

# Anterior Cruciate Ligament Injuries in Soccer Players : An Overview

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**Abstract.** Soccer is known as a sport with high risk of anterior cruciate ligament (ACL) injury. Until 1980s, an ACL injury was a career-ending injury for a soccer player, but afterwards with the technological advancement in the field of medical sciences it could be treated or cured to a greater extent. Prevalence of this injury is two times greater among female soccer players in comparison to their male counterparts. Many theories have been postulated to explain the reasons for greater occurrence of ACL injuries among female soccer players but the biomechanical elucidation is considered to be the most justified one. The theories are divided into intrinsic and extrinsic aspects depending on the involved factors. Intrinsic factors include variables as such limb alignment, joint laxity, ligament size, notch dimensions, wider pelvis, increased genu valgum, and increased tibial torsion while, extrinsic factors are body movement, shoe-surface interface, muscle strength, coordination, level of skill through conditioning and flexibility. ACL injuries are of three categories (Grade I, Grade II and Grade III) which occur mainly during non-contact episode of the game, e.g., during the landing, kicking, or during stance phases of high-risk postures such as sidestepping. The gender differences observed in knee joint kinematics and forces during these movements are thus viewed as important contributors to ACL injury potential. Primary prevention of ACL injury among soccer player is possible by appropriate intervention strategies, e.g., a variety of training protocols, proper education of the athletes, and bracing. Current studies focus on neuromuscular training as a preventive measure, with programs that include strength, flexibility, plyometrics, sports-specific agility drills, speed enhancement, balance and athlete education.

**Key Words:** Anterior cruciate ligament, injuries, soccer.

## 1. Introduction

Anterior cruciate ligament (ACL) injury is one of the most dreaded injuries among athletes [1]. ACL tear in soccer 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 soccer players out of competition at least four months every season. In professional soccer it has significant economic consequences.

Soccer is particularly known as a sport with a reasonably high risk for ACL injuries [2 – 5]. Until 1980s, ACL injury was seen as a career-ending injury for soccer players [6]. Sustaining an ACL injury also predisposes an individual to the risk of significant long-term debilitation, such as in the case of osteoarthritis [7].

Significant attention has focused on ACL research over the past two decades resulting in publication of more than 2000 scientific articles outlining injury incidence, mechanism, surgical repair techniques, rehabilitation, and prevention of injury to this important knee ligament [8]. The focus on ACL injury is warranted considering that the cost of reconstructing and rehabilitating the ACL in these athletes at a conservative cost of \$17,000 per patient [9]. However, nowadays, most athletes return to competition following reconstructive surgery, but the time loss from sport and the financial cost of suffering an ACL injury are high [7].

However, the present review has been focused to look momentarily the various aspects of ACL injuries among soccer players of both genders as focused in different angles of research and studies.

### 1.1. Anatomical position of ACL

The name “cruciate” is derived from the fact that these ligaments cross each other with anterior and posterior referring to their respective tibial attachments [10]. These ligaments are termed intracapsular because they are located within the articular capsule and extrasynovial because they lie outside the synovial cavity [10]. The ACL is made up of bundles of longitudinal fascicles that pass in lateral spiral rotation from femur to tibia. The femoral attachment on the medial surface of the lateral femoral condyle is a circular area tilted slightly forward from the vertical [11]. The tibial attachment is in front and bilateral to the anterior tibial spine [Fig. 1].

The ACL is the primary restraint to anterior translation of the tibia on the femur. It also provides secondary stabilization to varus/valgus rotation and internal/external rotation of the knee. Besides, ACL is a critical stabilizer that prevents hyperextension of the tibia [10]. The ACL has two discrete bands: an anteromedial and a posterolateral bundle, with an intermediate band occasionally present. When the knee is fully extended, the femoral attachment of the anteromedial bundle is anterior to the attachment of the posterolateral bundle, which is taut. When the knee is flexed, the positions are reversed, with taut anteromedial bundle, causing the ACL to wind on itself [10].

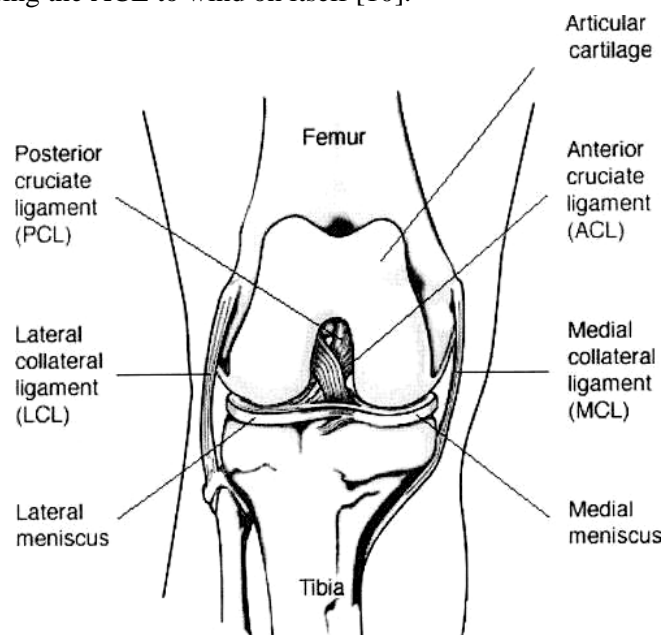


Fig. 1. Anatomical position of anterior cruciate ligament (ACL). (Ref. : <http://www.taosortho.com/images/ACL.htl.jpg>)

### 1.2. Types of ACL injury in soccer

The ACL tear may affect only a few fibres or the entire ligament. In clinical practice, it is crucial to differentiate between partial and complete tears because the treatment and prognosis is different [12].

A partial tear may be classified as a grade I tear (disruption of a few fibres) or a minor grade II tear (disruption of less than half of the fibres), in both cases the joint is stable. A partial tear may also be classified as major grade II tear which corresponds to disruption of more than 50% of the fibres. Under this classification, the knee joint is unstable to varying degree [13]. A grade III tear corresponds to disruption of all the fibres as complete tear, which causes the joint to be unstable in varying degree [13].

### 1.3. Incidence of ACL injury in soccer – Gender related prevalence rate

Prevalence of ACL injury in soccer has been ranked first among other sports with a rate ranging from 3.7 to 29.1 injuries per 1000 hour of practice and games [14]. Approximately 60% to 80% of soccer injuries occur at the lower extremities [14, 15]. Injuries to anterior and posterior cruciate and medial collateral ligaments are the most serious and frequent [14, 15]. Such injuries can occur in contact (60%) as well as non-contact (40%) situations [16].

In soccer, the occurrence of ACL injury is two folds greater in females than in males, and females are 3 times as likely to suffer a non-contact injury [17]. Movements for non-contact injuries include jumping, cutting, and landing which are inherent in soccer and could place one's knee in a compromising position [3].

Non-contact ACL injuries generally occur when the foot makes contact with the ground or shortly after performing the cutting or landing manoeuvres in soccer [18]. According to Pollard et al. [19] female athletes participating in cutting and jumping sports have been reported to have a 4 to 6 times greater chance of tearing their anterior cruciate ligament (ACL) than their male counterparts.

Bjordal et al. [3] reviewed ACL injuries that occurred to 176 soccer players in Norway over a period of 10 years. An overall incidence of 0.063 injuries per 1,000 hours of game was recorded, with women had significantly higher incidence (0.1 injuries per 1,000 hours of game) than men (0.05 injuries per 1,000 hours of game). Besides, ACL injury incidence during training was significantly lower (0.013) than during games (0.063) (Table 1). This may be due to the fact that there is more physical contact in a game over a practice session. This statement is also supported by study done by Giza et al. [20] in professional female soccer players, which showed that risk of ACL injury is doubled in games rather than in training.

Arendt and Dick [2] studied on 739 National Collegiate Athletic Association (NCAA) soccer teams over a period of 5 years (1989 – 1993) and depicted that ACL injury incidence in men (0.13) was significantly lower than women (0.31). They also extended their investigation on the same sample up to the year 2002. In the final year of the study period, ACL injury in men was significantly lower (0.07 injuries per 1,000 hour of exposure) than in the first year (0.12 injuries per 1,000 hour of exposure). However, ACL injury incidence among women in 2002 had not much different than the previous 13 years (Table 1).

**Table 1.** Occurrence rate of ACL injuries in soccer players of both sexes.

(Compiled from References 2, 3, 4 & 81)

Study	Population	ACL Injury
<b>Arendt and Dick (2)</b>	739 players of National Collegiate Athletic Association (NCAA)	1989 – 1993 : Male = 0.13 (per 1000 hours of play) Female = 0.31 (per 1000 hours of play)  1994 – 2002 : Male = 0.07 (per 1000 hours of play) Female = 0.28 (per 1000 hours of play)
<b>Bjordal (3)</b>	176 Club level players of Norway	Male = 0.05 (per 1000 hours of play) Female = 0.10 (per 1000 hours of play) Overall = 0.063 (per 1000 hours of play) During training the injury rate (0.013) is lower than during games (0.063)
<b>Gwinn (4)</b>	Professional and amateur level intercollegiate soccer players of US Naval Academy	Male = 0.08 (per 1000 hours of play) Female = 0.72 (per 1000 hours of play) Females are 9 times more prevalent than males
<b>Roos (81)</b>	Club level soccer players of Sweden	Overall injury rate : Match = 14.2 – 35 injuries / 1000 hour Training = 2.3 – 8.0 injuries / 1000 hour  Annual incidence : Male = 18 / 10000 players Female = 27 / 10000 players

Shea et al. [21] conducted a study based on insurance claim by paediatric and adolescent soccer players. It was found that the first ACL injury occurred at age 5 years, although ACL injury is considered rare before the age of 11 years. At ages 11-12 years, both males and females demonstrated an elevated frequency of ACL injury claims, and the risk appeared to be augmented up to the age of 18 years. A recent study by

Micheli et al. [22], demonstrated an increase in ACL reconstructive procedures for adolescents soccer players between 1992 and 1997 at a single institution. Shea et al. [21], also proved that pediatric and adolescent female soccer player also have superior risk of ACL injury, compared of their male equivalent.

The incidence is almost two times as high in females as their male counterpart [6]. Several factors may contribute to this gender difference. First, females may lack the fitness levels necessary for safe participation. They tend to train one-half the amount of time their male counterparts do [2]. Studies have proved that augmented training can decrease injuries as a result of superior strength, coordination and skill [16]. On the other hand, female soccer players tend to miss more time due to injury rather than male players who are more likely to play hurt and do not miss time from the sport [2].

Wojtys et al. [23] have looked at the relationship between menstrual cycle and the incidence of ACL injury. Results from the hormone assays indicated that the women had a significantly greater than expected percentage of ACL injuries during ovulatory phase and a less than expected percentage of ACL injuries during luteal phase of menstrual cycle. It is also remarkable to note that the age of onset of ACL injury in female athletes is close to the onset of menses (age 12 years for Caucasian females) [21]. Increased injury rate in the premenstrual and menstrual period was recorded compared to the rest of the menstrual cycle in 108 female soccer players who participated in First, Second and Third Leagues of the Swedish Football Association [24]. However, a lower rate of traumatic injury was seen in the group using oral contraceptive pills compared to the group non-user group.

## 2. Etiology of ACL injury in soccer

ACL injuries are often due to a non-contact injury when the player is pivoting or landing [6]. Tackling is the most frequent activity for a soccer player at the time of ACL injury [25]. Bjordal et al. [3], in their findings showed that 58% and 42% of ACL injuries were due to tackling in women and men, correspondingly. In men soccer players, 64% tackles were from the side, whereas, in women soccer players, ACL injuries were due to the tackling from side (44%) as well as from the front (32%).

Many theories have been hypothesized to explain higher incidence of ACL injury among women soccer players. These theories have been divided into intrinsic and extrinsic aspects. Intrinsic factors include variables such as limb alignment, joint laxity, ligament size, notch dimensions, wider pelvis, increased genu valgum, and increased tibial torsion [2, 26, 27]. These factors are crucial in understanding players' risk to injury. Notch width is the ratio of the width of the intercondylar notch to the width of the distal femur at the level of the popliteal groove. Soccer players with smaller notch widths are at higher possibility for ACL injuries than those with normal range of notch widths [2]. Hormonal differences have also been identified as a potential etiologic factor to explain the difference in ACL injury rates between adult male and female soccer players [28 – 30].

Extrinsic factors include body movement, shoe-surface interface, muscle strength and coordination, level of skill, conditioning and flexibility [2, 26, 27]. A shoe-surface interface with a high coefficient of friction has been recommended to increased injury due to excessive force on the knee, but too little friction can lead to slipping which itself can cause injury [16]. The player, coach and staff should carefully decide on footwear before making final decision [6]. The use of shoe with cleats would lower the risk of knee joint injuries [16]. Lambson et al. [31], compared 4 types of soccer shoes and evaluated the incidence of ACL tears among 3,119 high school soccer players during the 1989 – 1991 competitive seasons. They found that longer, irregular peripheral cleats produced significantly higher torsional resistance, which were associated with higher ACL injury rates than the other designs with flatter cleats.

Specific body movements in soccer, including planting, cutting, landing from a jump, and decelerating can influence the injury rates. A flexed knee position also allows the hamstrings to have a greater role to knee stabilization by controlling rotation and anterior displacement, thus reduce injury incidence [2]. On the other hand, in recent years, great attention has been dedicated to the understanding of neuro-muscular control differences between males and females. Female soccer players have been found to have different landing and cutting patterns from their male counterparts. Females have the tendency to land with a more extended knee than males do, and in cutting manoeuvres the knee is more extended, externally rotated, and valgus position than in males [32]. The recognition of these patterns should help to prevent injuries by instructing them and correcting their movement pattern accordingly. Conditioning and strengthening also can affect the incidence of injury. Teams with less than average training have a higher number of traumatic injuries [33]. It has been found that less-experienced soccer players had a significantly higher incidence of ACL injuries [34].

### 3. Biomechanical aspect of ACL injury – consequence of gender variation

Despite the ongoing evolution of training methods geared towards preventing ACL injuries, injury rates and the associated sex-disparity in these rates have not diminished [35]. In an attempt to explain the disproportionate incidence of ACL injury in female soccer players, biomechanical studies have evaluated gender differences in knee joint mechanics (kinetics and kinematics) during the performance of cutting tasks [36]. It has been theorized that the number of ACL injuries in female athletes is due to gender-related differences in the performance of athletic activities including playing football. The gender differences observed in knee joint kinematics and forces during these movements are thus viewed as important contributors to ACL injury potential [37, 38].

Sigward and Powers [36] demonstrated that there were no significant differences in average sagittal plane knee kinematics between male and female soccer players during early deceleration (Fig. 2a) and the fact was also consistent for the frontal and transverse planes (Fig. 2b & 2c). But during early deceleration, males demonstrated a significantly greater peak knee flexor moment (Fig. 3b) though a comparatively greater initial peak adductor moment was demonstrated by females than the males (Fig. 3a). As far as knee transverse plane moments are concerned, insignificant variation was noted (Fig. 3c).

Comparison of knee net joint moment impulse between the male and female soccer players indicated that males have larger values at the sagittal plane during early deceleration (Fig 4a) whereas insignificant difference was found in the frontal and transverse planes (Fig. 4b & 4c) [36].

In female soccer players, greater hip internal rotation with accompanying decreased lower leg internal rotation is seen with landing [39]. This position of increased femoral rotation with a decreased or externally rotated tibia and a knee moving toward extension is thought to be a common mechanism of ACL injury [40]. Meanwhile, according to Pollard et al. [19] females demonstrate decreased knee flexion and increased valgus motion during landing and cutting than the male soccer players. Both knee valgus motion and moments has been found to be predictors of ACL injury. Taken together, the knee joint mechanics exhibited by females are thought to place them at a greater risk of ACL injury.

It has recently been suggested that the deleterious knee joint kinematics patterns exhibited by female soccer players may be related to poor proximal control such as, hip weakness. Studies have identified that females possessed a greater reliance on the frontal and transverse planes at the hip when performing dynamic activities. Females employed different movement patterns at the hip in order to successfully perform the cutting manoeuvre [19]. In particular, females demonstrated more of a reliance on the frontal and transverse planes as opposed to the sagittal plane. This was supported by greater hip internal rotation and decreased hip flexion exhibited by females during the cutting manoeuvre.

Landry et al., [41] compared the neuromuscular aspect between genders during unanticipated cutting maneuvers which are thought to be more closely replicating a true soccer-like scenario where the ACL is most apt to be injured in a non-contact manner. During the pre-contact phase, there was a difference in rectus femoris activation shape between genders, with female having more rapid rise in muscle activity as initial ground contact approached. Females tended to have peak hamstring activity occurring earlier than males during the pre-contact phase. Hence females could use different neuromuscular control strategies that may be placing their ACL at a greater risk of being injured when executing athletic manoeuvres [41].

Neuromuscular fatigue and unanticipated movement tasks have both been shown in isolation to induce significant and potentially hazardous modifications in lower limb control during dynamic sports postures [42, 43]. The combined effects of such neuromuscular fatigue and decision making are a potentially high-risk scenario during dynamic landing tasks. The interaction between these factors further suggests that ACL injury during dynamic sports postures as such soccer may stem from fatigue induce modifications in both central and peripheral processing pathways (35).

Gender differences in neuromuscular control [9, 44, 45] and kinematics [46–51] have been implicated as predisposing factors of ACL injury. Female soccer players demonstrated greater knee extension [49, 50, 51], valgus angle [48, 49, 50], and hip internal rotation [39] than males during landing activities. They also exhibited greater knee-extension and valgus moments than their male counterparts during the landing phase of stop jump tasks, suggesting that this phase provides more stress to the ACL [52]. The combination of knee extension, genu valgus, and femoral internal rotation is believed to place the ACL in vulnerable and possibly damaging position [40]. However, further knowledge of potentially injurious lower extremity mechanics is

needed for the development of effective ACL prevention programs [36].

#### 4. Major Causes for ACL injury in Soccer

Non-contact ACL injuries in soccer frequently occur during dribbling, cutting, or quick changes of direction while contact injuries are caused by knee hyperextension or a valgus motion [16, 53]. For these reasons, the biomechanics of knee joint motion during activities such as landing, running and cutting manoeuvres have been extensively examined in soccer [54, 55, 56]. Although the above movements are common in various sports, the most important movement in soccer is the kick. In general, the side-foot kick is the most frequently used technique when a shorter and precise pass or shot is required, whereas the instep kick is used when a faster ball speed must be generated [57].

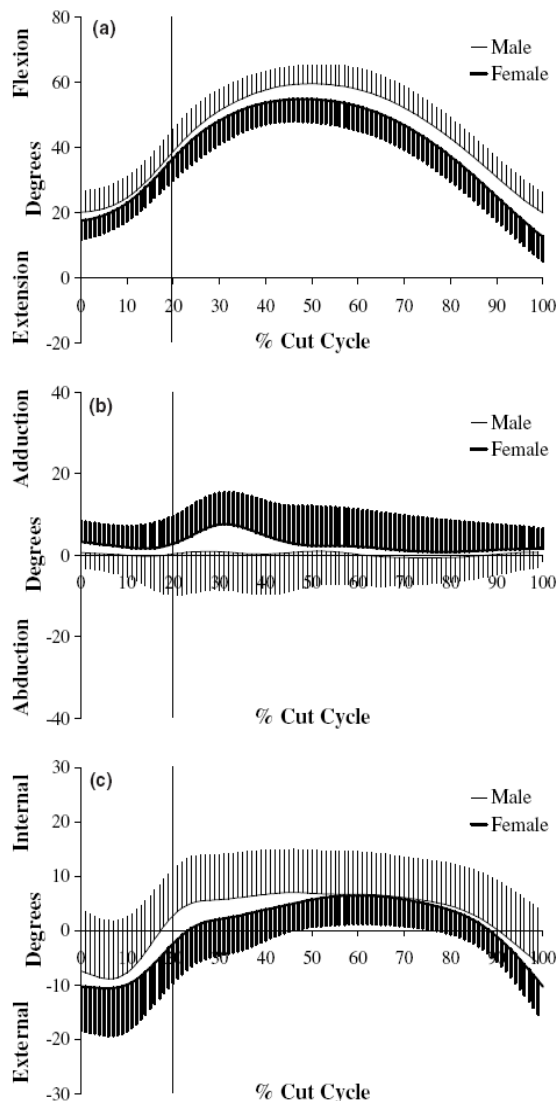


Fig. 2. Comparison of knee joint kinematics between male and female soccer players in the (a) sagittal, (b) frontal and (c) transverse planes during side step cutting. Vertical line indicates early deceleration phase. No significant gender difference was observed. (Adopted from Sigward and Powers [36])

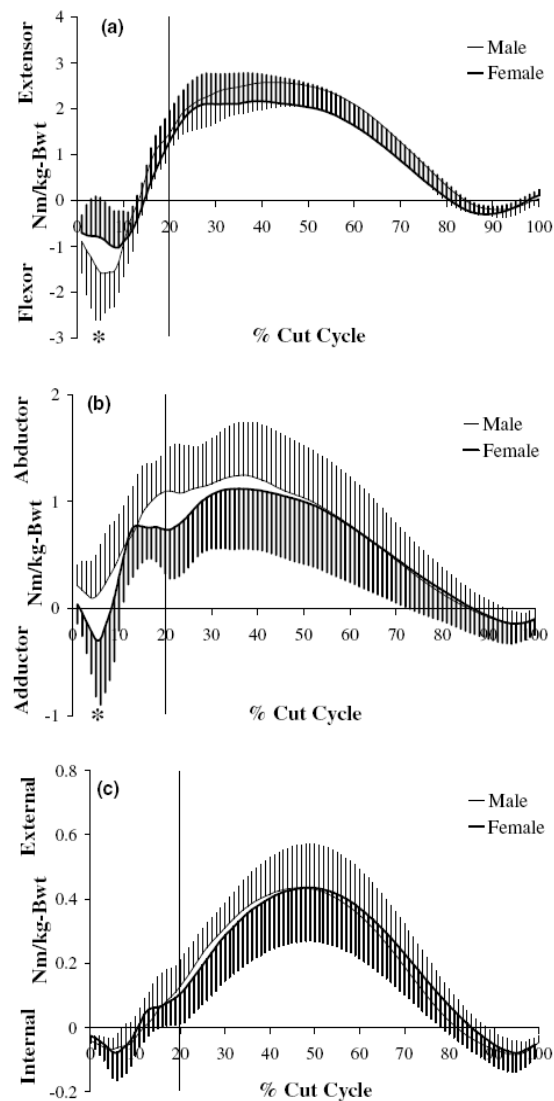


Fig. 3. Comparison of knee joint moments between male and female soccer players in the (a) sagittal, (b) frontal and (c) transverse planes during side step cutting. Vertical line indicates early deceleration phase. \*indicates significant gender difference ( $P < 0.05$ ). (Adopted from Sigward and Powers [36])

Typically, ACL injury occurs as a result of a non-contact episode during the landing or stance phase of

high-risk postures such as sidestepping [28, 42, 37, 58, 59]. These movements are key offensive strategies in soccer and commonly incorporate a sudden deceleration phase on impact, accompanied by a rapid speed and/or directional change to evade an oncoming defensive opponent [38, 60].

Injury to the ACL ultimately occurs as a result of knee loads that cannot be supported by bony structures and muscles, thus leading to large ligament loads [61]. It is increasingly recognized, however, that extreme knee loading scenarios may be potentiated through abnormal neuromuscular control elsewhere in lower extremity [61]. Hypotheses have been formulated related to gender differences in transverse plane and frontal plane hip rotations and in rear foot pronation [30, 62]. However, the data to support these theories are scanty.

A proper understanding of complete ACL injury mechanisms will require a biomechanical analysis of the entire lower extremity during actual sport movements [61]. Specifically, females exhibited increased peak knee valgus and rear foot pronation angles, and decreased peak hip flexion, hip abduction, hip internal rotation, knee flexion, and knee internal rotation during sidestepping compared with the males [61]. Decreased peak knee flexion has been reported in females for sidestepping [51] and has been interpreted as a risk factor for ACL injury because it increases the anterior drawer action of the quadriceps, as well as reduces the ability of the hamstrings to protect the ACL [37, 51]. Reduced knee flexion observed in women may be a consequence of lower muscle strength [61].

Prodomos et al (63) observed that the ACL tear incidences ratio between female and male soccer players is 2.67. Females had less internal tibial rotation during sidestepping than males [38]. This result to some extent counterintuitive considering that females have an increased incidence of ACL injuries, and internal tibial rotation is known to be a contributor to ACL loading [64, 65]. This observation suggests, therefore, that the increased valgus found in females during sidestepping is the dominant risk factor for ACL injury. Sidestep cutting maneuvers are also common mechanisms of non-contact or isolated ACL rupture [66].

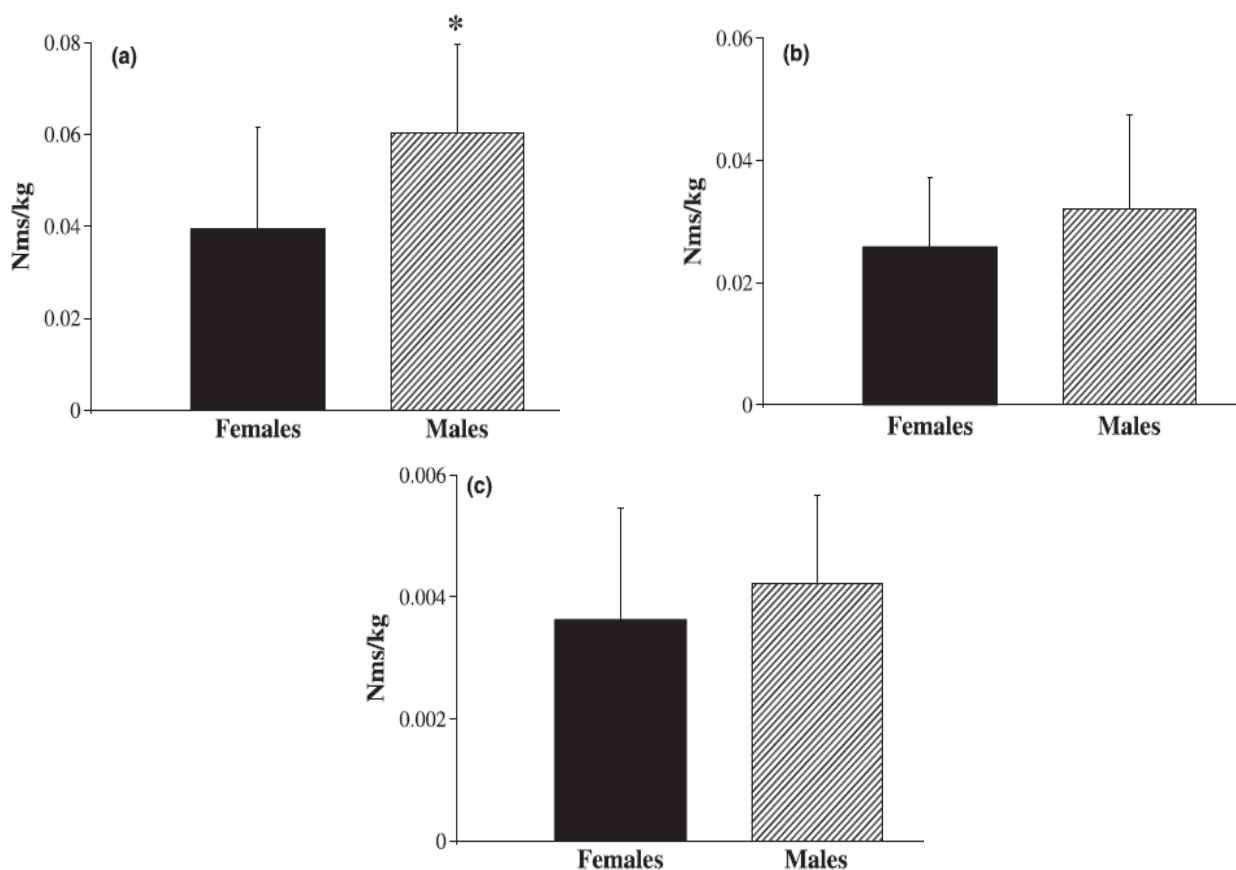


Fig. 4. Comparison of knee net joint moment impulse between male and female soccer players in the (a) sagittal, (b) frontal and (c) transverse planes during early deceleration of side step cutting. \* indicates significant gender differences ( $P < 0.05$ ). (Adopted from Sigward and Powers [36])

Increased knee valgus in female soccer players has also been reported previously [57, 62]. Knee valgus

is known to increase ACL loading [64, 65] and is viewed as another key mechanism of non-contact ACL injury [42, 59]. The increased knee valgus demonstrated by women compared to men during sidestepping had been proposed previously to stem from gender-based anatomical differences, such as Q angle [38]. Knee valgus loading during sidestepping is sensitive to neuromuscular control which is largely responsible for knee valgus, prevention of ACL injuries in women may be possible [61].

On average, during a 90-minutes game of soccer a player has 51 ball contacts, 26 of them with the foot [67]. In a recent study, soccer kicks accounted for approximately 51% of potential actions that may lead to an injury from a total of 18,000 playing actions in 10 soccer games [68]. The soccer kick is a high-speed movement with ball speeds ranging from 18 - 35 m.s<sup>-1</sup> [69]. During the kick, the swinging leg rotates backward and forward while body weight is distributed on the support leg [70]. Previous study found maximum vertical of ground reaction forces (GRF) of approximately 2.5 – 3.0 times body weight (BW), mediolateral forces of 0.8 – 1.26 BW, and anteroposterior of 0.5 – 0.7 BW during straight approach kicks [69, 71, 72]. These forces are higher than walking [73] and similar to running at cutting, starting, and stopping [74, 75].

It could be hypothesized that in soccer kicks from high approach angles, the knee of the support leg should be in a slight flexed position while rotating [76, 77]. However, it is known that external or internal rotation at near extension angles increases the ACL ligament strain [54, 65]. Such loads can be counteracted by increased activation of the surrounding musculature [54, 78, 79]. Due to this reason, the role of muscle activity of quadriceps and hamstrings in preventing ACL injuries in soccer has been emphasized extensively [53]. Soccer kicking is an activity of high incidence during a game. This means that the support leg of an average soccer player is loaded at least 20-25 times within 90-minutes period [70]. In soccer, it is recommended to kick with an approach angle of 35-45° which results in a higher ball speed [69, 80]. Study done by Kellis et al. [70], indicated that the higher the angle of approach, the higher the medial and posterior GRF. Furthermore, kicking from angled approach demonstrated higher external rotation displacement and knee angular velocities as well as a higher presupport biceps femoris (BF) electromyographic activity (EMG) compared with straight approach kicks [70]. These alterations are similar with those found during movements such as cutting, starting and stopping which induce significant loads to the knee joint ligaments.

## 5. Signs and symptoms of ACL injuries

A good diagnosis of ACL injury starts by obtaining a good history. ACL injury in most situations is a major traumatic event with a characteristic history [81]. ACL injury should always be suspected if there is a history of any kind of rotation or flexion injury, direct trauma or rapid deceleration. Soccer players usually describe the knee as 'going away' and in most cases, the injury type is non-contact. An audible 'pop' is heard in about 50% of cases [81]. Swelling may develop within a few hours, causing discomfort and pain. Such swelling is usually resulted from hemarthrosis that is caused by ACL injury in 70% cases. An effusion (secondary to bleeding) occurs within 6 – 12 hours after injury that causes difficulty of full weight bearing and full extension of the knee [82]. The patient may with time develop a recurrent 'giving way' problem and feels "about to fall" because of instability which often indicates a serious ACL injury that require surgery. Patients may also have limited active and passive ranges of motion [13].

## 6. Management and rehabilitation

Rupture of the anterior cruciate ligament (ACL) is classified as a severe injury which requires surgical treatment and keeps many athletes out of training and competition for months [83]. In professional soccer, this may have important economic consequences [83]. Roos [84] demonstrated that 70% of ACL-injured soccer players left soccer within 3 years after injury (whether they had been operated or not), in contrast to only 15% of uninjured players.

Since a neglected ACL injury leads to instability, torn menisci and eventually arthritis, early accurate diagnosis is essential for definitive treatment and preservation of the knee. Initially, isolated ACL tears are treated with RICE and crutches followed by protected active motion as the swelling subsides. A hinged brace should be worn if both ACL and medial collateral ligament are torn. An MRI study may be helpful but it is not always diagnostic for complete acute tears. An MRI is unreliable in long-standing tears because fibrosis owing to scar tissue may give the appearance of an intact ligament. The final determination of a torn ACL is made on clinical examination [81].

There are two important tests in diagnosing a torn anterior cruciate: The Lachman test and the Pivot Shift



test [81]. The Lachman test, which is more than 85 percent accurate, is the most important test for a torn ACL. With the patient in supine posture, the knee is held in 20-degree flexion. While the hamstring muscles are relaxed, the tibia is pulled gently forward with the femur stabilized. Comparison with the other knee reveals the normal knee has a definite endpoint as the tibia is pulled forward. When the ACL is torn the endpoint is indefinite [81].

Meanwhile, the Lateral Pivot Shift test is done on a supine and relaxed patient. The foot is internally rotated and allowed to sag into extension. The heel of the examiner's hand is placed on the proximal lateral tibia with a strong valgus stress. As the leg is flexed from full extension to 10 degrees of flexion, the tibia partially dislocates [13].

Patients with a positive pivot shift usually need surgery [13]. Indications for surgery are most commonly activity-related, which means that very active persons have the greatest need for surgery. The primary goal of arthroscopic surgical reconstruction of the ACL in professional athletes is to restore the physiological functions of the injured knee and to allow the patients to return to pre-injury sports activities and competitions [85]. For professional soccer players, the pressure to return to pre-injury competitive levels is immense and the goal of the surgical and rehabilitation sports teams is the fastest possible safe return to competitions of their patients.

It is advisable to delay surgery following acute trauma until the knee has settled down and the swelling and pain have resolved. The optimal time for the procedure is about 2-8 weeks after injury, although further delay may decrease the chances of successful end result slightly [13]. The graft selection is important. Most surgeons use the patient's own tissues, either from patellar tendon or the hamstrings tendons, for the reconstruction; both are very good grafts. In re-operation, allografts (tissue from cadavers) can be used, but it should not be the first choice in soccer. Synthetic ligaments should be avoided because of their stiffness and historically poor outcomes.

Reconstruction of the ruptured ACL is regarded as the treatment of choice. The procedure can be carried out arthroscopically or with a semi-open technique. A common arthroscopic technique for ACL injury allows for intra-articular insertion of the femoral fixation screws. Another variation of the technique requires an additional small skin incision on the lateral side of the knee. This variant is technically easier and more reproducible. However, during the last 30 years, at least 25 different operations have been proposed indicating that the results of surgery may not be optimal [86].

Rehabilitation following ACL surgery starts with early range of motion (ROM) exercise. Usually, the surgeon allows 0-70 degree range of motion in the immediate post-operative period. The most important aspect of the rehabilitation is to avoid muscle inhibition. Pain and swelling should be treated first with compression and cold. Early motion can also be helpful in reducing the swelling.

The most important muscles involved in rehabilitation are the quadriceps and hamstrings muscles. The hamstring muscles work as an agonist to the ACL and should be exercised early. However, according to Kvist and Gillquist [86] it should be of importance to strengthen especially the quadriceps and gastrocnemius instead of hamstrings for the rehabilitation after an ACL injury. Patient can start cycling as soon as range of motion has reached 100 degree, usually 3-4 weeks after an ACL reconstruction. Straightforward jogging is often possible after 2 months. However, activities that include cutting and pivoting should be avoided until 85% of the strength in the thigh muscles has been recovered. Such activities may be possible 4-6 months after surgery.

Closed kinetic chain (CKC) exercises rather than open kinetic chain (OKC) exercises play a primary role in ACL rehabilitation protocols. A CKC exercise is one where the foot is opposed by considerable resistance as such squatting and bicycling [87]. CKC activities are modeled as closed linkages where movement in one joint produces movements in all the other joints of an extremity [88]. Conversely, an OKC exercise is one where the distal segment is free to move across one joint independently, such as kicking [88].

There are rationales for prescribing CKC exercises after ACL reconstruction. According to Palmitier et al. [88], CKC exercises stimulate the functional movements that are common in sports and the activities of daily life. Besides, CKC exercises also increase tibiofemoral joint compression and emphasize co-contraction between hamstrings and quadriceps muscles [87]. Thus, they are thought to stabilize the joint and minimize the strain on the healing ACL [89 – 91]. However, it has been shown that increasing the resistance torque across the knee joint during an OKC exercise will further increase the peak ACL strains while a similar increase in resistance during a CKC will not [92].

The best exercises for rehabilitating the knee after ACL reconstruction are those that can maximize the

patients' ability to achieve full range of joint motion while minimizing muscle atrophy and risk to further injury [87]. Over the last decade rehabilitation protocols are generally based on the hypotheses that CKC exercises do not strain the anterior cruciate ligament graft in a harmful way [93–95]. Thus, exercises like mini-squats, weight shifts and balance training are frequently prescribed in the early phase of rehabilitation [87]. OKC exercises and the demanding CKC exercises such as lunges, parallel squats, and stair climbing and deep leg press are normally introduced around 6 to 8 weeks postoperatively [88, 96–98].

Heijne et al. [87] found that the step-up, step-down, lunge and one-legged sit to stand exercises did not produce greater strains on the ACL than the traditional two-legged squat. Thus, the high demand exercises such as the lunge could be prescribed at the same time as a squat, when one feels that the squat is a safe activity to perform after ACL reconstruction.

Meanwhile, candidate for non-operative treatment include very young and very old patients. Less active people who are not performing cutting or pivoting activities or can accept modifying their activities can often manage well and do not need surgery [13]. Alternatively, non-operative treatments such as muscle rehabilitation and bracing have therefore been tried [99]. Functional knee braces have been reported to stabilize the unstable knee by means of reducing anteroposterior translation, rotational instability, valgus and varus stresses. It also has been recommended for use in the knee with a partial ligament tear [100].

## 7. Preventive measures

Hewett et al. [9] estimated that as many as 2,200 ACL ruptures per year occur in female collegiate athletes in both the recreational and competitive ranks. Treatment and rehabilitation costs are estimated at \$17, 000 per ACL injury, which do not take into account the potential loss of long-term participation, loss of scholarship funding and further disability from arthritic changes in a reconstructed knee. For these reasons, a shift toward injury prevention is warranted.

Injury prevention training can alter potentially injurious lower extremity mechanics by decreasing hip internal rotation and increasing hip abduction angles during landing. Pollard et al. [19] found that following training, females exhibit decreased knee valgus moments, increased hip internal rotation angle and increased hip abductor moments during cutting. Hip extensors which are primary stabilizers of hip joint also increase in strength following training. The majority of ACL injury prevention training programs emphasize increased sagittal plane motion during landing which exhibit lower knee valgus moments and angles [19].

Injury prevention for the ACL can take many forms, including a variety of training protocols, players' education, and bracing. Current studies have focused on neuromuscular training as a preventive measure, with programs that include strength, flexibility, plyometrics, sports-specific agility drills, speed enhancement, balance and athlete education [9, 101]. Ihara and Nakayama [102] supported that the neuromuscular and proprioception training show the most encouraging evidence of effective ACL injury prevention when compared to bracing, footwear, and ski boot binding systems.

Soderman et al. [103] showed no significant change in incidence of ACL injury following balance board training in female soccer players. It was the only study to find no significant effect of proprioception or balance training on number of ACL injuries. As described in the meta-analysis published by Hewett et al. [9], a program combining multiple neuromuscular training components appears to provide a reduced risk of ACL injury. For example, plyometric training combined with technique training and biomechanical analysis has shown consistent effectiveness in reducing the incidence of ACL injury [104].

Other interventions could also include retraining muscle activation strategies to counter the loads experienced during sidestepping and crossover cutting manoeuvres. This may improve the muscular support of the external loads, thus reducing the potential loading of ligaments [55]. In terms of appropriate intervention to prevent non-contact knee ligament injuries, Besier et al. [42] indicated that training should include elements of unexpected and unanticipated movements. The CNS has the ability to selectively alter postural adjustments based on information acquired from previous tasks [105], so training to unanticipated visual cues, may provide an appropriate stimulus for the CNS to refine appropriate postural adjustments. If postural adjustments are made early enough, then the external loads applied to the knee joint could be dramatically reduced [55].

Training program should also focus on reducing reaction times to visual and mechanical stimuli [42]. Plyometric training has been shown to enhance muscle voluntary reaction times and reduce the time taken for muscles to produce peak torque [106, 107]. Hamstring voluntary reaction times and time to peak torque have also improved in subjects who have undergone a stability and balance training program [108]. In

addition, training for the game situation should involve drills that familiarize players with making rapid changes in direction, rather than having cutting tasks being preplanned [42]. Correction of neuromuscular imbalances is important for both the optimal biomechanics of athletic movements and reduction of knee injury incidence [48]. The use of this neuromuscular training program could potentially modify the collegiate athlete's motion strategies, improve performance, and lower the athlete's risk for injury [49].

Primary prevention of ACL injury among soccer players is possible if appropriate intervention strategies are adopted at proper time [42] :

- Reducing the external load applied to the knee joint by changing technique of postural Adjustments;
- Improving reaction time to allow more time to make appropriate kinematic adjustments during game situations; and
- Better interpretation of visual cues to increase the time available to preplan a movement.

## 8. Conclusions

The present review has contributed to the up to date understanding and knowledge in different aspects of ACL injuries among soccer players. It is evident that female soccer players are more prone to the ACL injury than their male counterparts due to the difference in joint angular rotation and biomechanical factors that are closely associated with various postural aspects of the game. Moreover, the stress bearing capacity of the knee ligaments and tendons among females are also comparatively less during different playing manoeuvres in soccer, e.g., cutting or jumping. Irrespective of sex, the ACL injury is more frequent during non-contact situations. It is mainly evident during tackling; but among males it occurs during tackling from front whereas among females it is due to the tackling from side (44%) and front (32%). Various opinions have been postulated regarding etiology and higher prevalence of ACL injury among soccer players. However, the most recent view indicate that neuromuscular fatigue is the most prominent cause of this injury in soccer and this idea also corroborated with the fact that the ACL injuries are mostly prevalent during non-contact situations of the game. Whatever may be cause, ACL tear in soccer seriously affects players' career with short-term and long-term consequences and requires surgical treatments and keeps majority of soccer players out of competition at least four months every season that imposes significant economic consequences. Therefore, to prevent such health and economical consequences primary guidelines which have been mentioned in the review, should be taken under strict care and constant vigil by the soccer players, trainers or instructors and other health professionals to avoid the possibility of ACL injuries during the match as well as during the training sessions.

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