Mild Traumatic Brain Injuries as a Possible Risk Factor for Anterior Cruciate Ligament Tears in Female High School and College Athletes

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Abstract

Tears in the Anterior Cruciate Ligament (ACL) and mild traumatic brain injuries (concussions) are among two of the most common and most career-ending sports medicine-related injuries. The ACL is a ligament detrimental in stabilization to the knee joint. It can be torn suddenly if it undergoes a quick twisting or cutting motion during play and often needs to be treated with surgical repair, physical therapy, and months of rest. Concussions occur after an individual sustains a blow to the head. Management of concussions typically requires brain rest from sports, electronics, lights, and sometimes academics. While many risk factors for ACL tears are non-modifiable, recent research has suggested that following concussion return-to-play guidelines could be a modifiable risk factor. This review aims to look at the relationship between these two very common injuries as an approach to practice proactive and patient-centric medicine.

Introduction

Tears to the ACL

Overview

- Most common in adolescent female athletes who participate in sports with quick cutting movements
- ACL is responsible for stabilization within the knee joint and functions properly with communication from afferent and efferent nerves, and proprioceptive receptors. Proper neurocognition is fundamental in joint stability.
- ACL tears can result in many early-onset chronic musculoskeletal conditions

Symptoms

- Pain, swelling, difficulty ambulating, and an audible "popping" noise at the time of injury
- Often present with other complications, such as tibial fractures, subluxation of the knee joint, or meniscal tears

Treatment

- Typically requires surgical repair, physical therapy, pain management, and rest
- The average recovery time is 9 months long before an athlete is cleared to play again
- Athletes are at risk for sustaining a second ACL tear after their first

Methods

Literature Search

- Performed in September 2018 and November 2018 using
  - PubMed
  - Google Scholar
  - Clinical Key
- Articles were selected based on their relevance to the question, their methods for conducting the study, and their results
- Exclusion Criteria that were used outside of relevance to concussions as a risk factor for ACL tears
  - Studies involving a clinical trial with animals
  - Studies that involved professional athletes
  - Studies that involved recreational athletes

Results

1. Diekfuss J, Grooms D, Yuan W et al. Does brain functional connectivity contribute to musculoskeletal injury? A preliminary prospective analysis of a neural biomarker of ACL injury risk. *J Sci Med Sport*. 2018. doi:10.1016/j.jsams.2018.07.004

- Longitudinal study of 57 females ages 15-17 that used preseason baseline MRI imaging to study regions of interest in the brain in those who sustained ACL tears during the high school sports season.

2. Gilbert, F., Burdette, G., Joyner, A., Llewellyn, T. and Buckley, T. (2016). Association Between Concussion and Lower Extremity Injuries in Collegiate Athletes. *Sports Health: A Multidisciplinary Approach*, 8(6), pp.561-567.

- Cross-sectional study of 335 college athletes who filled out a questionnaire regarding injury history with a hopes to find a correlation between ACL tears and concussions.

3. Grooms D, Page S, Onate J. Brain Activation for Knee Movement Measured Days Before Second Anterior Cruciate Ligament Injury: Neuroimaging in Musculoskeletal Medicine. *J Athl Train*. 2015;50(10):1005-1010. doi:10.4085/1062605050.10.02

- A study that compared brain activation of a 25 year old college football player with an ACL tear to the brain activation of a control using MRI imaging

4. Herman D, Barth J. Drop-Jump Landing Varies With Baseline Neurocognition. *Am J Sports Med*. 2016;44(9):2347-2353. doi:10.1177/0363546516657338

- A controlled laboratory study that quantifies data to analyze the relationship between jump-landing performances to concussion resolution index scores in 37 high school and college athletes

5. Herman D, Jones D, Harrison A et al. Concussion May Increase the Risk of Subsequent Lower Extremity Musculoskeletal Injury in Collegiate Athletes. *Sports Medicine*. 2016;47(5):1003-1010. doi:10.1007/s40279-016-0607-9

- An observational cohort study with 73 division 1 college athletes that determines a "window of susceptibility" where athletes are at risk of experiencing a lower extremity injury after a recent concussion.

6. Lapointe, A., Nolasco, L., Sosnowski, A., Andrews, E., Martini, D., Palmieri-Smith, R., Gates, D. and Broglio, S. (2018). Kinematic differences during a jump cut maneuver between individuals with and without a concussion history. *International Journal of Psychophysiology*, 132, pp.93-98.

- A controlled laboratory study that compares jump-cut movements between 9 previously concussed varsity athletes to 10 varsity athlete controls

7. Lynall R, Mauntel T, Padua D, Mihalik J. Acute Lower Extremity Injury Rates Increase after Concussion in College Athletes. *Medicine & Science in Sports & Exercise*. 2015;47(12):2487-2492. doi:10.1249/mss.0000000000000716

- An observational historical cohort study that compared 44 previously concussed NCAA Division 1 athletes with controls to compare the rates of lower extremity injuries among the two.

Table 1. Comparison of Study Designs: Presence of Mild TBI vs. Absence of Mild TBI

Study	Design	Total N	Population Demographics	Duration of Study	Control	Lower Extremity Injuries Observed	Outcome Measures
Diekfuss J., Grooms D., Yuan W., et al.	LS	57 high school soccer players	Female: 100% Age: High school Sports Played: 100% soccer	1 competitive high school soccer season	8 Athletes with no hx of ACL tears	ACL Injury	NCF, FC, ACLI
Gilbert F., Burette G., Joyner A., et al.	CSS	335 NCAA Division I Athletes	Female: 62.1% Male: 37.9% Mean Age: 21.2 y/o Sports Played: 94 soccer	NA: 21-item questionnaire was used	Those with no hx of concussion	Lateral Ankle Sprains, Knee Injury, and muscle strain	C-LAS, C-KI, C-LEMS, U-KI, U-LAS, U-LEMS
Herman D., and Barth J.	CLS	37 recreational athletes from University of Virginia	Age: 18-30 y/o HP: 20 LP: 17	NA	HP Athletes	ACL Injury	CRI, SRT, CRT, PS, JLP
Herman D., Jones D., Harrison A., et al.	OHC	73 NCAA Division 1 athletes exposed to concussions from University of Florida	Exposed: -52 Males -21 Females Unexposed: -82 Males -34 Females	90 days	116 Unexposed to concussion	Any Lower Extremity MSK Injury	Lower Extremity MSK Injuries
Lapointe A., Nolasco L., Sosnowski A., et al.	CLS	9 Previously concussed high school varsity athletes	Age: 18-26 y/o	NA	10 non-concussed: 6 Male and 4 Female	Knee Injury/Alteration	COM, JLP, Knee Varus, Knee External Rotation, Knee Flexion
Lynall R., Mauntel T., Padua D., et al.	OHC	44 NCAA Division I athletes exposed to concussions	Mean Age: 20.0 Male: 28 Female: 16	2 years	58 Athletes without concussions	Lower Extremity MSK sprains, strains, contusions, and fractures	Lower Extremity MSK Injuries 90, 180, and 365 days after concussion

Discussion

7/7 studies support the idea that a decline in neurocognitive function, which would result from a concussion, leads to a higher incidence of ACL tears or lower extremity injuries

Strengths

- 7/7 studies report statistical significance of a relationship between changes in neurocognition and lower extremity injuries with $p < 0.05$
- All studies display findings significant enough to further future research

Weaknesses

- 2 of the 7 studies did not show statistical significance for a relationship between concussions and ACL tears
- All but 1 study had sample sizes of less than 100 participants
- Bias and blinding unavoidable as participants were self-reporting concussion history

Future Research

- Focuses on a time frame post-concussion that athletes are susceptible to lower extremity injuries even if asymptomatic
- Studies to recruit larger population sizes
- Focuses on a relationship specifically between concussions and ACL tears to help clinicians better enforce return-to-play guidelines to patients.

Conclusion

The results of all of the studies are positive, indicating that a decline in neurocognitive function may be a risk factor for lower extremity injuries; however, more research is needed to definitively state that concussions are a risk factor for ACL tears in female high school and college athletes.

The current research is more than sufficient to support further studies with larger sample sizes to this topic. Sports are detrimentally important to the physical and mental well-being of athletes and modern day society. Clinicians are not providing the best care to their patients if they do not further explore preventative medicine.

Overall, current research is not sufficient to change clinical practice, but important enough to continue exploring. Future research supporting a link between concussions and ACL tears in high school and college female athletes could result in stricture return-to-play guideline adherence.

Table 1 Note:
Study: TBI = Traumatic Brain Injury, LS = Longitudinal Study, CSS = Cross Sectional Study, CLS = Controlled Laboratory Study, OHC = Observational Historical Cohort Study
General: NA = Results not Applicable, HP = High Neurocognitive Performance, LP = Lower Neurocognitive Performance, MSK = Musculoskeletal
Outcome Measures: NCF = Neurocognitive Functioning, FC= Functional Connectivity, ACLI = ACL Injury, C-LAS = Concussion & Lateral Ankle Sprain, C-KI = Concussion & Knee Injury, C-LEMS = Concussion & Lower Extremity Muscle Strain, U-KI = Unrecognized Concussions & Knee Injury, U-LAS = Unrecognized Concussions & Lateral Ankle Sprain, U-LEMS = Unrecognized Concussion & Lower Extremity Muscle Strain, CRI = concussion resolution index, SRT = Simple Reaction Time, CRT = Complex Reaction Time, PS = Processing Time, JLP = Jump-Landing Performance, COM = Center of Mass