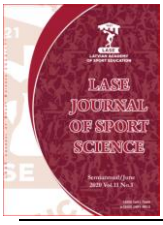

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ORIGINAL RESEARCH PAPER

KNEE ANTERIOR CRUCIATE LIGAMENT INJURY IN SPORTS

Svens Vilks

Latvian Academy of Sports Education
Address: Brivibas Street 333, Riga, Latvia
Phone: +37126659911
e-mail: Svens.Vilks@lspa.lv

Abstract

Anterior cruciate ligament (ACL) tears are very common in sports, and accounts for a great number of athletic knee injuries. The injury rate is increasing from year to year, creating a long period of inactivity for athletes. It can be career ending and "return to sport" period takes almost a year. Purpose:The purpose is to overview the latest information about the most common ACL injury mechanisms in sports, the biomechanical and other risk factors that can increase the risk of ACL injury, and to review what does "return to sport" exactly mean and to summarize the best preventive measures. Methods: This systemic review was performed using PubMed search engine by searching specific keywords about ACL injury and team sports, the scientific articles were published from January 2015 to August 2021. Non-English articles were excluded. Results: A total of 25 sources and 2 books were included, summarized, and divided into 4 topics: anatomy, epidemiology (subdivided into injury mechanism, biomechanical and other risk factors), "return to sport" (RTS) and prevention. It was found that most often the injury mechanism is "non-contact", occurs more during competition compared to practice, female athletes are at greater risk and that RTS criteria must be assessed individually. Conclusion: The best preventive measures include improving the technique of sports specific athletic movements (jumps, landing & cutting motions), involving proprioceptive & neuromuscular training exercises and by strengthening muscles of the leg.

Keywords: *anterior cruciate ligament, injury, team sports, return to sport*

Introduction

Anterior cruciate ligament (ACL) injuries are one of the most common injuries in musculoskeletal system in physically active individuals and can happen to anyone – young or old, male or female, professional or amateur. It is a debilitating injury, with a long "*return to sport*" period and sometimes even can end the professional career of an athlete (Grassi et al., 2020). Alarmingly the number of ACL injuries in paediatric setting is rising and that is a significant concern, especially for children involved in various athletic programs and that has been found to be true worldwide. (Werner et al., 2016; Shaw & Finch, 2017; Weitz et al., 2020). In sports, especially pivoting sports, the ACL is exposed to huge amount of stress – jumping, landing, cutting motions, changes of direction, sudden deceleration, and other specific movements, dramatically increase the load on the knee joint, therefore the injury rate is quite high, and the risk of re-injury remains, especially after returning to sport. In the past decade there is a rise in ACL research, main topic undoubtably being ACL reconstruction (ACLR) and different kinds of grafts to choose from for the ACLR (Herzog et al., 2018). Other less popular topics include reviews of the injury mechanism, where video analysis has proven to be more advantageous in complex situations, compared to cadaver and MRI analysis (Waldén et al., 2016). Treatment can be non-operative or operative, depending on the individual situation of the athlete, his or her goals and the main activities, with the surgical treatment considered to be more favourable (Paschos & Howell, 2016). It is estimated that about 200'000 ACL reconstructions (ACLR) are done annually in the United States (Kaeding et al., 2015), some sources estimating even close to 350'000 ACLR in the US and a 1-2 million worldwide (Davies et al., 2017), and from 2002 to 2014 the number of surgeries in the USA had increased by 22% (Herzog et al., 2018). Despite that it has been reported that surgical treatment has good outcomes, the injury increases the risk of other injuries, like meniscal tears and is linked to early-onset osteoarthritis. Injury can also affect long term health of the knee joint and the quality of life for the individual affected by the ACL injury (Davies et al., 2017). It is not uncommon to get reinjured, tearing an ACL graft or injuring the ACL of the contralateral knee, which may be devastating to the athlete (Kaeding et al., 2015). The aim of this review is to gather the latest information on ACL anatomy and epidemiology, overview the criteria for "*return to sport*" and to summarize the best preventive measures available to date.

Material and Methods

A systemic review was performed on ACL-related scientific articles published between January 2015 and August 2021. The main search engine

used was PubMed, the search terms were *anterior cruciate ligament* or *ACL* in combination with *injury*, *sports*, *team sports* or *return to sport (play)*. Research studies and articles were included based on their compatibility with the 4 chosen topics: *anatomy*, *epidemiology*, *return to sport (RTS)* and *prevention*. Only those articles with quantitative research design type and that matched at least 2 of the chosen topics were included. Automatically excluded were those articles not published in English.

Results

Author chose to include only the newest and most related information, from 25 sources and 2 books, that were found using PubMed search engine. Author reviewed and summarized these articles into 4 topics, that were chosen beforehand.

Anatomy:The knee joint, although more complex, is categorized as hinge joint. Three bones articulate in it, creating two separate joints – tibiofemoral and patella-femoral joint, between the tibia and the femur, and between the patella (kneecap) and the femur. The knee joint is enclosed in an articular capsule, creating a cavity that is filled with synovial fluid. Two fibrocartilaginous discs, called menisci, are located above the lateral and medial condyles of tibia, improving the femoral-tibial congruence. The menisci also cushion the compressive force and increase the stability of the knee joint (Affatato, 2015). There are six ligaments that provide stability and anterior cruciate ligament is one of those, primarily preventing hyperextension of the knee joint, by restricting anterior sliding of the tibia. Other intra-articular ligaments are posterior cruciate ligament and transverse ligament, that connect both menisci. Two collateral ligaments, that are extra-articular, on medial and lateral side, prevent abnormal movement in the varum–valgum direction (Fig. 1.)

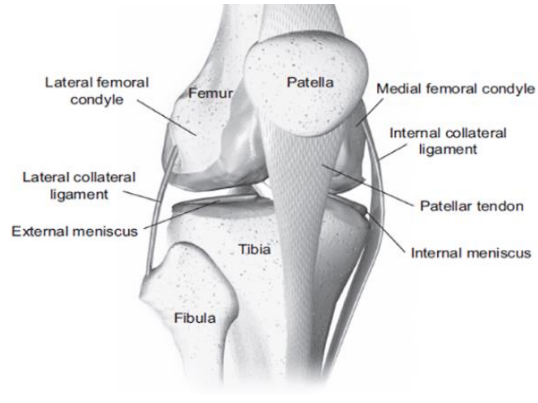


Figure 1. The skeletal anatomy of the knee joint, with the soft tissues, except ACL and PCL (Affatato, 2015)

The knee joint has a wide range of motion together with high resistance to external stress, but the centre of rotation is not fixed during the flexion/extension movement. Due to the complexity, all three anatomical planes should be reviewed and a six degrees of freedom (DoF) system of movement used, including three rotations and three translations, that are restricted by the fibrous capsule, ligaments, and muscles (Fig. 2.)

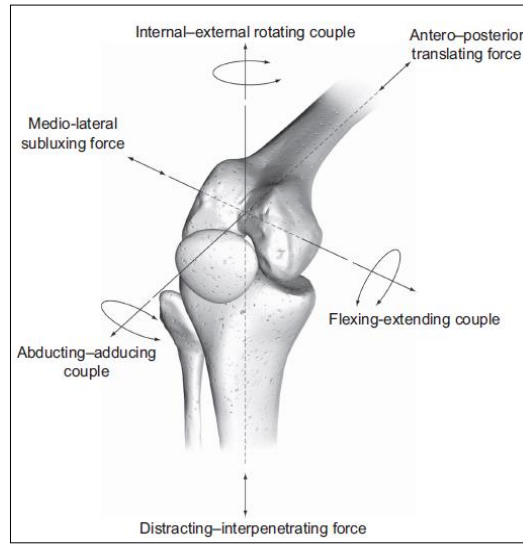


Figure 2. Six DoFs of movement: three rotations and three translations (Affatato, 2015)

The mechanism of knee flexion also implies a combined movement of rolling and sliding of the femoral condyles over the tibial plate, also called *rollback*, allowing a wide rotation on the sagittal plane. Interestingly, a phenomenon called "*screwhome*", means that the rotation depends on the degree of flexion, and in fact during flexion the femoral condyles rotate internally, but in full extension of the knee, an external rotation can be observed (Affatato, 2015).The anterior cruciate ligament (ACL) is a bit triangular, about 30 mm in length (+/- 5mm), 10 mm in breadth and about 5 to 10 mm in width, depending on the individual and it is much thinner in the middle section, compared to the part attached to the bone (Marieswaran et al., 2018). The ACL consists of two functional bundles – anterior medial bundle (AMB) and posterior lateral bundle (PLB), working synergistically and providing stability in the event of complex loads. It is found that PLB is responsible mainly in rotation and in anterior-posterior laxity control (Musahl et al., 2017). Sonnery-Cottet & Colombet, (2016) illustrates the behaviour of these functional bundles during the flexion of knee joint in Figure 3.

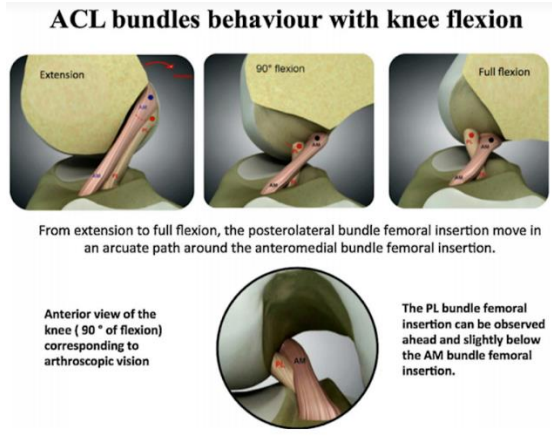


Figure 3. Role of AM and PL bundles during knee flexion

Marieswaran et al., (2018) in their research also compare the anatomical differences between ligaments and tendons, showing the comparison of tensile strength of ACL and patellar tendon provided in Figure 4.

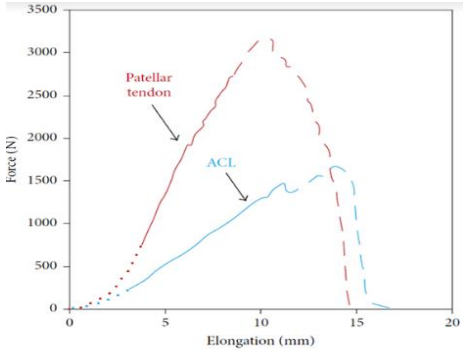


Figure 4. Tensile strength of ACL and the patellar tendon. The dotted lines represent the toe region, continuous lines represent the linear region, and dashed/broken lines represent the field region

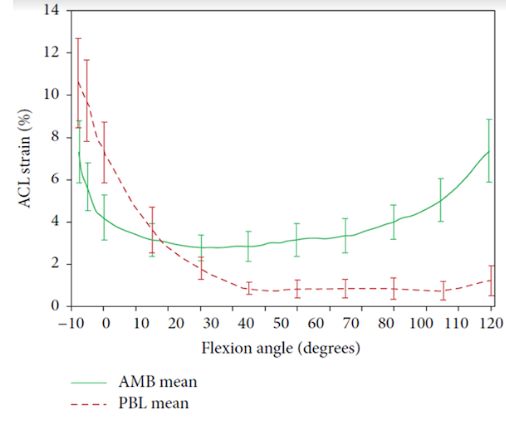


Figure 5. Average strain in AMB and PLB as a function of knee flexion angle; as shown in the figure, AMB is under tension during the extension at the knee joint and PLB is under tension during flexion

Also showing the average strain of AMB and PLB as a function of knee flexion angle provided in Figure 5.

For better understanding of biomechanical factors that can lead to an ACL injury of the knee, it is worth looking at the forces that act on the knee joint, that have been analysed using simulated models on various phases of

gait and has helped to calculate the forces acting on ACL (Marieswaran et al., 2018), shown in Figure 6.

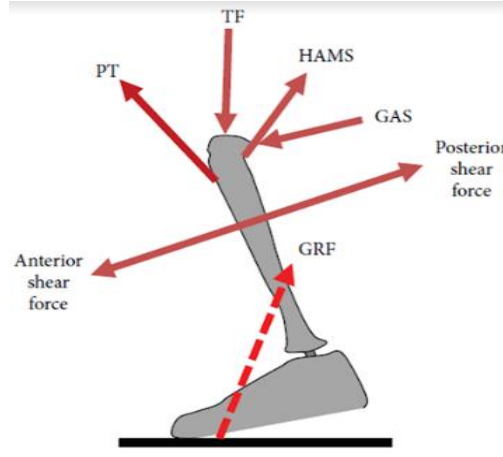


Figure 6. Forces acting on the knee joint. TF: Tibiofemoral force; PT: patellar tendon force; HAMS: hamstring muscle force; GAS: gastrocnemius muscle force; GRF: ground reaction force

Epidemiology: In Italy from 2001 to 2015 analysing past surgeries the conclusion was that ACL surgery count increased each year from ~10'500 to 17'500, respectively, and interestingly 67% of surgeries were performed in North Regional hospitals (Longo UG et al, 2021). Weitz et al., (2020) concluded that the incidence of paediatric ACL injury is increasing and has been steadily growing since 1997 till 2014 in Finland. The increasing incidence is mentioned in many of articles reviewed, some suggesting that it may be due to increased involvement in high school sports activities in paediatric setting and overall increase of people doing more sports in all levels of competition (Kaeding et al., 2017). The incidence rate of ACL injury differs from sport to sport but interestingly with a common conclusion that during competition there is a much higher risk. Kobayashi et al., (2010) overviewed more than 1,700 athletes, and found that ACL injury occurs 49.8% during competition and 34.8% was during practice. Sandon et al., (2021) reported data from 2875 players, and found that 66% of injuries happen during the game, opposite of 28% during practice and Waldén et al., (2016) found that the soccer match injury rate was 20 times higher than the practice injury rate. Grassi et al., (2020) also found that the risk during Series A soccer match is 14 times higher than the injury rate during practice. *Injury mechanism.* In sports it is more common to have an "non-contact" injury than "direct contact", although it does not apply to every type of sport, for example, in a recent research it was found that 99% of ACL

injuries in Judo happen in "direct contact" way (Takahashi et al., 2019). Authors also found that in team sports (e.g., basketball, volleyball & handball) non-contact injury was the more common cause, respectively 67%, 86,5% and 68,5%, especially in female soccer and basketball non-contact injuries were as high as 72.2% and 76.7%. Sandon et al., (2021) reported that in 59% of cases of 2875 soccer players, the injury mechanism was also "non-contact" and Kobayashi et al., (2010) report of 1700 athletes of different sports, also the "non-contact" mechanism was found in 60% of the cases. In a systemic video analysis, it was reported that 85% of professional soccer players had suffered a "non-contact" injury, of which most playing situations were pressing, re-gaining balance after kicking and landing after header, and interestingly that most were while defending and half of the time the players did not have the control of the ball (Waldén et al., 2015). Nevertheless, Parsons et al., (2021) reported that "direct contact" injury rates are higher in boys and men, compared to girls and women, which may be partially explained by participation in different types of sports.

Gender as a risk factor. The higher incidence rate of ACL injury among female athletes has been reported in many articles, with numbers ranging from 1.7- to 2- and even 4- times higher rate than male athletes. Explanations suggested that it may be due to female athletes having a greater exposure in sports or that female athletes may have different muscle group dominance, that joint stability relies more on ligaments than muscle and that there could be an altered neuromuscular control of the trunk compared with male athletes. (Britt et al., 2020; Herzog et al., 2018; Montalvo et al., 2019; Sandon et al., 2021)

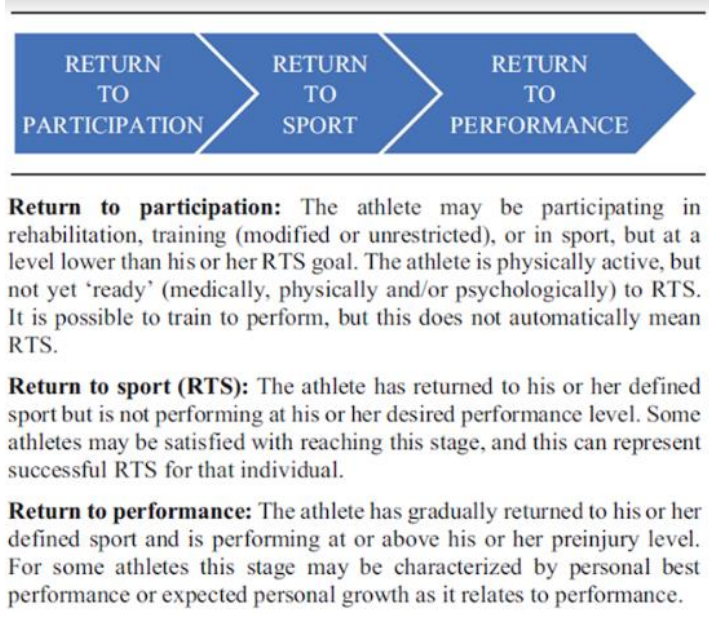
Biomechanical factors. Waldén et al., (2015) found that knee valgus in combination with external rotation was present in most of the cases, but a dynamic valgus collapse was observed in only a few cases. Kobayashi et al., (2010) also reported a dynamic position at the time of injury of 1,603 athletes and it was found that of 793 cases (49.5%) the knee was in internal-external rotation, but the knee in external-internal rotation, was present in 142 cases (8.9%), while hyperextension was reported in 97 (6.1%) cases. Parsons et al., (2021) in their review show a possible categorisation of intrinsic and extrinsic risk factors for "non-contact" ACL injury and one of the factors is also dynamic knee valgus. Shown in Table 1.

Table 1.
Categorization of intrinsic (I) and extrinsic (E) risk factors for "non-contact" ACL injury

Modifiable risk factors	***Non-modifiable risk faktors***
Environmental	***Environmental***
Meteorological condition (E)	Playing situation (E)
Playing surface (E)	Opponent behavior (E)
Rules (E)	Unanticipated events during play (E)
Referees (E)	***Anatomical***
Coaching (E)	Q angle (I)
Equipment	Navicultural drop (I)
Footwear (E)	Structural knee valgus (I)
Knee braces (E)	Postural alignment (I)
Anatomical	Notch size, ACL geometry and propertie (I)
Foot pronation (I)	Tibial slope angle (I)
Body composition and body mass index (I)	Generalised joint hypermobility or laxity (I)
Neuromuscular	***Hormonal***
Dynamic knee valgus (I)	Menestrual phases (I)
Muscle strength (I)	Hormone concentrations (I)
Muscle strength ratios (I)	***Demographic***
Muscle activatin patterns (I)	*Age (I)*
Muscle stiffness (I)	Maturation (I)
Physical fitness and muscle fatigue (I)	Previous contralateral knee ACL injury (I)
Skill level (I)	Familial history and genetics (I)
Neurormuscular contrl (I)	Sex (I)
Proprioception (I)	Height (I)
Psyhological (I)	Race (I)
Personality (I)	Sport played (I)
Stress response (I)	

Return to sport (play). Recovery from the ACL injury has many options and depending on situations it can be operative or non-operative treatment. Both treatment options are acceptable and must be assessed individually. It is worth pointing out that operative treatment is preferred in sports with jumping, cutting and pivoting movements (e.g., soccer, basketball, handball, football) and without operative treatment there is a higher risk for secondary injury. If the individual is involved in straight plane activities (e.g., running, swimming, cycling, weightlifting) than non-operative treatment is an acceptable option. Sometimes progressive rehabilitation before the operative treatment may be offered, to improve impairments and overall function. (The Panther Symposium ACL Treatment Consensus Group et al., 2020). The "*return to sport*" (RTS) commonly is used as a measure for assessment of outcomes after an injury, and Ardern et al., (2016) already purposed to use RTS continuum comprising three elements: "return to participation", "return to sport" and "return to performance" (summarized in Figure 6.). This definition of elements allows

to clearer describe the recovery process of an athlete and components like performance and involvement in competition.



6. Figure Three elements or "return to sport" (RTS) continuum

Grassi et al, (2020) found that average time lost for a professional soccer player is 9 to 12 months and only about 65% of injured players return at the same playing level 3 years post injury. From 71 female soccer players with ACL injury, it was found that only 37% returned to the preoperative level of play, but 66% return to playing soccer at any level (Britt et al., 2020). Although, Lai et al., (2018) showed that in elite athletes average period of "*return to sport*" (RTS) was 6 to 13 months and 83% of athletes did RTS, with elite soccer player rate of 85% and elite basketball player rate of 83%. Similar rate was found in NBA basketball players, 84%, but interestingly only 66.7% of athletes with right leg ACL injury returned, compared to the left leg injury where all of the athletes returned (DeFroda et al., 2021). To assess outcome parameters and establish criteria for "*return to sports*", the First Congress in Sports Physical Therapy outlines five specific recommendations to guide the practitioner when deciding to clear an individual for RTS (Ardern et al., 2016), grouped together as follows:

1. Use a group of tests (aka: a test battery).
2. Choose open tasks (less controlled) over closed tasks (more controlled) when possible.
3. Include tests with reactive decision-making elements.

4. Assess psychological readiness to RTS.
5. Monitor workload throughout the RTS transition.

Even though, every sport is unique and specific "return to sport" criteria must be determined individually. With many similarities between athletes and specific sport elements, such as jumping, landing, cutting, rapid acceleration or deceleration, there is a proposition to include extrinsic criteria to assess "return to sport" readiness (Unverzagt et al., 2021). Criteria summerized in Table 2.

Table 2.

Extrinsic Criterion Used to Assess Return to sport Readiness*

Extrinsic Criterion	*Means of Measuring*
Range of motion	Hip, kneed ankel (tibial shaft angle)
Neuromuscular control	Functional movement Screen Y-Balance Test, Single leg squat, Tuck Jump Assessment, Landing Error Scoring System
Strength	Isokinetic testing time to peak torque, peak torque
Power	Hop testing: Anterior hop, triple hop, triple crossomer hop, timed hop, hop & stop
Agility and cutting	Tranzer lateral agility screen, Trazer Flanker test, reactive agility test
Psychologic readiness	ACL-Return to Sport After Injury, 2000 IKDC Questionnaire**

*Means of measuring should be left to the discretion of the evaluating facility
** IKDC: Internatinal knee Documentation Committee

Prevention. Neuromuscular and proprioceptive training appears to be supported in literature as the main preventive measures and have been found to decrease the incidence of injury to the knee and specifically the ACL, however no specific group of exercises were determined to be better than others (International Olympic Committee Pediatric ACL Injury Consensus Group et al., 2018; Sandon et al., 2021). The components of neuromuscular-control and proprioception include balance training, plyometric (jump) training, strength and resistance training, running-technique training (combined technique training and running exercises [e.g., shuttle run, bounding run]), and stretching (Dargo et al., 2017; Shaw & Finch, 2017). There are many preventive programs that are developed for ACL injury prevention, but the injury rate is still increasing and the disparity between men and women have not change for the last 20 years. The involvement in these programs seem to decrease the "non-contact" ACL injuries but must be delivered in structured and supervised manner (Parsons et al., 2021).

Discussion

The author of this review agrees that the ACL injury of the knee in is a widely researched topic, that is not yet fully understood, and the injury incidence rate still increases, partly due to increasing activity and

involvement in sports by the youth (Kaeding et al., 2017; Weitz et al., 2020). This review also supports previously suggested higher ACL injury risk for women, compared to men and unfortunately the disparity of men and women sustaining ACL injury has not change for the last two decades, with only recently being addressed as a serious issue (Parsons et al., 2021). This review also agrees with previously made suggestions that the "non-contact" injury mechanism is more common in sports but found some situations where "direct contact" is more common (Kobayashi et al., 2010; Sandon et al., 2021; Takahashi et al., 2019; Waldén et al., 2015). Nevertheless, author agrees that the role of opponent or teammate in the sudden change of movement right before the injury happens, must be considered in team sports (Waldén et al., 2016). The review suggests using the RTS three element continuum provided be (Ardern et al., 2016) to better evaluate the recovery process of an athlete and other components associated with it, despite that Davies et al., (2017) argues that, there is no standardized definition for what exactly "*return to sports*" (RTS) mean, in the sense of the playing level that the athlete returns. Suggestion is to use the full continuum and explain RTS term in context with other elements. For better outcome results after the ACL injury and to reduce the possibility of reinjury, author agrees that five RTS recommendations and criteria must be used and assessed individually, preferably done 9 months post-surgery (Ardern et al., 2016; Kaplan & Witvrouw, 2019; Unverzagt et al., 2021). This review also describes preventive measures that may decrease the risk of ACL injury, including neuromuscular and proprioceptive training, as well as modulating game-like situations and incorporating jumping, landing, cutting and pivoting movement exercises into each practice session that have been previously proved to be successful (Dargo et al., 2017; Shaw & Finch, 2017). Parsons et al., (2021) argues that none of the programs have considered different approach regarding gender of the athlete, and preventive programs that include strength training, as well as resistance training, in which women participate less frequent than men, as it may be to masculine, could be one of the reasons why women have higher risk of ACL injury. Thus, there is need for research on optimizing preventive measures and improving "return to sport" outcomes. This review is not without limitations and multiple factors must be considered. Firstly, the search was done only in PubMed database, meaning that there could be a lot more relevant articles if other databases were used. Secondly, this review did not analyse the number of people included in research studies, although the number was mentioned for some studies, nor did it analyse the quality of the selected studies. Despite these limiting factors, the aim of the research was obtained and provides a theoretical knowledge about ACL injuries in sport

and demonstrates a practical value as well for some specialists. Finally, it is worth mentioning that all recommendations in this review should be approached and interpreted with caution.

Conclusion

The ACL injury in sports is very common and can happen to anyone at any age and level of competition. Female athletes are undoubtedly at a greater risk of ACL injury, due to various factors, ranging from biological differences to participating in sports more. Injury mechanism in most cases is "non-contact", with some exceptions were "direct contact" is more common. Another interesting finding is that higher incidence rate is during competition versus training, meaning that not only biological factors play a role in athlete's that sustain ACL injury or re-injury. There is a proposed "return to sport" (RTS) continuum with three elements, that should be used to clearer describe the recovery process of an athlete. Although, there is no one-size-fits-all injury prevention, programs that include neuromuscular-control and proprioceptive training, decrease the incidence of the ACL injury and other knee injuries. Therefore, trainers should consider including these elements, and even can select individual components that they believe are most appropriate for the athlete, regardless the sex or the sport.

References:

1. Affatato, S. (2015). *Surgical Techniques in Total Knee Arthroplasty and Alternative Procedures* (1st ed.). Woodhead Publishing. http://dx.doi.org/10.1533/9781782420385.1.3
2. Ardern, C. L., Glasgow, P., Schneiders, A., Witvrouw, E., Clarsen, B., Cools, A., Gojanovic, B., Griffin, S., Khan, K. M., Moksnes, H., Mutch, S. A., Phillips, N., Reurink, G., Sadler, R., Grävare Silbernagel, K., Thorborg, K., Wangensteen, A., Wilk, K. E., & Bizzini, M. (2016). 2016 Consensus statement on return to sport from the First World Congress in Sports Physical Therapy, *Bern. British Journal of Sports Medicine*, 50(14), 853-864. https://doi.org/10.1136/bjsports-2016-096278
3. Britt, E., Ouillette, R., Edmonds, E., Chambers, H., Johnson, K., Bastrom, T., & Pennock, A. (2020). The Challenges of Treating Female Soccer Players With ACL Injuries: Hamstring Versus Bone–Patellar Tendon–Bone Autograft. *Orthopaedic Journal of Sports Medicine,* 8(11), 232596712096488. https://doi.org/10.1177/2325967120964884
4. Dargo, L., Robinson, K. J., & Games, K. E. (2017). Prevention of Knee and Anterior Cruciate Ligament Injuries Through the Use of Neuromuscular and Proprioceptive Training: An Evidence-Based Review. *Journal of Athletic Training*, 52(12), 1171-1172. https://doi.org/10.4085/1062-6050-52.12.21

5. Davies, G. J., McCarty, E., Provencher, M., & Manske, R. C. (2017). ACL Return to Sport Guidelines and Criteria. *Current Reviews in Musculoskeletal Medicine*, 10(3), 307-314. https://doi.org/10.1007/s12178-017-9420-9
6. DeFroda, S. F., Patel, D. D., Milner, J., Yang, D. S., & Owens, B. D. (2021). Performance After Anterior Cruciate Ligament Reconstruction in National Basketball Association Players. *Orthopaedic Journal of Sports Medicine*, 9(2), 232596712098164. https://doi.org/10.1177/2325967120981649
7. Grassi, A., Macchiarola, L., Filippini, M., Lucidi, G. A., Della Villa, F., & Zaffagnini, S. (2020). Epidemiology of Anterior Cruciate Ligament Injury in Italian First Division Soccer Players. *Sports Health: A Multidisciplinary Approach*, 12(3), 279-288. https://doi.org/10.1177/1941738119885642
8. Herzog, M. M., Marshall, S. W., Lund, J. L., Pate, V., Mack, C. D., & Spang, J. T. (2018). Trends in Incidence of ACL Reconstruction and Concomitant Procedures Among Commercially Insured Individuals in the United States, 2002-2014. *Sports Health: A Multidisciplinary Approach*, 10(6), 523-531. https://doi.org/10.1177/1941738118803616
9. International Olympic Committee Pediatric ACL Injury Consensus Group, Ardern, C. L., Ekås, G., Grindem, H., Moksnes, H., Anderson, A. F., Chotel, F., Cohen, M., Forssblad, M., Ganley, T. J., Feller, J. A., Karlsson, J., Kocher, M. S., LaPrade, R. F., McNamee, M., Mandelbaum, B., Micheli, L., Mohtadi, N. G. H., Reider, B., … Engebretsen, L. (2018). 2018 International Olympic Committee Consensus Statement on Prevention, Diagnosis, and Management of Pediatric Anterior Cruciate Ligament Injuries. *Orthopaedic Journal of Sports Medicine*, 6(3), 232596711875995. https://doi.org/10.1177/2325967118759953
10. Kaeding, C. C., Léger-St-Jean, B., & Magnussen, R. A. (2017). Epidemiology and Diagnosis of Anterior Cruciate Ligament Injuries. *Clinics in Sports Medicine*, 1(36), 1-8. https://doi.org/10.1016/j.csm.2016.08.001
11. Kaeding, C. C., Pedroza, A. D., Reinke, E. K., Huston, L. J., MOON Consortium, Spindler, K. P., Amendola, A., Andrish, J. T., Brophy, R. H., Dunn, W. R., Flanigan, D., Hewett, T. E., Jones, M. H., Marx, R. G., Matava, M. J., McCarty, E. C., Parker, R. D., Wolcott, M., Wolf, B. R., & Wright, R. W. (2015). Risk Factors and Predictors of Subsequent ACL Injury in Either Knee After ACL Reconstruction: Prospective Analysis of 2488 Primary ACL Reconstructions From the MOON Cohort. *The American Journal of Sports Medicine*, 43(7), 1583-1590. https://doi.org/10.1177/0363546515578836
12. Kaplan, Y., & Witvrouw, E. (2019). When Is It Safe to Return to Sport After ACL Reconstruction? Reviewing the Criteria. *Sports Health: A Multidisciplinary Approach*, 11(4), 301-305. https://doi.org/10.1177/1941738119846502
13. Kobayashi, H., Kanamura, T., Koshida, S., Miyashita, K., Okado, T., Shimizu, T., & Yokoe, K. (2010). Mechanisms of the anterior cruciate ligament injury in sports activities: A twenty-year clinical research of 1,700 athletes. *Journal of Sports Science and Medicine*, 9(4), 669-675.

14. Lai, C. C. H., Ardern, C. L., Feller, J. A., & Webster, K. E. (2018). Eighty-three per cent of elite athletes return to preinjury sport after anterior cruciate ligament reconstruction: A systematic review with meta-analysis of return to sport rates, graft rupture rates and performance outcomes. *British Journal of Sports Medicine*, 52(2), 128-138. https://doi.org/10.1136/bjsports-2016-096836
15. Marieswaran, M., Jain, I., Garg, B., Sharma, V., & Kalyanasundaram, D. (2018). A Review on Biomechanics of Anterior Cruciate Ligament and Materials for Reconstruction. *Applied Bionics and Biomechanics*, 2018, 1-14. https://doi.org/10.1155/2018/4657824
16. Musahl, V., Karlsson, J., Kuroda, R., & Zaffagnini, S. (Eds.). (2017). Rotatory Knee Instability: An Evidence Based Approach. *Springer International Publishing*. https://doi.org/10.1007/978-3-319-32070-0
17. Parsons, J. L., Coen, S. E., & Bekker, S. (2021). Anterior cruciate ligament injury: Towards a gendered environmental approach. *British Journal of Sports Medicine*, 55(17), 984-990. https://doi.org/10.1136/bjsports-2020-103173
18. Paschos, N. K., & Howell, S. M. (2016). Anterior cruciate ligament reconstruction: Principles of treatment. *EFORT Open Reviews*, 1(11), 398-408. https://doi.org/10.1302/2058-5241.1.160032
19. Sandon, A., Krutsch, W., Alt, V., & Forssblad, M. (2021). Increased occurrence of ACL injuries for football players in teams changing coach and for players going to a higher division. *Knee Surgery, Sports Traumatology, Arthroscopy*. https://doi.org/10.1007/s00167-021-06604-w
20. Shaw, L., & Finch, C. (2017). Trends in Pediatric and Adolescent Anterior Cruciate Ligament Injuries in Victoria, Australia 2005–2015. *International Journal of Environmental Research and Public Health*, 14(6), 599. https://doi.org/10.3390/ijerph14060599
21. Sonnery-Cottet, B., & Colombet, P. (2016). Partial tears of the anterior cruciate ligament. *Orthopaedics & Traumatology: Surgery & Research*, 102(1), S59-S67. https://doi.org/10.1016/j.otsr.2015.06.032
22. Takahashi, S., Nagano, Y., Ito, W., Kido, Y., & Okuwaki, T. (2019). A retrospective study of mechanisms of anterior cruciate ligament injuries in high school basketball, handball, judo, soccer, and volleyball. *Medicine*, 98(26), e16030. https://doi.org/10.1097/MD.0000000000016030
23. Unverzagt, C., Andreyo, E., & Tompkins, J. (2021). ACL Return to Sport Testing: It's Time to Step up Our Game. *International Journal of Sports Physical Therapy*. https://doi.org/10.26603/001c.25463
24. Waldén, M., Hägglund, M., Magnusson, H., & Ekstrand, J. (2016). ACL injuries in men's professional football: A 15-year prospective study on time trends and return-to-play rates reveals only 65% of players still play at the top level 3 years after ACL rupture. *British Journal of Sports Medicine*, 50(12), 744-750. https://doi.org/10.1136/bjsports-2015-095952
25. Waldén, M., Krosshaug, T., Bjørneboe, J., Andersen, T. E., Faul, O., & Hägglund, M. (2015). Three distinct mechanisms predominate in non-

contact anterior cruciate ligament injuries in male professional football players: A systematic video analysis of 39 cases. *British Journal of Sports Medicine*, 49(22), 1452-1460. https://doi.org/10.1136/bjsports-2014-094573

26. Weitz, F. K., Sillanpää, P. J., & Mattila, V. M. (2020). The incidence of paediatric ACL injury is increasing in Finland. *Knee Surgery, Sports Traumatology, Arthroscopy*, 28(2), 363-368. https://doi.org/10.1007/s00167-019-05553-9
27. Werner, B. C., Yang, S., Looney, A. M., & Gwathmey, F. W. (2016). Trends in Pediatric and Adolescent Anterior Cruciate Ligament Injury and Reconstruction. *Journal of Pediatric Orthopaedics*, 36(5), 447-452. https://doi.org/10.1097/BPO.0000000000000482

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