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The multiple factors that contribute to noncontact lower extremity sports injuries

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Acute lower extremity (LE) injuries constitute a significant problem for team sports, with major long- and short-term consequences for athletes and their teams. For this reason, a wide range of research has been focused on strategies of prediction and prevention for LE injury. Knowledge of the key risk factors and their interrelationships in the system of injury etiology is the first and essential step towards formulating appropriate prevention procedures. This paper presents recent evidence regarding the factors related to the risk of acute noncontact LE injuries. The literature review identifies many intrinsic and extrinsic factors implicated in the etiology of LE injury, of which previous injury, gender and workload appear to have a stronger association with the occurrence of injuries. The evidence for a group of well-researched modifiable factors, such as strength variables, balance, fatigue and flexibility, is conflicting. Despite the evidence for each factor independently, the etiology of LE injury appears to be complex and dynamic, and research in sports injuries should, therefore, incorporate new methodologies capable of capturing this dynamic complexity in order to better understand and prevent sports injuries.

Πληθώρα παραγόντων κινδύνου συνεισφέρουν στην εκδήλωση τραυματισμών μη επαφής στα κάτω άκρα

Περίληψη στο τέλος του άρθρου

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1. INTRODUCTION

Acute noncontact lower extremity (LE) injuries are associated with long-term consequences for the health and performance of athletes.[1] The most common LE injuries are acute knee injuries,[1] including rupture of the anterior cruciate ligament (ACL),[2] acute ankle sprains,[3] and muscle strains, mainly to the hamstrings, adductors, quadriceps and calf muscles.[4] A severe knee injury can be devasting for athletes, with significant short-term (i.e., time away from sport) and long-term implications. ACL injuries often result in concomitant injury (meniscus 55–65%, cartilage 16–46%),[5] and a low rate of return to pre-injury activity level.[6] Muscle injuries, such as hamstring strain, constitute a significant problem for athletes and teams, as the incidence rate of such injuries and the rate of re-injury continue to be high, in spite of the increased amount of research on the issue.[7] After an ankle sprain, re-injury and chronic instability are common.[3]

Noncontact injuries constitute a significant problem for teams. Injuries have a considerable impact on team performance,[8] as coaches face the challenge of setting up the team despite the absence of essential players who are recovering from noncontact injuries.[8] Professional teams spend a considerable amount of their budget on the medical care of athletes. For instance, the one-month rehabilitation of a player with a hamstring strain in a European soccer team costs € 500,000.[9] Reduction of sports injuries will, therefore, contribute to the financial health and viability of the teams and health systems.

For these reasons, improvement of the prevention strategies is extremely important for lowering the occurrence of acute noncontact injuries and reducing their negative consequences. Identification of how specific risk factors act in the etiology of injury is a significant step towards the appropriate implementation of injury prevention strategies. This review presents an overview of the etiology of noncontact LE injuries and the main risk factors. A literature search was conducted in Scopus and PubMed databases for this purpose.

2. RISK FACTORS

Researchers have identified various risk factors for acute noncontact LE injuries through the years, which are categorized into intrinsic, namely the internal factors related to the athlete, and extrinsic, including environmental factors, equipment and factors related to training.[10] In addition, the risk factors can be divided into modifiable and nonmodifiable, based on the possibility of modification of their qualities by various interventions.[10] For example, age, previous injury and gender are nonmodifiable factors, since they cannot change. Factors such as neuromuscular characteristics, strength imbalance and flexibility are modifiable factors, as their qualities can be modified via exercise-based injury prevention programs and behavioral approaches.[10] As presented in table 1, the risk of injury is a dynamic and complex phenomenon,[11] and the internal and external factors related to the athlete are subject to dynamic interaction. The following sections present a comprehensive overview of the various risk factors implicated in the etiology of LE injury.

2.1. Intrinsic modifiable risk factors

2.1.1. Biomechanics of movement. Various LE injuries occur during jump-landing, cutting[2,3] and sprinting tasks.[7] A rigid landing technique, with minimal flexion of the trunk, hip and knee joints, is considered a risk factor for a variety of LE injuries.[2,12] ACL injury has been linked with specific movements, such as internal rotation of the hip and abduction of the knee during landing.[2] In addition, reduced core muscle strength, reduced activation of the gluteus maximus, reduced range of motion of the ankle and increased internal rotation of the hip are all factors related to changes in knee kinematics, increasing the knee abduction angle.[13] In addition, sprinting kinematics and muscle recruitment patterns are involved in strain injury of the hamstrings.[7]

2.1.2. Muscle strength, imbalance, flexibility, asymmetry. Strength variables are well documented, but there is low evidence regarding their ability to predict injury.[14] Some evidence supports the concept that reduced hip adductor strength, either as absolute strength or in comparison with that of the hip abductors, is a risk factor for groin injury.[15] Acute hamstring injury is associated with increased peak torque of the quadriceps muscle,[7] and decreased eccentric action of the hamstrings.[7,16] The strength of eccentric inversion, concentric plantar flexion, and peroneus brevis reaction time are among the risk factors associated with lateral ankle sprain injury.[3] Regarding ACL injury, decreased strength of the hamstrings appears to increase loading on the ligament during a side-step maneuver.[17] Evidence on the impact of muscle imbalance as a univariate risk factor for injury is ambiguous,[14,18] but there are reports that strength imbalance significantly increases the rate of various LE injuries, including hamstring strains, ankle sprain injuries and various knee injuries.[19,20] Although decreased flexibility is considered a weak risk factor for muscle injuries, flexibility is a significant component of injury prevention programs.[21] Limb asymmetries are common in many sports, reflecting the demands of each sport. Asymmetry exceeding 10–15% imposes abnormal forces

Table 1. Characteristics of dynamic complexity in the etiology of sports injury.[60]

Dynamic, adaptive and history-dependent	The various factors change over time, and nothing remains static and unchanged over a long period. Changes occur through interactions among the various factors, and as a result, the athlete becomes adjusted. The qualities of intrinsic, modifiable factors become adapted by their exposure to extrinsic factors (training, workload, playing situations, etc.)
Tightly coupled	One factor in the system interacts with other factors, and with the entire system
Characterized by feedback	Because of couplings between various factors, the change in a factor affects the whole system, and gives rise to feedback, which activate the system dynamics
Nonlinearity	Nonlinearity arises from the interaction of multiple factors. The cause of an injury could be the effect of multiple nonlinear interactions between internal and external factors
Self-organizing	As a complex system, the etiology of sports injuries has its own internal structure. Disruption of one factor generates specific patterns that affect other factors, based on the feedback mechanism
Policy resistant	Many different parameters act in the system of the etiology of sports injuries. When implementing actions, we may not take into consideration all the different parts of the system, and as a result, side effects may arise

on the lower extremities, increasing the risk of injury.[22] The average symmetry index (ASI) is a measure that presents the percentage of asymmetry between the lower limbs, and is derived from the equation: ASI=[1−dominant lower limb/non-dominant lower limb]×100.[22] It is a measure of asymmetry in power, velocity, jump height, jump distance and jump landing task.[22]

2.1.3. Postural and core stability. Single leg postural stability[23] and core proprioception[24] deficits have been linked with risk for ACL tear, ankle sprains and various knee injuries in various populations. In one study, the center of pressure (COP) displacement was significantly higher for both lower limbs in the injury group than in the non-injured group.[23] In addition, deficits in the star exertion balance test (SEBT) are linked with acute noncontact LE injuries.[25] Recently, it has been suggested that increased contralateral pelvic hike is connected with noncontact knee injury among young team sports players and with noncontact ACL injury in females.[26]

2.1.4. Body composition. Body mass index (BMI) is a crucial component in the etiology of various LE injuries, such as lateral ankle sprain[20] and knee injuries.[27] In an action such as changing direction, athletes with higher BMI impose a greater risk of injury to knee and ankle joints because of the inability of heavier athletes to control their momentum effectively.[27]

2.1.5. Fatigue. Acute fatigue affects the injury risk profile negatively by altering the intrinsic modifiable risk factors.[28–30] It has been reported that acute fatigue reduces postural control, the sense of position of the ankle joint and the muscular strength qualities of the hamstrings and quadriceps,[28] and specifically, it affects the isokinetic hamstring:quadriceps ratio.[28] The evidence is ambiguous regarding the possible increase in risk of ACL injury due to acute fatigue.[31]

2.2. Intrinsic nonmodifiable risk factors

2.2.1. Previous injury. A previous injury constitutes probably the most significant risk factor for most LE noncontact injuries.[16,32] The risk of a new injury is increased in the first few weeks after an injury, when the athletes return to practice and games.[32] Some data indicate that a history of an ACL injury is related to an increased risk of subsequent hamstring injury.[16] Regarding muscle injuries in lower extremities, a previous injury to other muscle groups increases the rate of injuries up to 3-fold in male professional football players.[33] Inappropriate rehabilitation and the biomechanical limitations and imbalance that may remain after an injury probably explain the severity of a previous injury as a risk factor for new injury.[7,34] A history of concussion has been associated with an increased risk of various musculoskeletal LE injuries.[35,36] Concussed athletes are 3.39 times more likely to sustain a musculoskeletal injury after return to play.[36] The underlying mechanism is neuromuscular control impairment following concussion, and this relationship persists despite apparent clinical recovery.[35] In addition, psychological factors in athletes with a previous injury have been connected with an increased risk of a new injury.[37]

2.2.2. Gender. Female athletes sustain ACL injuries at a higher rate than their male counterparts, with evidence of significant gender differences in ACL injury from the onset of puberty.[2] Hormonal, anatomical, and biomechanical parameters have been associated with these gender differences. Hormonal factors and, to a more significant degree than in males, muscle strength imbalance, have a significant impact in female athletes during this period.[2] It appears that these factors affect movement biomechanics, and as a result, female athletes tend to land with their knees in a valgus position more commonly than males, increasing the risk of ACL injury.[2]

2.2.3. Age – maturation. The older team sports athletes appear to be more prone to muscle injury,[38] and specifically an association between age (>24 years) and hamstring injuries has been reported.[16] Regarding young athletes, an increased rate of acute noncontact LE injuries around the onset of puberty has been documented.[39] Additional factors that appear to increase the risk of injury of younger team members are slower growth rate, later maturation, heavier weight at the start of the season, and increased chronological age.[39] All of the above variables appear to have a causal relationship with the rate of play and the workload. For instance, players with lower growth rates tend to be tallest, and are heavier because they probably have already passed the adolescent growth spurt. These players also tend to play more in games, increasing the risk of injury.[40]

2.2.4. Genetic factors. DNA sequence variants may play an essential role in the properties of soft tissues, such as the collagen fibrils and the musculoskeletal soft tissues, and their response to a mechanical load.[41] Genetic factors appear to be an essential component of the multifactorial etiology of a hamstring injury, for example.[7]

2.2.5. Anatomy and alignment. A high Q angle increases the risk for acute knee injuries and affects lower extremity function in combination with other factors.[2] Specific morphological characteristics of knee bones, such as decreased intercondylar notch width, small ACL size, inadequate tibiofemoral congruity and stenosis of the intercondylar notch[42] have all been associated with ACL injury.[42]

2.2.6. Psychological factors. Team sports athletes who have experienced a recent negative life event tend to have higher anxiety and stress levels, and when playing, to be involved in situations that increase their risk of acute injury.[43] Strong evidence has been presented regarding higher levels of common mental disorders, such as anxiety/depression, distress, sleeping disturbance and smoking, in players who had sustained previous injuries and or underwent surgery.[37]

2.2.7. Neurocognitive. Recent studies have indicated a connection between deficits in an athlete's cognitive ability and biomechanical parameters that increase the risk of ACL injury; specifically, experiments showed that visual-spatial memory is associated with knee valgus during a cutting task.[44]

2.3. Extrinsic risk factors

2.3.1. Workload. The workload measures the demands imposed on the athlete during practice or competition.[45] Workload can be divided into external loads that quantify the athlete's work, such as distance covered, speed, number of jumps, etc., and internal loads that measure an athlete's psychological and physiological load.[45] A commonly used method to record workload is the acute to chronic workload ratio (ACWR), which considers the acute workload (last 1-week period) divided by the chronic workload (average of the previous 4-weeks).[46] Multiple variables should be considered when recording workload, some of which are based on global positioning system (GPS) variables, such as total distance, low- and high-intensity distance, sprint distance, accelerations, and decelerations.[46] ACWR appears to be associated with acute noncontact injuries,[71] and a low chronic workload combined with high ACWR is also associated with noncontact injuries.[47] Moreover, the combination of a low acute with a low chronic workload is considered a risk factor for noncontact injuries,[45] whereas a high chronic workload is associated with a low risk of injury. The mechanism of these relationships is not clear, but the high chronic workload may produce protective adaptations in the athlete's internal factors.[45]

2.3.2. Shoes and surface. Numerous studies have been conducted on the incidence of LE injuries on artificial surfaces and natural grass.[48,49] First- and second-generation synthetic surfaces are associated with higher injury rates compared with natural grass.[48] The injury rate between the newer artificial surfaces and natural grass is comparable,[49] although in the opinion of soccer players, more injuries occur on artificial turfs.[50] There is evidence that high friction surfaces affect movement biomechanics, increasing the risk of ACL injury,[51] and high friction shoe-surface interaction affects the occurrence of acute noncontact LE injuries in indoor pivoting team sports.[52] In addition, it appears that some components of soccer shoes can predispose to LE injuries;[53] specifically, the production of light construction shoes, designed to enhance characteristics of players such as speed, power, endurance and better touch with the ball, has decreased the protective quality of the shoes.[53] The absence of arch support to prevent overpronation, and the cleats in combination with the playing conditions and surface are components that exert a negative effect on injury risk.[53]

2.3.3. Sport, playing position, and climatic conditions. Depending on the sport and the position characteristics, different loads are imposed on athletes.[54] To date, there is no consensus concerning the playing position as a risk factor. In soccer, however, goalkeepers appear to have a lower injury risk than other players, and forward players tend to have more injuries during the game.[54] Regarding the sport as a risk factor, basketball athletes of both sexes, and female volleyball athletes are more prone to present an ankle injury. In contrast, soccer athletes report the highest incidence of ACL injury,[1] and handball players sustain acute knee and ankle sprain injuries.[55] Muscle injuries in the hamstring muscle group have a high incidence in football, constituting around a third of the total injuries.[7] Finally, in soccer, the leg that is preferred for kicking the ball appears to sustain more acute noncontact LE injuries; most quadriceps and adductor muscle injuries were reported in the kicking leg.[38] Finally, LE injuries appear to have different rates depending on the climatic region;[56] the available data indicate that more ACL and ankle sprains are reported in warmer than in cooler areas. The reason is not clear, but the climatic conditions affect the conditions of playing surfaces and, consequently, shoe-surface friction.[56]

2.3.4. Bracing-external support. The restriction in the range of movement that bracing produces is associated with parameters that increase the risk of injury, such as like knee valgus, and therefore with various different LE acute and overuse injuries. Furthermore, bracing support may promote increased loads in the contralateral lower extremity.[57]

2.3.5. Internal team communication. Poor communication between coaches and medical staff has been associated with a higher burden of injuries in high-level football teams.[58] Low levels of communication have been related to a variety of factors, such as low levels of prevention strategies, pressure on the injured athlete to return to play before full rehabilitation, and no appropriate modification of workload following injury. The leadership style of coaches can influence collaboration and communication with the medical staff negatively affecting the psychological state of the athletes, and increasing the likelihood of stressful consequences.[58]

3. DISCUSSION

The wide range of risk factors that have been documented prove that sports injury is a complicated and multifactorial phenomenon.[11,59] Intrinsic and extrinsic factors combine to create a specific injury risk profile, characterized by complexity, in which the many components/factors interact with each other in a nonlinear fashion. From that viewpoint, one factor in isolation might not have a significant impact on the injury etiology, but in a systems approach, a change in one factor can promote changes in various other factors.[11]

Examples of nonlinearity and complexity in the etiology of injury can be exemplified by the factors of age, gender, and previous injury, all of which are associated with alterations in the athlete's neuromuscular profile. Modification strategies that improve the neuromuscular characteristics of athletes could reduce the significance of the previous injury, gender, and age as risk factors.[7] Another example is the complex interaction between workload, fatigue, and modifiable factors. High ACWR can cause acute fatigue, with a negative effect on neuromuscular and biomechanical factors.[45] On the other hand, a long-term high workload can sometimes bring about positive adjustments to an athlete's internal quality.[45] The above characteristics should all be considered in combination with the athlete's age, gender, BMI and history of injury. These individual characteristics of athletes can create a specific complex and dynamic interrelationship between the various factors. Finally, components such as the exposure of athletes to risk in training and competition, the type of training, and the rehabilitation from injuries, all cause dynamic modifications on modifiable factors through time.[59]

In conclusion, preventive strategies should incorporate targeted injury prevention programs, with holistic approaches and strategies to reduce the incidence of injury.[11,59] These approaches could include workload modifications, and should incorporate psychological support, and a high level of collaboration and communication among the team's support staff. It is crucial to collect data on injuries frequently during the season, and record the modification in the modifiable factors that make athletes more or less susceptible to injury.[59] In this way, more targeted policies can be introduced to prevent injuries.[59] Sports injury research is needed that incorporates methodologies to examine this dynamic complexity in injury etiology.[11]

ΠΕΡΙΛΗΨΗ

Πληθώρα παραγόντων κινδύνου συνεισφέρουν στην εκδήλωση τραυματισμών μη επαφής στα κάτω άκρα

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Οι οξείς μη επαφής τραυματισμοί στα κάτω άκρα συνιστούν ένα μεγάλο πρόβλημα για τα ομαδικά αθλήματα, με βραχυπρόθεσμες και μακροπρόθεσμες επιπτώσεις τόσο για τους αθλητές όσο και για τις ομάδες. Γι' αυτόν τον λόγο ένας μεγάλος όγκος έρευνας έχει εστιάσει στην πρόβλεψη και στις στρατηγικές πρόληψης των αθλητικών τραυματισμών. Η γνώση των κύριων παραγόντων κινδύνου και των αλληλεπιδράσεών τους μέσα στο συνολικό σύστημα της αιτιολογίας του τραυματισμού αποτελεί ένα βασικό πρώτο βήμα για τη διαμόρφωση κατάλληλων πρακτικών πρόληψης. Έτσι, ο σκοπός του παρόντος άρθρου είναι η αποτύπωση των πρόσφατων δεδομένων σχετικά με τους παράγοντες που αυξάνουν τον κίνδυνο για τους οξείς μη επαφής τραυματισμούς στα κάτω άκρα. Μετά τη βιβλιογραφική ανασκόπηση πολλοί ενδογενείς και εξωγενείς παράγοντες βρέθηκαν να εμπλέκονται στην αιτιολογία του τραυματισμού. Παράγοντες όπως ο προηγούμενος τραυματισμός, το γένος και το φορτίο φαίνεται να έχουν ισχυρότερη συσχέτιση με την εμφάνιση τραυματισμών. Επί πλέον, αντικρουόμενα είναι τα αποτελέσματα για μια σειρά από επαρκώς μελετημένους τροποποιήσιμους παράγοντες κινδύνου, όπως οι μεταβλητές δύναμης, ισορροπίας, κόπωσης και ευλυγισίας. Ωστόσο, παρ' όλα τα δεδομένα που υπάρχουν για κάθε παράγοντα κινδύνου μεμονωμένα, η αιτιολογία του τραυματισμού φαίνεται να είναι ένα περισσότερο περίπλοκο και δυναμικό φαινόμενο. Γι' αυτόν τον λόγο είναι απαραίτητο να ενταχθούν νέες μεθοδολογίες στην έρευνα για τους αθλητικούς τραυματισμούς, οι οποίες θα είναι ικανές να αποτυπώσουν τη δυναμική πολυπλοκότητα της αιτιολογίας του τραυματισμού. Με αυτόν τον τρόπο θα κατανοηθούν καλύτερα και θα προληφθούν οι αθλητικοί τραυματισμοί.

Λέξεις ευρετηρίου: Αθλητικοί τραυματισμοί, Αιτιολογία τραυματισμών, Παράγοντες κινδύνου, Πρόληψη τραυματισμών

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