuscular capacities in both rested and fatigued states. However, due to the paucity of current data available, specific responses to fatigue and the subsequent effects on movement mechanics in male youth soccer players requires investigation.

A further point of consideration is the effects of chronic fatigue on the level of afferent feedback. Specifically in males, measured responses to a simulated eccentric fatigue protocol have demonstrated that although muscle function was restored close to baseline post 96 hours, electromechanical delay was significantly greater for all of the reported contraction conditions (38). The author proposed that this may be due to changes in post-synaptic events, specifically exciting-contraction coupling (38, 68). This has implications for monitoring neuromuscular readiness to re-perform following periods of heavily fatiguing exercise which include of a high number of eccentric muscle actions, such as the repeated decelerations and changes of direction occurring in soccer. Therefore, despite the aforementioned study utilizing adult male subjects, it is reasonable to assume that neuromuscular performance will be altered in youth males when preceded by fatiguing conditions. Subsequently, assessments of neuromuscular function performed in a pre-fatigued state may enhance ecological validity. However, there is currently a paucity of data to describe the baseline characteristics of male youth soccer players, and is thus a logical start point. Following this, the effects of acute fatigue on movement performance can be more accurately identified.

PREVIOUS INJURY

Previous injury has been reported as a significant risk factor for future injury occurrence (19; 30, 41). For example, male soccer players with a history of ankle or knee sprain were at a greater risk of re-injury to the same sites (odds ratio (OR) = 4.6 and 5.3 respectively) (4). Furthermore, Ekstrand and Tropp (20) followed 639 male soccer players over a period of one season, identifying that those who had previously experienced an ankle sprain were at a 2.3 times greater risk of injury. Evidence of this risk factor in youth players has also been reported, with males and females (age range U12-U18) that experienced a previous injury presenting a two-fold greater risk of a secondary occurrence (41). Also, there was a three-fold risk for subjects who encountered two or more injuries suggesting that this is a pertinent risk factor for youth soccer players as the risk of re-injury seems to increase exponentially with the number of injuries occurred (41).

When interpreting the available research for previous injury as a risk factor for re-injury, practitioners should be cognizant of the fact that often the relationship between previous injury and subsequent re-injury is measured via a retrospective analysis, which relies on the individual's ability to recall their own injury history. Such methodologies may lead to recall bias which can occur in both long and short term retrospective reporting (40). Thus, a greater body of research is required in paediatric male populations that utilize prospectively recorded injury data and subsequent tracking of players over a longitudinal period. An example of this type of research design, albeit in adult populations, was used to determine previous injury as a risk factor in elite male soccer (30), confirming that players who experienced an injury in the first season were at a greater risk of sustaining any type of injury in the following season than previously non-injured players (hazard ratio 2.7; 95% confidence interval 1.7 to 4.3). Also, players who encountered a hamstring, groin, or knee joint injury were 2-3 times more likely to experience an identical injury in the following season. This highlights the lack of prospective screening and associated surveillance data and the need for detailed reporting of injury history during the initial athlete screening process, and subsequent monitoring of changes in movement patterns following the occurrence of an injury. Further, appropriate rehabilitation and training interventions are required to ensure that suitable neuromuscular control is displayed, and athletes are able to demonstrate 'low risk' movement patterns prior to returning to play.

The mechanisms associated with a high level of injury recurrence are not clearly understood. However, it has been suggested that neuromuscular inhibition may lead to altered movement and stabilization patterns (53). An example of this has been identified following injury to the ACL, whereby maximal voluntary quadriceps activation is significantly reduced following injury (39). Furthermore, neuromuscular inhibition patterns effecting knee joint stabilization have been reported following injury, with the hamstrings demonstrating greater deficits in eccentric rather than concentric strength (14, 43). A key role of the hamstring musculature during landing and deceleration tasks is to counteract the anterior shear of the tibia relative to the femur, providing control and joint support through eccentric actions (56). Altered activation patterns of the hamstrings will likely increase the risk of knee joint injuries due to a reduced ability to attenuate forces, and this risk will be magnified in the presence of poor neuromuscular control. Moreover, the gluteal musculature, which provide key synergistic actions to assist with knee joint stabilization, subtaler joint positioning, and resultant center of mass control have demonstrated inhibition following the occurrence of an ankle injury (9, 25). Thus, practitioners involved in the assessment and prevention of injury should be cognizant of altered movement patterns and muscular activation sequencing which may occur following an injury, and their relative effect on injury reoccurrence. Specifically in male youth athletes, there is a paucity of information confirming the mechanisms associated with injury reoccurrence, and therefore further investigation is warranted.

SUMMARY

For individuals working with youth athletes, and in particular, male youth soccer players, a range of factors need to be considered to aid in the prevention of injury. Some of the key factors have been presented in the manuscript and are summarized below:

1. Injury risk may be higher in youth male soccer players, particularly during critical periods of accelerated growth and development
2. A clearer definition of the term 'skill' is required to differentiate between technical sport proficiency and movement competency. In addition, a validated assessment to outline the movement proficiency of youth athletes is required
3. Individuals should also be aware that confounding factors including fatigue and previous injury heighten injury risk, highlighting the importance of appropriate

screening protocols to identify alterations in neuromuscular control and the implementation of monitoring approaches to manage training volume

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