Anterior Cruciate Ligament Injury in Female Volleyball Players: A Review

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Abstract

Volleyball is one of the most popular sports among the female athletes. Although volleyball is considered as a non- contact game, high incidence of injuries are reported for volleyball players. Knee injuries are one of the most common types of injuries in volleyball. This study aimed to review the literature regarding the anterior cruciate ligament (ACL) injuries focused on the volleyball players. A review literature was conducted via searches in Google Scholar, Scopus, PubMed, EBSCO host (Medline Database, Sport Discus), and Science Direct (2011 to march 2021) using various key terms such as "anterior cruciate ligament" and "knee injury". Based on the evidences, although the internal and external risk factors for ACL injury have been extensively studied, the biomechanical factors that expose athletes to this injury are still unclear. To answer the specific question of the present study, different factors associated with ACL injury especially in female's athletes, a comprehensive review of basic and applied studies is necessary. In this paper, after explaining about ACL injuries extracted from articles, the role and application of ACL, its mechanics and patho-mechanics have been discussed. Also, occurrences of ACL injury in volleyball ranks among the other sports, athlete/non-athletes, gender and age of players, is divided as well. It is believed that biomechanical and neuromuscular differences in the trunk and lower limbs are the most likely reason for the significant difference in the high prevalence of non-collision ACL injury in female compared to men.

Keywords: ACL injuries; Female's athletes; Risk factors; Volleyball

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Introduction

Volleyball is a team sport and with more than 900 million estimated fans ranks the fifth most popular and widespread sport in terms of global popularity, where the football (soccer) is top of the list. Nevertheless, no source for the fan numbers has been found (1). It is a fast-paced sport in which players are more likely to fall and collide with each other. Moreover, doing the wrong movements can put pressure on the motor tissues and damage them (2). Injury is occurred as a result of participation in an organized intercollegiate game or practice, required the attention of an athletic trainer or physician, and resulted in the restriction of participation one or more days beyond the day of injury (3). The term 'sport injury' also refers to damage in part of the body causing a time off practices or competition (4). It is caused by accidents that occur during play or exercise. They may also be the result of incorrect teaching methods (2).

Volleyball involves repeated, whole-body maximal ballistic actions in addition to rapid lateral movement in response to external stimuli. For this reason, volleyball is accepted as a serious competitive sport with a fairly high musculoskeletal injury rate (5). Mainly, half of the injuries to limbs in volleyball are muscular injuries. The most common joints injured in volleyball are the shoulders, knees, and elbows (6). More than 51 percent of injuries occur to the lower extremity (7), and due to its construction and function, the knee joint is a joint at risk of injury

As mentioned the majority of ACL injuries in volleyball caused by the explosive, bounding nature of volleyball (8), which puts extraordinary amounts of strain on the lower extremity, putting the ligaments at risk, significantly (9). Despite this, the technical details related to ACL injure, are still a topic for debate. The aim of this review study was to investigate the risk factors associated with ACL injury in female's athletes. In addition, to answer the specific question in this paper, we introduce the anatomy of the ACL.

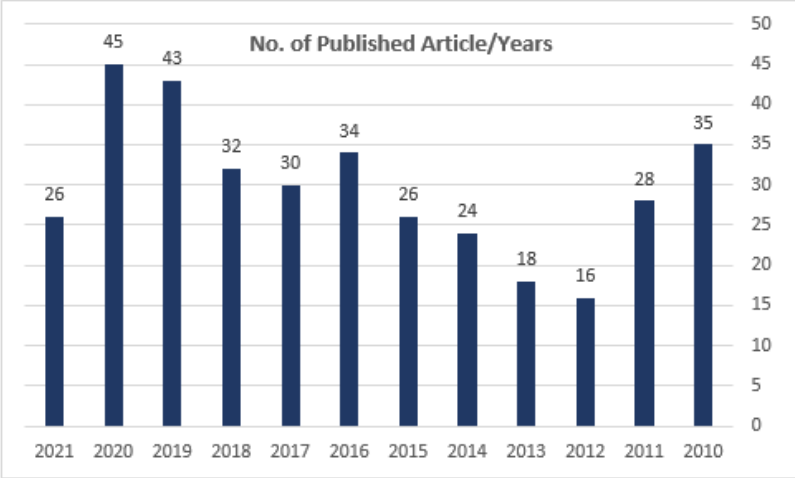

Figure 1. Publication status in terms of title ACL injury in Science Direct during periods of 2010-2021

Material and Methods

Several studies have already carried out about ACL injuries in volleyball in the first decade of the 21st century (10-12). Gheidi and Sadeghi (13) and Voskanian (10) have separately examined the statistical databases about effect of ACL injuries in female athletes for a long time before 2010. Furthermore, Serpell, Scarvell (14) studied a summary of literature since 1980 to 2011. A review of the literature was conducted via searches in Google Scholar, Scopus, PubMed, EBSCO host (Medline Database, Sport Discus), and Science Direct databases for more than last 10 years (2011 to march 2021) using terms such as "anterior cruciate ligament", "knee injury", and "risk factors for prevention of injuries". Other keywords such as "landing biomechanics ACL injury", "Vertical drop jump task ACL injury", "Incidence of ACL injury", and "Non-contact ACL injuries in female athletes" were also used in the search titles.

During review of the literature, unpublished reports, published non-English articles, case studies, and articles which did not conducted on human samples were excluded from the study. In addition, studies that examined the methods of reconstruction and rehabilitation of this injury were not included in the present study.

The quality of a review study depends to the quality of the references. So, at the first, available the articles were categorized, as well as the following subsets: age, gender, and amateur and professional divisions. For instance, a total of 357 articles published just by science direct, over the past decade (Figure 1).

Generally, after the initial search of keywords, a total of 550 articles including paper, essay, chapter, editorial or treatise, were obtained according to the inclusion criteria. After deleting similar articles and non-English articles, 72 articles were selected. Finally, after studying the articles, 35 articles were selected that provided information about ACL injuries in female's volleyball athletes (Figure 2).

Results

Investigations related to ACL injury in volleyball players are mentioned at Figure 1. A review on these studies have shown that the knee joint may withstand heavy loads in situations involving multiple movement plates, especially movements such as landing, jumping, and cutting.

Knee valgus collapse (increasing in knee valgus, hip adduction. and external tibial rotation) was introduced as the main mechanism of ACL injury (15). It is clearly evident that ACL insufficiency leads to cartilage and meniscal injuries, which in turn can lead to early degenerative changes (16).

Unfortunately, little attention has been paid to this type of injury especially in woman. Thus, it seems to be a challenging and needs a lot concern of ACL injury by female athletes/non-athletes

Previous studies also have explored that occurrence of ACL injury in elite athletes has been estimated to be 1.6 injury per 1000 athletes per hour of play (17).

Authors demonstrated that each person's skeletal structure may be a risk factor for injury (18-21). They are also noticed that abnormalities damaged the anatomical structure of the athlete. Some abnormalities are inherent and over time lead to increased energy expenditure, fatigue, and secondary postures, but it remains to be seen whether this alignment can

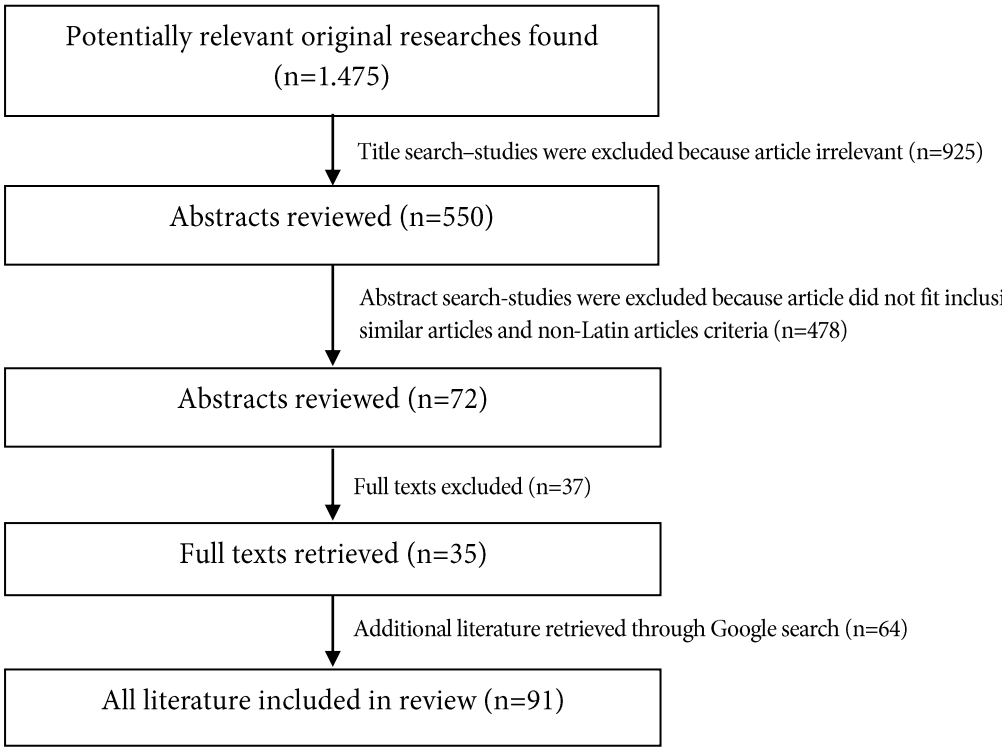

Figure 2. Flow diagram presenting search results

affect the athlete's performance (22). Most studies on the relationship between lower limb alignment and ACL injury have studied one or two more effective anatomical variables independently (23-25).

Joseph *et al.* (16) found no difference in the progression of injuries in athletes and non-athletes. These results also demonstrated that both athletes and non-athletes would be equally susceptible for long-term meniscal and cartilage injuries if ACL reconstruction was not carried out early. Because, the ACL can be ruptured during cases such as quick change of direction, sudden stop, improper landing when jumping, sudden deceleration, and a direct hit or collision (26). Moreover, sneakers whose sides are stiffer and stronger than the middle of the sole make a person more prone to injuries (27). So, all athletes/non-athletes may be affected (22-25).

ACL injury prevalence in volleyball ranks among the other sports

ACL is ruptured in athletes in active sports such as soccer, basketball, skiing, and gymnastics (28). However, there is differences in incidence rates of ACL injury by sport type (collision, contact, limited contact, and noncontact) (28). There is little consensus about which type of sport has the most injuries. It seems that sports like football, wrestling, martial arts, and volleyball are among the sports in which the most sports injuries occur (29). Nicolini *at al.* (30) obtained 16th ranks for ACL injury in volleyball among a total of 33 sports categories, with 27% injury. In Slovenia, among the female playing professional basketball, handball and, basketball team players had the greatest ACL-injury risk and volleyball players had the lowest ACL-injury risk (P=0.04) (31).

However, revision on the injuries and illnesses patterns sustained during the games of the XXXI Olympiad, revealed 9.8 injuries and 5.4 illnesses per 100 athletes over the 17-day period (32). Based on this study, the injury incidence was highest in BMX cycling, boxing, mountain bike cycling, taekwondo, water polo, and rugby (38, 30, 24, 24, 19 and 19% of the athletes injured, respectively), and lowest in canoe slalom, rowing, shooting, archery, swimming, golf and, table tennis (0%–3%). Besides, most injuries occur in the knee, shoulder, and groin area, but in addition to these, they can include other injuries such as cruciate ligament rupture, ankle sprain, inflammation, and pain in the front of legs (29).

ACL injury ranks in volleyball injuries

Analyses of injury typology of female elite volleyball players of Serbia shows that the most frequent injuries were injuries of the ankle (33%), followed by shoulder injuries (20%), and other injuries, and that the jumping phase had the highest occurrence of injury (33). Nicolini et al.(30) reported 27% ACL injury in volleyball athletes.

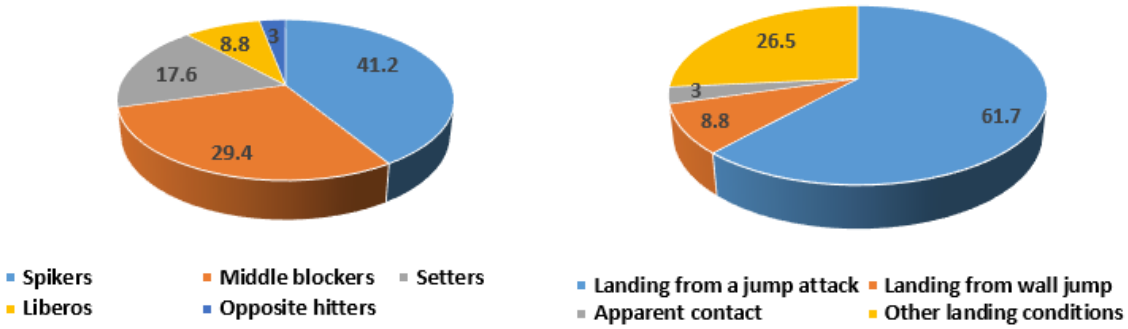

Figure3. ACL injury mechanism during role of players and volleyball movement [Data from Devetag, Mazzilli (5)]

According to the National Collegiate Athletic Association (NCAA), the ligament sprains are the most common types of injuries in volleyball players with the rate of 28.2 percent, followed by muscle strains (%21.7), tendinosis (%7.5), and contusions (%4.6 percent). In addition, NCAA reported that ligament sprains of the lateral ankle (15.6 percent) are the most common types of injury in female's volleyball, followed by concussions, quadriceps muscle strains, and abdominal strains (4.1, 4.0, and 3.0 percent, respectively) (34). The NCAA report also indicated that ACL sprains account for 0.6 percent of all injuries.

The results of the available evidence suggest that neuromuscular defects including ligament dominance, quadriceps dominance, leg dominance, and trunk dominance are associated with the underlying mechanisms of ACL injury, and these defects during dynamic activity can increase lower extremity joint loads.

Volleyball ACL injury in collision/non-collision mechanism

From 34 ACL ruptures reported during the professional career of female's' volleyball players of A1-A2 Italian volleyball league, thirty-three (97%) were non-contact and only 1 (3%) with contact (5). Devetag *et al.*(5) demonstrated that the most injury (61.7%) occurred in landing from a jump attack, while 8.8% occurred in landing from wall jump. The rest occured with apparent contact and in other landing conditions (5).

According to the Ludwig and Atanda (35) and Xu *et al.* (36), about %70-90 ACL injuries have a non-collision mechanism and occur when the athlete has no other contact with an object or other player. Most non-collision injuries are accompanied by reduced acceleration, landing, and repetitive rotations that result in significant eccentric exertions on the quadriceps. Moreover, the non-contact injury of ACL is generally caused by the large force or moment generated by the player himself on the knee joint, so that the force of ACL exceeds its ultimate load capacity (36).

Classification of ACL injury in volleyball by age

Froehle *et al.* (37) reported the effect of athlete's age on ACL Injury that may be driven by differences in the process of pubertal development.

On the other hands, volleyball has become one of the most popular sports worldwide, practiced by millions of people of all ages and genders (7). Weitz *et al.* (38) reported increasing the incidence of ACL injury with age, and the highest incidence was observed among 17-year old (113.5 per 100,000 person-years).

Looking at the injuries rate reported by the National Association of College Sports (NCAA) and Surveillance Systems (ISS) provide an individual 16 years information about 15 sports across a university age group (only 18-23 years)(34, 39). According these reports, about 5,000 ACL injuries have been reported over 16 years, averaging 313 damages per year. Assuming 15% of the total population, this equates to more than 2,000 ACL injuries per year (34, 39). Moreover, based on these two reports, if ACL injuries are classified as one percent of total injuries of a team, female's sports are at the highest level of injury, as well as associated with non-contact sports. At younger age (14-18 years old), in basketball, injuries are more than others and in female, it is almost 4 times more than men. However, at the university level, it is almost equal. Doctors believe that part of the reason for the increase in ACL injuries may be due to improper sports training conducted for many adolescents (40). Continuous exercise without a set time, playground, the instruction of inexperienced coaches to start, stop, and spin quickly makes adolescent athletes more vulnerable (41). Nicolini *et al.* (30) demonstrated the mean age of 27.1 years old for ACL injury among the volleyball athletes. Furthermore, the prevalence of ACL injuries in skeletally immature athletes has dramatically increased over the past decade (35).

Classification of ACL injury in volleyball by athletes' role

Based on the Devetag *et al.*(5) study, the most injured knee was the left limb (64.7%) respect to the right limb (35.3%). ACL injuries are associated with injury to other knee ligaments (internal or external lateral ligament) or meniscus of the knee.

Applying a strong force from the outside to the knee can lead to triple injuries including ACL injury, knee internal lateral ligament injury, and delayed injury of the internal meniscus. Therefore, it is predictable that attackers will have the most damage. According the Devetag *et al.*(5), in terms of players' role, 41.2% ruptures occurred in attackers, followed by the middle blockers (29.4%), setters (17.6%), liberos (8.8%), and opposite hitters (3%). Also, Karita *et al.*(42) reported a total of 76.9% ACL injury during spiking, 80.8% injures during landing, and 61.6% of ACL injuries with single-leg landing after spiking were occurred. Most of ACL injuries (84.6%) were occurred in front of the attack line near the net (42).

For the same stated reason, volleyball is routinely classified as a high-risk sport with about 63% of musculoskeletal injuries observed during jumping and landing movements which are fundamental parts of blocking and spiking in volleyball (5) (Figure 3).

Discussion

Sports injuries are commonly caused by overuse, direct impact, or the application of force that is greater than the body part can structurally withstand (43). The five most common sports injuries are ankle sprain, groin pull, hamstring strain, shin splint, and ACL tear, which occur when players are landing with one leg, and high or low flexion angle knee in landing moment after block or attack (44). Volleyball, like other sports, can be associated with injuries (2). It is a fast-paced sport in which players are more likely to fall and collide with each other (45). Also, doing the wrong movements can put pressure on the motor tissues and damage them (8). The most common joints injured in volleyball are the shoulders, knees, and elbows. In general, half of the injuries to the limbs in volleyball are muscle injuries, which are usually in the form of muscle strains (2). Then, there are ligament strains, which make up about a quarter of volleyball sports injuries. So, to answer the specific question of the present study, biomechanical factors associated with ACL injury in female athletes, a comprehensive review of basic and applied studies is necessary.

ACL is one of the most important knee ligaments which plays main role in stabilizing the shear forces in the joint. The ACL originates from the inside of the outer aspect of the femur and continues to the anterior protrusion of the tibia. This ligament is bent in the knee position but is stretched in the standing or straight knee position and prevents the knee from moving backwards (46). The most important function of the ACL is to limit the movement of the tibia forward and its internal rotation in the action of smoothing the knee and to prevent the displacement and pressure caused by coming out of the midline of the knee joint (47).

The cruciate ligaments inside the knee are crosswise in front of each other so that the ACL is in front of the posterior cruciate ligament. The main function of these ligaments is to prevent the leg from sliding back and forth towards the thigh. The ACL is located in the middle of the knee joint and obliquely, preventing the leg from sliding forward. This ligament is also effective in maintaining the rotational stability of the knee (48).

Almost half of all ACL injuries are associated with damage to other knee structures such as articular cartilage, meniscus, or other ligaments (48). Incomplete ACL ruptures are rare and most injuries are complete or near-complete. It should be noted that the ACL rupture may be associated with dislocation or partial dislocation of the patella, so the patella should also be carefully examined(49). During the physical examination, the doctor examines all the damaged structures and compares them with the patient's healthy knee. Most ligament injuries can be diagnosed with a thorough knee examination(50).

It is amazing that based on the STOP Sports Injuries website(51), each year, more than 460,000 high school students-including more than 410,000 girls-participate in interscholastic volleyball. As participation has increased over the past two decades, the number of volleyball-related injuries has risen as well.

In the US, female's volleyball athletes are 10 times more likely to rupture a cruciate ligament than men(52). However, among all sports, men had a significantly higher rate of recurrent ACL ruptures (4.3) than female (3.0) (P=0.04) (53). Although the higher rate of ACLs tear in volleyball has persisted in female compared with men, over the last 10 years, no distinct physical or historical measurements could be attributed to this different rate of injury. Many physiotherapists also confirm that female athletes are more prone to cruciate ligament injuries than men (54). According to theNicolini, Carvalho (30) reports, ACL injuries were observed 54% in female and 46% in male.

Several theories have been proposed to explain the underlying mechanisms of gender differences in ACL damage (55). These theories include external and internal variables (anatomical, hormonal, neuromuscular, and biomechanical differences) (56).

Female have a wider pelvis, compared to men. These biomechanics of the knee increase the Q angle (a line that connects to the patella from the upper anterior iliac spine and from the patella to the tibia protrusion). Due to this angle of the Q, female are more prone to sports injuries in the knee ACL than men (57, 58).

In female, it is up to 5 degrees higher than men, which enables them to control the knee poorly and increases the risk of valgus or other side effects on the knee, especially during jump or spin.

According to the Froehle *et al.* (37) divergent pubertal developmental trajectories in males and females likely underlie a suite of high-risk traits that appear widely in post-pubertal females, but less commonly in males.

Based on the binomial logistic regression of Froehle *et al.*(37), there was a significant negative effect of age at menarche on ACL injury risk (X2=4.37; P=0.04; b=-0.45±0.22).

Hormonal factors refer to changes in the mechanical components of the ligaments which occur based on the estrogen and progesterone levels at different stages of a woman's menstrual cycle. Estrogen and progesterone make the ligament prone to excessive softness and stretching in female (59, 60). Monthly hormonal fluctuation may relax ligaments at certain times, increasing risk of ACL tear.

Neuromuscular and biomechanical factors are modifiable internal variables. Furthermore, a previous study are believed that risk factors of ACL injuries in female athletes are associated with neuromuscular disorders (61).

In the middle of the menstrual cycle, increased relaxation of the knee joint is a detrimental factor in the knee joint (62). The results of a study showed the greatest amount of damage occured at this stage. Excessive amount of relaxation hormone is one of the effective factors in the occurrence of ACL injury (63). Serum levels of this hormone are higher in elite female athletes who have seen the above injury (56). A group of researchers also suggested that performance of motor skills in the premenstrual phase was likely to decrease (60). On the other hands, unlike men, female bend their knees less when landing on the ground after jumping to throw the ball, thereby applying more pressure to their knees and they are more prone to anterior cruciate ligament injury. Furthermore, females are more likely to strengthen the muscles in the front of the thigh. As a result, more pressure is applied to the ligament when there is a sudden change in motion.

Anyway, although ACL injury is multifactorial in nature and many external and internal factors affect the incidence of this injury, structural differences of the lower extremities, movement patterns, special mechanisms of quadriceps activation during tibial displacement, landing pattern, and hormone production levels are among the specifics factors associated with the ACL injury (64).

There are several risk factors which cause injuries such as inadequate warm-up, cold muscles, gender, aging, previous injury, muscle weakness, and type of grass (65). So, all athletes/non-athletes may be affected (see 3.1). As mentioned in 3.2 and 3.3, because volleyball involves repetitive overhead motions, such as spiking and blocking, players are prone to overuse injuries of the shoulder, rotator cuff tendinitis, ankle sprains, patellar tendinitis, ACL injury, and low-back pain. In addition, volleyball players are particularly susceptible to finger injuries. Classification of ACL injury in the volleyball by gender showed that anatomical factors include increasing the Q angle, foot pronation, knee hyperextension, general joint relaxation, and size and shape of the femoral condylar space, which increase the rate of injury in female (58). The injury collision/non-collision mechanism appeared to be a forceful valgus collapse with the knee close to full extension combined with external or internal rotation of the tibia (66). Section of 3.5 showed that ACL injury is not a negligible knee injury in the paediatric population (38). Finally, based on the statistical data in section 3.6, single leg landing after spiking close to the net was the most common cause of injury, and most of wing spikers injured the knee opposite to their dominant hand as mentioned by Karita *et al.* (42).

Neuromuscular disorders are defined as impairments in muscle strength and activation patterns, which lead to increasing the loads on the knee joint and ACL(61). Female athletes show neuromuscular control deficiencies during exercise, which can increase the load on the lower limb joints(67). The results of the available evidence suggest that neuromuscular disorders including ligament dominance, quadriceps dominance, leg dominance, and trunk dominance are associated with the underlying mechanisms of ACL injury(68). These defects during dynamic activity also can increase the loads of lower extremity joints (69). Studies have also indicated that knee joint may withstand the heavy loads in situations involving multiple movement plates, especially movements such as landing, and jumping (70). We found that knee valgus collapse (*e.g.* increasing of knee valgus, hip adduction, and external tibial rotation) was introduced as the main mechanism of ACL injury (71).

Conclusion

This review study provided information about the characteristics of ACL injuries, specifically in female's volleyball players. This study emphasizes that volleyball is routinely classified as a high-risk sport. Therefore, it is necessary that coaches teach players variations of landing in order to avoid possible chronic overloading of ACL.

ACL stretching can be prevented by doing exercises which improve deep sense perception, such as one-legged balance. Another of the most effective ways to prevent ACL injuries in female is to increase the strength of the quadriceps muscles, especially the inner muscle called the internal extensor muscle, and to ensure a balance between the strength of the hamstrings and the quadriceps muscles.

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