Journal of Athletic Training 2010;45(5):516–518

www.nata.org/jat

Recommendations for Defining and Classifying Anterior Cruciate Ligament Injuries in Epidemiologic Studies

Stephen W. Marshall, PhD

Departments of Epidemiology, Gillings School of Global Public Health; Exercise and Sport Science, College of Arts & Sciences; and Orthopaedics, School of Medicine, University of North Carolina at Chapel Hill

The purpose of this article is to discuss the current knowledge on the etiology of anterior cruciate ligament (ACL) injury, particularly with regard to definition and classification of contact and noncontact injuries. In 2008, Scott McLean presented a keynote presentation at ACL Research Retreat IV entitled "The ACL Injury Enigma: We Can't Prevent What We Don't Understand."[1] Dr McLean's commentary addressed modifiable neuromuscular ACL risk factors, particularly the need to accelerate the exchange between the laboratory and the sports field (arguably still our most pressing area).

Today, I believe his words resonate in a deeper sense than possibly he ever intended. To our detriment, we have invested 2 decades and millions of dollars in research into the problem of noncontact ACL injury without defining in clear and unambiguous language what we mean by *noncontact ACL injury*. Although this research effort has clearly been far from wasted, I predict future investigations would benefit from a more focused and detailed description of the causes of ACL injury.

THE LITERATURE LACKS A CLEAR DEFINITION OF *NONCONTACT*

Authors[2–6] of a number of articles have presented injury-event details based on video or biomechanical reconstructions of the event. However, none of the case-series articles[2–6] have provided clear conceptual criteria that allow one to define in precise operational terms what is meant by "noncontact" ACL injury. As a result, no clear definition or consensus about the meaning of the term *noncontact* exists.[7]

Based on these articles, the typical scenario for noncontact ACL injury can be summarized as follows: No large external force was applied directly to knee (eg, no direct blow to the knee from an opponent or object, including the ground); the patient may have been cutting and planting while running or landing from a jump. The leg is often near full extension, and sometimes contact with another player appears to knock the patient off balance or otherwise disrupts the motor-control pattern (ie, a physical perturbation). Sometimes the perturbation is cognitive or mental rather than physical: that is, an opponent blocks the patient's intended path of movement, and the patient needs to rapidly adjust his or her planned course of movement.

NEGATIVE CONSEQUENCES OF THE ABSENCE OF A CLEAR DEFINITION OF *NONCONTACT*

The lack of clear definition of the term *noncontact* is a major methodologic limitation of the current literature. I will present 2 examples of how of this limits research.

Investigators interested in examining in detail the sex differences in ACL injury incidence have long relied on data from the National Collegiate Athletic Association (NCAA) Injury Surveillance System. The sex difference in ACL injury incidence was first identified using data from this source[8,9] and, more recently, it has been used to examine long-term trends in ACL injury incidence.[10,11] However, before the 2004–2005 academic year, this source provided no standardized definition of *noncontact*. It was left to individual athletic trainers to interpret the meaning of this term as they wished. As a result, the interpretation of differences in noncontact ACL injury rates, especially over time, is problematic. This limitation has also been discussed in a broader context by Krosshaug et al.[7]

Another example occurs when one attempts to compare results from different studies. In the area of ACL intervention studies, Gilchrist et al[12(p1478)] conducted a randomized trial of an intervention program in 61 NCAA female soccer teams and found a positive effect. They used these definitions: "A *contact injury* was defined as an ACL injury sustained as a result of direct contact to the knee or another body part by another player or object during the course of play. A *noncontact injury* was defined as an ACL injury sustained by an athlete without extrinsic contact by another player or object on the field." It is clear that any player contact, regardless of the body region, was classified as contact.

However, Pfeiffer et al,[13(p1771)] studying a nonrandomized high school population, defined *contact* as "direct contact of the player's knee region with an opponent or another form of collision, such as with an inanimate object." Thus, they included "indirect contact" injuries—injuries resulting from player contact—so long as the contact was not directly to the knee. Pfeiffer et al[13] found no effect of their program. Given the small number of endpoints observed in these studies (12 in Gilchrist et al[12] and 6 in Pfeiffer et al[13]), it appears the exclusion or inclusion of a just a few cases can have a major effect on the study results and possibly explains in part the

discrepant findings (although we should note other major differences between the studies in terms of design and methods).

A CLASSIFICATION SYSTEM FOR CONTACT

In connection with the Joint Undertaking to Monitor and Prevent ACL Injury (JUMP-ACL) study,[14] we have accumulated a series of 75 incident ACL injuries to date (injuries are still accumulating as follow-up of the cohort continues). For the purposes of the study, we defined an *ACL injury* to be either surgical reconstruction to repair a torn or ruptured ACL or nonsurgical (conservative) management of a torn or ruptured ACL, as confirmed by magnetic resonance imaging and clinical examination of the knee. All 75 injuries are in participants who had no previous history of surgical reconstruction for ACL injury at the time they entered the study. Patient narratives are collected as part of a standardized injury questionnaire that is administered to all participants after the incident ACL injury. Based on patient narratives from our population-based sample, we have grouped the type of contact into 4 subtypes: direct contact (DC), indirect contact (IC), classic noncontact (CNC), and other noncontact (ONC). When pooled, the 3 subgroups of IC, CNC, and ONC form a relatively homogeneous set of events that we refer to as noncontact/indirect contact (NCIC). The NCIC group corresponds approximately to the type of injuries loosely described as ''noncontact'' in most of the literature. The next 3 paragraphs discuss the 4 subtypes (DC, IC, CNC, and ONC) and how they are defined.

The distinguishing feature of DC injuries is that the knee joint, or a region of the femur proximal to the knee or the tibia distal to the knee, is struck forcefully. Contact to the knee is identified as the cause of injury. An example of a patient narrative reporting a DC injury is ''My opponent kicked the inside of my knee and it torqued outwards. I heard and felt audible pops.''

The distinguishing feature of IC injuries is a physical perturbation. The knee is *not* struck directly with force. Instead, the injury results from the athlete's own movements. However, his or her movements are disturbed by a physical perturbation at the time of or immediately before the injury event. Physical perturbations can be contact with an opposing player (but without major direct force to the knee) or a high-energy fall or crash (without opponent contact). An example of a patient narrative reporting an IC injury is ''I attacked for the shot, planted my left leg, was pushed by a defender, and hyperextended my knee and heard a pop.''

The CNC and ONC injuries are defined by a different type of perturbation: a disruption to the planned motor task that requires a rapid update to the intended motor-control plan. Typically, an opponent unexpectedly materializes in a new position and poses a new challenge. This perturbation is not physical, and therefore we term it a *cognitive perturbation*. As with IC, the knee is not struck directly with force, and the injury results from the athlete's own movements. The CNC and ONC categories include situations involving unanticipated ground contact and medium-energy falls. The distinction between these subtypes is that a CNC injury occurs during sport activities (such as basketball) or activities that resemble sports activities (such as practicing a dunk in a gym), whereas an ONC injury occurs during nonsport activities, such as walking or working in the yard. An example of a patient narrative reporting a CNC injury is ''As I was sprinting forward toward the front wall, I planted my knee hard and it buckled and I collapsed.'' An example of a patient narrative reporting an ONC injury is ''I was in a tree working on a fence. To get down, I simply slid from where I was sitting and fell about a foot to the ground. When I hit the ground, I heard and felt a pop.''

Patient narratives are an imperfect source of injury-event data because they depend on accurate recall of events that occur rapidly.[7] We believe that the information obtained in the JUMP-ACL study is sufficiently accurate to permit development of the classification system outlined above. However, replication and refinement by other researchers is needed.

CONCLUSIONS

This article presents a method for clearly defining noncontact (or NCIC) ACL injuries. The defining features of the NCIC injury are that it results from the athlete's own movements, which typically are disturbed by a physical or cognitive perturbation either during or immediately before the injury event. In the interests of greater clarity, I encourage use of the term *noncontact/indirect contact*, or NCIC, instead of *noncontact*. I recommend that future researchers, injury surveillance systems, and clinic-based registries of ACL injury begin to use the injury-contact classification system presented in this article.

ACKNOWLEDGMENTS

This project was supported by grant 5RO1 AR050461 from the National Institute of Arthritis and Musculoskeletal and Skin Diseases. Funds for the pilot study were provided by the American Orthopaedic Society for Sports Medicine.

REFERENCES

1. McLean S. The ACL injury enigma: we can't prevent what we don't understand. *J Athl Train*. 2008;43(5):538–540.
2. Boden BP, Dean GS, Feagin JA Jr, Garrett WE Jr. Mechanisms of anterior cruciate ligament injury. *Orthopedics*. 2000;23(6):573–578.
3. Krosshaug T, Slauterbeck JR, Engebretsen L, Bahr R. Biomechanical analysis of anterior cruciate ligament injury mechanisms: three-dimensional motion reconstruction from video sequences. *Scand J Med Sci Sports*. 2007;17(5):508–519.
4. Krosshaug T, Nakamae A, Boden BP, et al. Mechanisms of anterior cruciate ligament injury in basketball: video analysis of 39 cases. *Am J Sports Med*. 2007;35(3):359–367.
5. Hewett TE, Torg JS, Boden BP. Video analysis of trunk and knee motion during non-contact anterior cruciate ligament injury in female athletes: lateral trunk and knee abduction motion are combined components of the injury mechanism. *Br J Sports Med*. 2009;43(6):417–422.
6. Boden BP, Torg JS, Knowles SB, Hewett TE. Video analysis of anterior cruciate ligament injury: abnormalities in hip and ankle kinematics. *Am J Sports Med*. 2009;37(2):252–259.
7. Krosshaug T, Andersen TE, Olsen OE, Myklebust G, Bahr R. Research approaches to describe the mechanisms of injuries in sport: limitations and possibilities. *Br J Sports Med*. 2005;39(6):330–339.
8. Arendt E, Dick R. Knee injury patterns among men and women in collegiate basketball and soccer: NCAA data and review of literature. *Am J Sports Med*. 1995;23(6):694–701.
9. Arendt EA, Agel J, Dick R. Anterior cruciate ligament injury patterns among collegiate men and women. *J Athl Train*. 1999;34(2):86–92.

10. Mihata LC, Beutler AI, Boden BP. Comparing the incidence of anterior cruciate ligament injury in collegiate lacrosse, soccer, and basketball players: implications for anterior cruciate ligament mechanism and prevention. *Am J Sports Med*. 2006;34(6):899–904.
11. Agel J, Arendt EA, Bershadsky B. Anterior cruciate ligament injury in National Collegiate Athletic Association basketball and soccer: a 13-year review. *Am J Sports Med*. 2005;33(4):524–530.
12. Gilchrist J, Mandelbaum BR, Melancon H, et al. A randomized controlled trial to prevent noncontact anterior cruciate ligament injury in female collegiate soccer players. *Am J Sports Med*. 2008;36(8):1476–1483.
13. Pfeiffer RP, Shea KG, Roberts D, Grandstrand S, Bond L. Lack of effect of a knee ligament injury prevention program on the incidence of noncontact anterior cruciate ligament injury. *J Bone Joint Surg Am*. 2006;88(8):1769–1774.
14. Beutler AI, de la Motte SJ, Marshall SW, Padua DA, Boden BP. Muscle strength and qualitative jump-landing differences in male and female military cadets: the JUMP-ACL study. *J Sports Sci Med*. 2009;8(4):663–671.

Editor's note: Stephen W. Marshall, PhD, is an associate professor in the Departments of Epidemiology and Orthopedics and an adjunct associate professor in the Department of Exercise and Sport Science, University of North Carolina at Chapel Hill. He is also a JAT *Statistical Consultant.*

Address correspondence to Stephen W. Marshall, PhD, CB#7435, Department of Epidemiology, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-7435. Address e-mail to SMarshall@unc.edu.