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Research Article

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The Risk Factors Affected Upon Non-Contact ACL Injury in Gymnastics, Swimming and Basketball Collegiate Student Female Players

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ABSTRACT

The purpose of the present study was to determine of the risk factors affected upon non-contact ACL injury in Gymnastics, Swimming and basketball collegiate student female players. If an athlete injured anterior cruciate ligament the most important thing is to identify factors that affect the injury. However, growing research implicates hormonal, anatomical, environmental and neuromuscular factors that may predispose athletes to these injuries. For this research selected 510 athletes for assess ACL injury factors by two different methods (A) Questionnaire and (B) Interview that information collected among athletes who were play Gymnastics, Swimming and basketball. Our results indicate 61.4% of ACL injury occurred in practice time and 38.6% of ACL injury was during competition. Also, our finding showed that 69% mechanism of injury was non-contact, 4.7% via accident and 26.3% with unknown reason. Furthermore, dynamic alignment at the time of the injury included: Knee-in & Toe- out 44%, Knee-out & Toe-in 22.5 and Hyperextension 11.1%. The ACL prevents the femur from moving forward during weight bearing. It also helps to prevent rotation of the joint. Injury of the ACL most often occurs when an athlete is pivoting, decelerating suddenly or landing from a jump. The injury can also be caused by another player falling across the knee. ACL injuries are, probably, the most common devastating knee ligament injuries amongst sports persons. Usually these injuries are isolated, mainly in non-contact sports, but many often are a part of more complex ligamentous injuries. They occur more often in contact sports, such as basketball. In conclusion, our study produced strong evidence in support of a significant some factors influencing of ACL injury in Gymnastics, Swimming and basketball collegiate student female players.

Keywords: Non-Contact, Anterior Cruciate Ligament, Risk Factors

Introduction

The anterior cruciate ligament (ACL) is the major passive restriction to anterior translation of the tibia on the femur, with the reported incidence of primary ACL injury as 1.5% to 1.7% per year in healthy athletic population [1,2]. After an ACL injury, athletes present with the main complaint of knee instability for which ACL reconstruction (ACLR) is the current gold standard operative management [3,4]. A recent patient satisfaction survey concluded that athletes who can resume their sporting activity are more likely to be satisfied with the outcome of the ACLR [5]. Several risk factors for primary ACL injury have been studied and identified. Female sex race and participation in pivoting sports have been widely reported as risk factors for primary ACL tear. Other reported risk factors include enhanced posterior tibial slope narrow notch width small size ACL, limb malalignment, neuromuscular control vertical directed and short femoral tunnel length and graft tunnel length [6-13]. In recent years, there has been tremendous improvement in surgical techniques, methods of fixation and rehabilitation protocol relating to ACL reconstruction [14]. Despite this, the reported incidence of ACL re-injury remains high; 6% for ipsilateral graft injury and another 6% for contralateral knee ACL tear [15]. The social and economic burden of ACL injuries is substantial. Lifetime costs are reported at nearly $40,000 for reconstructive surgery and almost $90,000 for conservative treatment [16-18]. The incidence rate for ACL injuries in the general population has been reported to be 68.6 per 100,000 person-years, with particular susceptibility in male athletes in their early twenties and females in late adolescence the latter are three times more likely to suffer an ACL injury than males [19-20]. Hormonal, anatomical, neuromuscular and proprioceptive aspects may contribute to this sex difference [21]. Additionally, there is an increased risk of developing joint degeneration, such as osteoarthritis, later in life after ACL injury [22]. For professional athletes, an ACL injury is especially devastating, as it is often career-ending [23]. Therefore, it is crucial to regularly assess athletes at risk of ACL injury or reinjure and, most importantly, to offer them tailored preventive countermeasures [24]. Several functional-performance factors have been proposed to be associated with an increased risk of ACL (re)injury. In particular, the knee abduction angle and moment (i.e., inward movements of the knee in the frontal plane) determined by three-dimensional (3D) motion capture has been one of the main focuses of research related to ACL (re)injuries in the past [25-28]. Greater relative knee abduction angles during various dynamic movement tasks were revealed to be associated with a higher risk of injury although the ability of screening tests to predict ACL (re)injuries has been the subject of substantial

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controversy [25]. Other factors reported in the literature with potential associations with the occurrence of ACL (re)injuries include lower extremity (LE) or core muscle strength deficits, lack of muscle preactivity during side-cutting, LE asymmetries in jump distance or speed, lack of balance and joint laxity [29-34]. The phase of the menstrual cycle and the extended duration of the menstrual cycle also appear to influence the occurrence of injuries [35]. Of the proposed morphologic measures, some of the most frequently mentioned were tibial slope angle, femoral notch width and body mass index (BMI) [29,30,36]. The mechanism of non- contact ACL injuries has been elucidated (see "ACL Injury Mechanisms," below). However, numerous theories have been proposed to explain what predisposes patients to non-contact ACL injury. These theories are divided into four categories: hormonal, anatomical, environmental, and neuromuscular (table 1) also anatomical position of Anterior Cruciate Ligament (ACL) showed in figure 1.

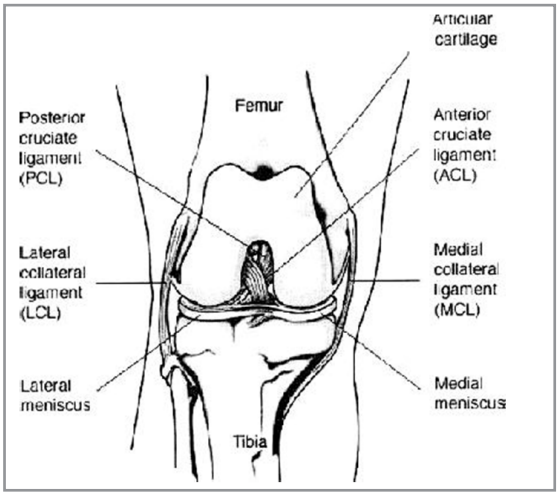

Figure 1: Anatomical position of Anterior Cruciate Ligament (ACL). (Ref: http://www.taosortho.com/images/ACL.ht1.jpg)

Table 1: Proposed Causes of ACL Injury

Hormonal	Estrogen
Anatomical	ACL size Intercondylar notch Lower-leg alignment Knee joint laxity Muscle flexibility
Environmental	Playing style Shoe-surface interface uneven playing surface
Neuromuscular	imbalanced muscular strength, imbalanced muscular recruitment

It has been well recognized that multiple factors, whether individually or in combination, contribute to Non-contact ACL injury. The ongoing mission of the ACL research retreat is to bring clinicians and researchers together to present and discuss the most recent advances in ACL injury epidemiology, risk factor identification, and injury-risk screening and prevention strategies and to identify future research directives [37]. A different approach to the problem of ACL tears involves prevention. New treatment options, such as regenerative treatments based on tissue engineering methods, are being developed but are not available for clinical use [38-40]. Indeed, a number of ACL injury prevention programs have been developed and have been shown to reduce ACL injury rates significantly [41-43]. These programs usually target high-risk groups, such as young female athletes, and aim to improve dangerous motion patterns. For example, a program may aim to improve landing technique from "flat foot" landing with an extended lower extremity to landing with deep hip and knee flexion. However, the effectiveness of these programs has not been comprehensively analyzed and described. Consequently, identification of factors associated with increased risk of suffering ACL injury during sport and physical activity has become a focus of musculoskeletal research. This information is needed to understand the mechanisms that produce this debilitating injury and may allow identification of those at increased risk so that targeted interventions can be implemented. Researchers have utilized a range of measurement techniques, focused on different at risk groups, evaluated many sports, identified an array of injury mechanisms, and utilized different study designs. Current investigations concerning ACL injury risk focus on a range of potential factors, and the majority of these studies are based on small sample sizes and, as a result, are underpowered. Research in this field has primarily focused on a single potential risk factor in isolation. Over time it became apparent that multiple variables act in combination to influence ACL injury risk [44]. ACL tear in basketball is quite frequent and they seriously affect players' career with short-term and long-term consequences. It has also been seen that ACL injuries are very invalidating events that require surgical treatments and keeps majority of basketball players out of competition at least four months every season. Injury rates as high as 2.8 and 3.2 injuries per 10,000 athlete exposures have been reported in women's collegiate basketball and soccer [45].

Materials and Methods

Information on some factors influencing of non-contact ACL injury was collected in 2 different ways, from the questionnaire (n=372) and through interviews with injured players (n=138). Information was collected prospectively through the 2018-2019. The sport activities that were considered for the study included:

Swimming, basketball and Gymnastics female athlete (Table 2).

Table 2: Sports activities participation (n = 510)

Sport	N	Rate (%)	Height (m)	Weight (kg)	Age (yrs)
Basketball	268	52.5	1.73	65.3	22.7
Swimming	146	18.9	1.71	63.9	21.8
Gymnastics	96	28.6	1.68	61.7	20.1

In an epidemiological study we assessed the evolution in the incidence and possible risk factors of knee injuries, especially anterior cruciate ligament injuries in Gymnastics, Swimming and Basketball among collegiate student female players. As a result, all acute injuries that occurred during training activities or during competition are reported and collected in the injury registry. Of course, an understanding of the non-contact injuries mechanism has lagged behind diagnosis and treatment. However, growing research implicates hormonal, anatomical, environmental and neuromuscular factors that may predispose athletes to these injuries [46]. Also, there are some factors which include genetic, cognitive function, previous injury, and extrinsic risk factors. Case-control studies are an efficient method for studying relatively rare events such as ACL injuries (in comparison with more common musculoskeletal injuries associated with sports, such as ankle sprains) because

they allow researchers to accumulate a large sample size in a relatively short period, depending on the level of competition and the sport under investigation. All injured players were interviewed during the 2018-2019 to compare player recall with the questionnaire. The interview data were also used to check whether the questionnaire we obtained was a representative sample. The entire athletes were diagnosed as having an ACL injury confirmed by magnetic resonance imaging (MRI) and/or an arthroscopic procedure. Approximately seventy five percent of the subjects visited the clinic within one month, and 25 percent of the subjects visited the clinic within one week after an ACL injury incident. We classified the activity of the subject at the time of the ACL injury in two categories (A) competitions (B) practice. Also we classified the injury factors in three categories (A) Non-contact: No contact with another person or things at the time of the injury (B) Accident: Particular situations during sports activities such as basketball and (C) Unknown: The injury factors data missing in medical records, and dynamic alignment at the time of the injury. We classified the dynamic alignment at the time of the injury into six categories [47].

1. Knee-in & Toe-out: Knee valgus and foot abduction position
2. Knee-out & Toe-in: Knee varus and foot adduction position
3. Hyperextension: Hyper-extended knee position
4. Unclear: Injury factors that were not expressed clearly by the patients
5. Unknown: The injury factors data missing in medical records
6. Other

Results

The ACL is a ligament whose main purpose is to prevent anterior translation of the knee along with prevention of hyperextension, resistance of internal rotation of the tibia, and assists with stabilization of varus and valgus stresses [48]. The length of the ACL varies from 25 to 35 mm long, 7 to 12mm wide, and 4 to 7 mm thick [42]. The ACL has two bundles of fibers that start at the posterolateral femoral condyle and cross the notch of the center of the knee to end at the anterior medial tibia. The main mechanism of injury to the ACL being torn is usually non-contact involvement. When it happens though, it is most often in contact sports. These sports are Gymnastics, Swimming and Basketball. The reason for this difference in the type of sport and how it happens involves the activities done in each sport. With these sports, there is usually a rapid change of direction or landing form a jump involved. The most frequent way that the ACL is torn is the athlete has a planted foot with the knee in an almost extended position (sometimes hyper-extended). An example is the foot is planted for a pivot and then the athlete cuts quickly resulting in an increased rotation at the knee. The tibia is generally rotated toward the inside or mid-line of the body while the knee is flexed greater than 90° [8]. Hormonal differences between men and women could to some extent explain the discrepancy in injury rates. The risk of an ACL injury seems to be higher in the preovulatory than the postovulatory phase of the menstrual cycle [49,50]. Results from measurement of estrogen, progesterone and luteinizing hormone metabolites levels at the time of the anterior cruciate ligament tear have indicated that women had a significantly greater than expected percentage of anterior cruciate ligament injuries during midcycle (ovulatory phase) and a less than expected percentage during the luteal phase of the menstrual cycle [51]. Also recent research in the area of ACL injury risk factors has centered on neuromuscular performance. Neuromuscular control of the knee involves a complex interplay between the neurologic system and the muscles that cross the knee joint. Perhaps in non-contact ACL injury, expected motor recruitment patterns that control the knee are altered, which lead to injury. Activity, Injury factors and Dynamic alignment at the time of the injury showed in Figure 2 and table 3 and 4 respectively.

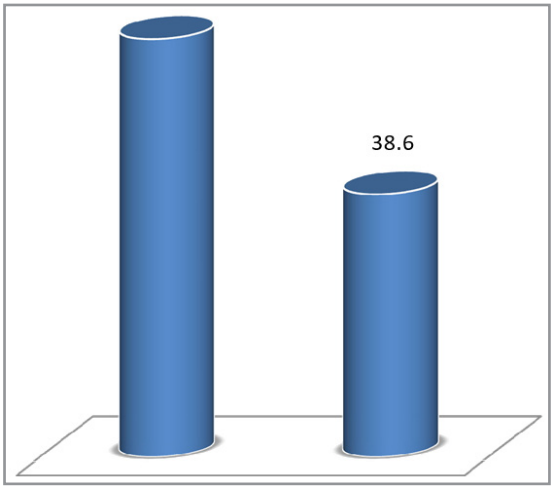

Figure 2: Activity at the time of the injury

Table 3: Injury factors at the time of the injury

Injury mechanism	Total (510)	Rate (%)
Noncontact	352	69
Accident	24	4.7
Unknown	134	26.3

Table 4: Dynamic alignment at the time of the injury

Position	Total (510)	Rate (%)
Knee-in & Toe-out	224	44
Knee-out & Toe-in	115	22.5
Hyperextension	57	11.1
Unclear	69	13.5
Unknown	24	4.7
Others	21	4.2

Discussion and Conclusion

Understanding the injury pattern of a particular sport and its inherent risk factors is a key area of current sports medicine [52]. ACL tears can also occur during rough play, mover vehicle collisions, falls, and work-related injuries. About 80% of sports-related ACL tears are “non-contact” injuries. This means that the injury occurs without the contact of another athlete, such as a tackle in basketball. Most often ACL tears occur when pivoting or landing from a jump. The knee gives-out from under the athlete when the ACL is torn. Our result showed an ACL injury occurred more often during a practice than during competition. The situations during a competition and a practice are different in many respects. Athletes usually spend a much longer time in practice than in competition. Non-contact ACL injuries typically occur during deceleration and change of direction with the foot fixed Knee torsion that results from making a sudden directional

change on a planted foot has been implicated as a cause of ACL tears. Data such as contact versus non-contact, position of the knee and lower leg, direction of knee collapse, direction of body twisting, and other events were recorded. The number of variables an athlete must respond to in team sports may explain the higher incidence of injuries in sports such as Gymnastics, Swimming and Basketball. It may not be possible to measure neuromuscular control and muscle activation variables during dynamic activities after an ACL disruption. The investigation on the dynamic alignment at the time of the injury revealed that the knee-in & toe-out alignments were most often reported. In retrospective interviewing studies, the subjects often encounter difficulty in recalling the dynamic alignment at the time of the injury, which may be related to the passage of time between the injury and the interview. The interview was usually held long after the injury occurred; for example, reported that the interview was held 3.4 years after the injury on average. In addition, whether the information obtained is accurate or not may depend on how the subject described the dynamic alignment at the time of the injury. Therefore, there might be questions about the accuracy of the information obtained in the retrospective interviewing study [53,54]. We confirmed that the data from both sources (questionnaire and interview) exactly matched each other. The number of variables an athlete must respond to in team sports may explain the higher incidence of injuries in sports such Gymnastics, Swimming and Basketball. Though the exact moment of injury was impossible to determine from interview, the position of the leg before collapse in most of non-contact injuries was near foot strike with the knee in slight flexion. None were associated with a sharp, pivoting motion of the body around a planted leg or varus collapse of the knee. Valgus collapse of the knee in varying degrees was noted in most injuries. These findings have several important implications. Our findings concluded that most important risk factor for ACL injuries in sports involving jumping, cutting and pivoting maneuvers among Gymnastics and basketball. In general, swimmers who prefer breaststroke to any other style of swimming are at a higher risk of experiencing knee pain. Sometimes, it so happens that if while doing the 'whip kick' movement of breaststroke, a swimmer's knee is poorly placed, there comes excessive pressure on the knee joint as well as the collateral ligament and ACL. When afflicted by this syndrome, the ligament becomes strained. This condition is referred to as Breaststroke Knee. The Breaststroke Knee is a specific condition where a swimmer's knee becomes swollen and they experience acute pain while doing any physical activity. A swimmer can easily prevent the Breaststroke Knee by doing regular warm up and cool down sessions. Stretches, exercises, and physiotherapy can prove to be equally helpful. Though Breaststroke Knee can be usually treated with medication, in some cases, surgery may be required. In accordance to other studies, we also found that competitive activities were more likely to induce ACL injuries than training activities. Several explanations might be found for the higher incidence of ACL injuries in older players such as fatigue due to longer training and competition times, higher speed and a more aggressive play [55,56]. Of interest is that a higher level of performance was not associated with an increased risk for ACL injuries, despite the fact that the aforementioned parameters are even more pronounced in elite basketball players. Better training modalities and prevention measures may explain this finding [57,58]. The highest injury prevalence occurs at different ages according to sex: 23-24 years in female athletes. Many related studies have found a significant correlation between age and injury incidence [59,60]. The data from this study confirm these results, indicating age as a potential risk factor for injury incidence in elite Gymnastics athletes. Sex difference according to weight category is a clear indicator that men suffer more injuries in all weight categories with the exception of the intermediate weight category. Moreover, the weight category emerges as a possible injury risk factor. The injuries occurred predominantly during landing, pivoting and sudden direction change. Although the majority of the injuries did not involve contact at the assumed point of injury, the movement patterns were likely perturbed by an opponent, for example, by pushing before the injury. Further research is needed to achieve a better understanding of elite sports, in relation to sex and different training systems.

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