Exploring relationship between ACL injuries and reaction time, hormonal changes, and environmental factors

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Abstract

In the United States, around 100,000 to 250,000 people experience ACL injuries annually, calling for major surgery and 9-12 months of recovery time. This results in less physical activity and difficulty in activities of daily living. In this review paper, we will discuss the relationship between ACL injuries and reaction time, hormonal changes, and environmental factors. This, as a result, will help us determine the severity of the impact of each factor on ACL tears. Furthermore, it provides us with a greater understanding of how performance is altered post-injury. Additionally, it is important to gain a greater knowledge of how baseline neural cognition and reaction time may relate to the risk of experiencing an ACL injury. It is important to understand the differences in injury risk between males and females, specifically the anatomy and growth rate paired with hormonal changes that could occur. Ultimately, this will develop our understanding of the after-effects of ACL injuries, such as post-traumatic osteoarthritis, and how future prevention programs may be altered to adapt to such scenarios.

Introduction

The anterior cruciate ligament (ACL) is a significantly important ligament within the body as it connects the femur to the tibia. This as a result prevents anterior translation of the tibia. However, there are some instances when the ACL may tear partially or completely. Within the United States, between an estimated 100,000 to 200,000 people sustain ACL related injuries annually, making this one of the most frequently occurring injuries (Larwa et al., 2021). Some consequences of this injury include expensive surgical treatment and time-consuming recovery process. Furthermore when first confronted with an ACL injury, the re-rupture rate of another ACL tear is 6-31% (Paterno, 2015). Furthermore ACL injuries may also provoke early osteoarthritis.

Furthermore, more necessary research is to be implemented within the anatomy of the ACL and how specific biomechanics can influence not only anterior cruciate ligament injury rates (ACL rates), but visuomotor reaction time (LEVMRT). Diving deeper, more research can also be done into the difference between noncontact vs contact injuries, hormonal cycles in men vs female and how it may impact LEVMRT, and also how environmental extrinsic factors such as turf style or even weather may impact the chance of ACL injury.

Ultimately, this paper will explore the relationship between ACL injury rates and its influence on reaction time on patients who have experienced the injury, but also how factors such as

hormonal difference which are sex specific and environmental factors in high risk activities may influence both ACL injury risk and also LEVMRT.

Literature Review

The Anatomy and Mechanism of Anterior Cruciate Ligament tears

The Anterior Cruciate Ligament (ACL) originates on the femur and inserts into the tibia bone (Figure 1 (Cimino & Volk, 2010)). These ligaments are made out of a highly organized collagen matrix. To break the ligament down further, it can be broken into two sections: the anteromedial and the posterolateral bundles. The cruciate ligament joins are connected to the tibia and the femur, and are crucial to the knee joint. Both posterior and anterior cruciate ligaments work to prevent over-anteroposterior positioning of the tibia to the femur. Against anterior displacement, the ACL is the main stabilizer. Regarding a more in depth explanation of when the ACL may be most stiff, the anteromedial bundle is most stiff when it is at 90 degrees of flexion, while the posterolateral bundle is most stiff at full extension of the knee. (Markatos et al., 2013)

Compressing the ACL against the medial border of an intercondylar notch is often seen as a significant influence on ACL injury risk (Boden et al., 2013; Shimokochi & Shultz, 2008). Research has found that quadriceps force is the greatest when nearing full extension, causing ACL injury (Boden et al., 2013). However, simultaneous hamstring activation is seen as a protection mechanism for the ACL (Boden et al., 2013).

Adding more weight to the knee during a change from being weight-free to carrying some form of weight results in anterior movement of the tibia. While in the provocative position, where the body and limb aligns to increase the risk of a non-contact ACL injury, the tibia slope to the femur was more vertical, the lateral compartment’s point which experienced force was closer to the sulcus point on the lateral femoral condyle. Lastly, the lateral femoral condyle became closer to the tibia plateau on the anterior over the posterior surface. Ultimately, this shows that the ACL is more in danger to ACL injuries while in a provocative position. (Boden et al., 2013)

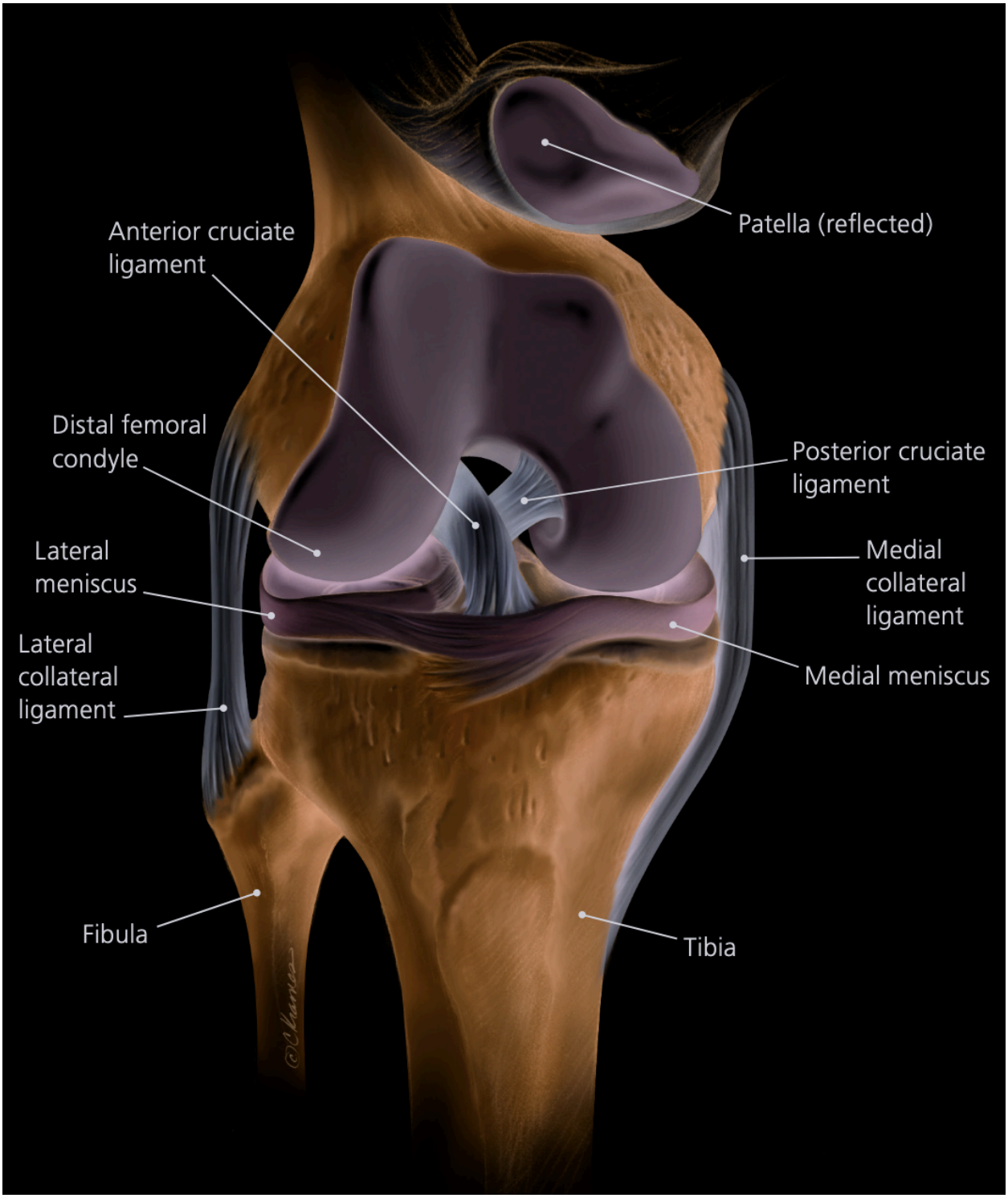

Figure 1. Anatomy of the ACL (Cimino and Volk, 2010)

Impact of environmental factors on ACL tear

In terms of the environmental factors which were most correlated to an ACL injury that was shown by numerous logistic regression, 5 prevailed: fresh and grippy snow, icy slope conditions, freezing temperatures, and lastly skiing on easier than normal slopes. Ultimately, aside from age, these were the main environmental factors which were determined to be the most predictive and correlated to a future ACL injury (Posch et al., 2023).

There was a relationship between weathers with low rainfall and then high evaporation and noncontact ACL injury. Australian football players were used to examine the risk factors for 12 months. Among the risk factors, weather proved to be one of the strongest risk factors. However other slightly less influential risk factors included previous ACL injury. (Orchard et al., 2001).

Females had a higher chance of receiving an ACL injury on artificial turfs in soccer compared to natural grass fields, while males had no difference. This correlation did not last for training sessions, it only occurred for games. In training sessions there was no difference in injury risk on artificial turfs versus natural grass turfs. (Xiao et al., 2022).

Relationship between reaction time and ACL tears

Generally as records have shown, noncontact ACL injuries are relatively proportional to a slower reaction time, though the information between contact ACL injury and reaction time is lacking. Those with contact ACL injuries portrayed a slower LEVMRT when their ACL was stabilizing. Group differences with the stable ACL reaction time task portray disturbances in the perceptual function when the tissue remains in a postural control during a LEVMRT task. After an ACLR, some with contact ACL injuries might require additional learning training programs related to motor movement to improve perceptual-motor performance. Those with a contact related ACL injury portrayed a decreased LEVMRT in the during that the ACLR limb was rehabilitating. The differences between the groups during the ACLR stable LEVMRT do indicate deficiencies within the motor function while a surgical limb remains at postural control for a reaction timed activity which they have been presented with. Two years was a normal point of interest to interpret a successful return to an activity and clinical results after an ACLR. In fact, the contact group often demonstrated a lower LEVMRT over the non contact ACL injury group while the surgical limb was rehabilitating. The action of anticipating or to carry out a rapid motor related response while the limb is not in movement can often create uncertainty within tasks, being unable to prevent a collision between the individual and another person/thing, lowered reaction time of recognition

within stimuli, or even a selection of an improper reaction of a motor response to a specific scenario. (Reiche et al., 2024)

Usually, an ACL tear is correlated with lowered performance after returning to sports post injury, including increased rates of re-injuring the ligament. Despite construction, ACL tears include neuroplasticity, which ultimately increases the reliance on vision and as well as preparation time in movements. As a result, this increased dependence on vision and LEVMRT leads to motor control deficiencies, especially within high risk sports. No matter the condition, FS was on average faster, however the ACLR group demonstrated a lowered ability to slow a muscle onset when asked to stop an activity in the FS in order to activate an infrequent step. Still, there is no prominent disparity between the groups even regardless of preparation time. Ultimately, the results imply that deficient motor control skills post injury and a lower LEVMRT may increase the rate of re-injuring the ligament through muscle onset. (Lu et al., n.d.)

Correlation between Gender / Hormonal Changes and ACL tears

When compared to males, females are at an inclined chance of ACL injury. This is because of intrinsic disparities including increased quadriceps angle as well as an elevated posterior tibial slope. Although they have a lower chance of injury, males experience ACL reconstruction procedures more often. There is conflicted evidence that regards gender disparities in failure and ACL rehabilitation rates, however males ultimately portray a higher chance to return to the original sport or a sport they were playing. Females in turn show lower functional results and ultimately have lowered biomechanical metrics following an ACL reconstruction procedure. Ultimately, the evidence results as inconclusive. (Devana et al., 2022)

There were many classifications for the factors which influenced risks, such as anatomic, environmental, hormonal, and biomechanical. Neuromuscular traits seem to be the most significant in females. The biggest situations for noncontact injuries are most often by deceleration or rapidly changing a direction of travel, and also landing too hard. Before an injury, a change in body motion can also be seen, where quad activation is a major factor pre-injury (“The Female ACL,” 2016)

Males injure their ACL’s much more than females who are within similar situations such as the same sport. The disparity in rates is most probably due to multifactorial reasons. Due to an increased level of susceptibility to getting hurt, females are at a higher chance of risk for knee laxity, rupture, and more when compared to males. While many other individuals and research paper composers have demonstrated that the ultimate result of rehabilitation in men and women are both similar. Women have portrayed a higher level of laxity after multiple forms of

reconstruction such as hamstring and bone patellar tendon bone reconstructions. An explanation which could work can lay in ligament remodeling. (Slauterbeck et al., n.d.)

ACL Tear Prevention Strategies

Multifactorial prevention programs are most usually seen as effective within the purpose of dropping the incidence of the injury for both males and females alike. Furthermore, programs should ultimately utilize a fusion of strength, stretch, aerobic, and plyometric training as well as balance training as well to most efficiently utilize and maximize the effects of rehabilitation. Education and feedback on proper landing technique as well as further causes of ACL injury would also be beneficial to rehabilitation. Prevention programs should also be put into effect 6 weeks before a major event or prior to a season for maximum efficiency. Prevention programs with multifaceted parts such as all of the components listed previously have been seen as effective when combatting the increased risk of ACL injury for both mena an women alike. (Acevedo et al., 2014)

There is however questionable debate about the type of ACL injury prevention strategy that is most effective, as well as if this technique applies differently to different age groups. In one, ACL injury prevention strategies do have a considerable effect on all athletes based on metadata analysis, however no ultimate prevention training strategy proved to be superior over another. (Clar et al., 2025) Other papers however include that different age demographics may experience a higher level of prevention likelihood, as high school students are more likely to avoid an ACL related injury over a college student/athlete. Throughout all ages, though, the meta analysis determined that ACL NMT (Anterior Cruciate Ligament Neuromuscular Training) is most effective as acting prevention training strategies, as well as trained implementers that specifically use exercises targeted towards lower body strength training, with emphasis on exercises that include practicing landing from a jump. (Petushek et al., 2019). However most prevention programs are put into effect around 6 weeks before a major game or event is to take place. As research shows, the 11+ warmup method can utilize the same NMT targeted program however in the form of a warmup, ultimately anticipation, decision making and a call to action in order to utilize cognitive factors as a form of training. As a result, the 11+ warmup method provides not simply a physical warmup, however a neurocognitive and ecological preparation before a game takes place, improving bodily durability which would prevent ACL tears however potentially improve athletic performance. (Grooms et al., 2024)

Discussion

The ultimate function of the paper is to demonstrate that ACL injuries can be triggered through anatomical, environmental, cognitive, and hormonal factors. Although it has a clear mechanical purpose in buttressing the joint to prevent anterior movement of the tibia, it is still vulnerable to damage. This review specifically dives into how reaction time, hormonal changes, and environmental factors can influence the chance of ACL injury.

The role of LEVMRT and cognitive processing in ACL injury is one of most importance. Athletes with compromised motor control after the injury show lack of rapid response and also cognitive ability in decision making. This as a result could elongate the rehabilitation process and also increase the chance of another ACL related injury. The data points to the finding that ACL recovery is not simply within muscles however requires neuroplastic changes which impact cognitive functions. Therefore programs which include a neurological approach would seem to be more effective than typical programs.

Furthermore another important discovery lies within hormonal differences of men and women. While males have a lowered sense of vulnerability because of anatomical and neuromuscular disparities, long term outcomes do not contain sufficient evidence to conclude with one final reason. Furthermore studies can point to worsened functional achievement after reconstruction within women, while other studies point to the opposite. The evidence points to the suggestion that rehabilitation strategies might need to incorporate gender specific techniques in order to target the disparities in hormonal influences on the ligament.

Furthermore the paper discusses the significance of extrinsic factors. Playing surfaces such as grass or concrete to weather can take drastic impacts in influencing ACL injury chances. Cold environments can reduce hamstring activation, which is a prevention mechanism of getting ACL injuries. This finding stresses the importance of warming up before an activity for muscular and cognitive preparation, especially in sports related activities.

Ultimately the most effective way to approach rehabilitation is to use multifactorial training programs. While it is not determined what type of multifactorial training program approach may be most effective, there is evidence that points to high school athletes being more responsive to rehabilitation and greater protective yields through multifactorial training rehabilitation programs.

Limitations of the Current Literature

Although rehabilitation remains seemingly prosperous, there are limits. Much of the evidence for hormonal impacts of ACL injury in contrast means there is a lack of research within the field of long term effects. Adding on, LEVMRT deficiency is associated with higher chance of ACL injury however the specific cause for the injury does not have a clear correlation. Lastly extrinsic

factors are heavily dependent on sports related injuries, not a general application of ACL injuries as a whole.

Future Directions

Future research should continue to investigate neurocognitive factors in ACL risk and recovery, particularly how training interventions targeting LEVMRT might reduce reinjury rates. Additionally, further exploration of hormonal influences on ligament laxity across different phases of the menstrual cycle may allow for more individualized prevention programs for female athletes. Lastly, ecological validity in prevention research should be prioritized, ensuring that training protocols are tested under realistic game and practice conditions.

In the future research should be focused on how cognitive abilities can further impact recovery and how targeting reaction time can reduce the chance of getting injured once again. Furthermore hormonal influences should be studied within a menstrual cycle to determine how to target rehabilitation towards female individuals. Furthermore there should be research into determining how environmental scenarios can be applied to all fields beyond sport dependent factors.

Conclusion

Ultimately, all aspects of ACL injury cannot be understood and combined into one aspect but they need to be separated into multiple different components. By understanding all aspects and all areas of complexion we are able to truly understand the depth of ACL injury and how to better improve ACL injury rehabilitation.

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