

# TIME FOR A PARADIGM SHIFT IN CONCEPTUALIZING RISK FACTORS IN SPORTS INJURY RESEARCH

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Certified athletic trainers are positioned to play an integral role in sport-related, recreation-related, and exercise-related injury research and prevention efforts. The Centers for Disease Control and Prevention<sup>1</sup> have specifically identified certified athletic trainers and their potential to contribute to this important area of research in their recently published *Injury Research Agenda* for 2009–2018. From a public health perspective, identifying factors associated with injury is one of the initial steps in the injury prevention process. The ultimate goal of this line of research is to identify populations that are at greatest risk for subsequent injury and to develop effective screening and intervention strategies to reduce the incidence and burden of injury. Therefore, the manner in which risk factors are conceptualized in initial research has significant bearing on the development of subsequent screening and intervention strategies.

In the current issue of the *Journal of Athletic Training*, Reinking et al<sup>2</sup> examined the factors associated with exercise-related leg pain in high school cross-country athletes. After a discussion of modifiable and nonmodifiable risk factors, the authors conceptualized risk factors for exertional leg pain as intrinsic (within the body) or extrinsic (outside the body) factors; sports injury researchers have traditionally conceptualized risk factors associated with injury in this manner.<sup>3–5</sup> This study provides an opportunity to discuss how risk factors are conceptualized in the context of sports injury research. The seminal work by sports injury researchers such as van Mechelen et al<sup>3</sup> and Meeuwisse<sup>5</sup> provided a theoretic framework for sports injury research, and although these models have evolved since they were first described,<sup>6–9</sup> they have consistently characterized risk factors for injury as *intrinsic factors* and *extrinsic factors*. It is important to consider that injuries often result from the complex interaction of multiple factors<sup>3,7,10</sup> in a dynamically changing environment,<sup>6</sup> but the characterization of risk factors as intrinsic or extrinsic limits the clinical importance and usefulness of results in relation to future injury screening and prevention efforts. More importantly, characterizing risk factors in this manner provides limited insight into whether something can be done to intervene and mitigate the contributing influence of any given factor or combination of factors with regard to subsequent injury.<sup>11</sup> Injury epidemiologists and public health professionals, on the other hand,

use a different approach to conceptualizing risk factors for disease or injury by focusing on those risk factors that are modifiable and those that are nonmodifiable.

Conceptualizing risk factors as *modifiable* and *nonmodifiable* is important from a clinical and injury prevention perspective, because modifiable risk factors are amenable to intervention.<sup>11</sup> Researchers<sup>12,13</sup> of chronic diseases, such as cardiovascular disease, hypertension, and type 2 diabetes, have conceptualized risk factors as modifiable and nonmodifiable. Some of these risk factors include physical activity, diet, smoking, and obesity, to name a few. Subsequent intervention efforts have been developed and evaluated to address these factors, with various degrees of success. Conceptualizing risk factors as modifiable and nonmodifiable aligns with the “Translating Research into Injury Prevention Practice (TRIPP)” framework described by Finch,<sup>9</sup> which applies a public health approach to sports injury prevention.

Clinicians and injury researchers are most interested in modifiable risk factors associated with injury because they provide the vector for developing injury prevention interventions. Although nonmodifiable risk factors may not be useful as targets for intervention, they are particularly important in identifying populations that are at greatest risk for injury, so that injury prevention strategies can be directed to those with the most pressing need. This information can be used to develop risk profiles for specific injuries, to screen athletes to identify those at greatest risk for injury, and to guide injury prevention interventions that target modifiable risk factors. This information can also be used to develop interventions and social marketing campaigns that are culturally and ecologically appropriate for the populations at greatest risk for injury.<sup>14</sup> When only nonmodifiable risk factors associated with injury are known, this information can be used to counsel athletes and parents about potential risks during the preparticipation screening process, so they can make informed decisions about participation.

Recently, researchers have conceptualized risk factors as modifiable and nonmodifiable in the sports medicine literature. Emerging research<sup>10,15–17</sup> into the risk factors associated with anterior cruciate ligament (ACL) injuries is one of the best examples in the sports medicine literature of how the conceptualization of risk factors has evolved. Early work<sup>15</sup> in this area conceptualized risk factors as *intrinsic* and *extrinsic*, while recognizing the importance of focusing on factors that are modifiable. Subsequent consensus statements<sup>10,16</sup> on the risk factors for ACL

**Table. Modifiable and Nonmodifiable Risk Factors for Noncontact Anterior Cruciate Ligament (ACL) Injury Categorized as Intrinsic (I) or Extrinsic (E) and Using the Scheme Described in Several Consensus Statements<sup>10,16,17</sup>**

Modifiable Risk Factors	Nonmodifiable Risk Factors
<p>Environmental</p> <ul style="list-style-type: none"> <li><i>Meteorologic conditions (E)</i></li> <li><i>Playing surface (E)</i></li> <li><i>Footwear (E)</i></li> <li><i>Knee braces (E)</i></li> <li><i>Rules (E)</i></li> <li><i>Referees (E)</i></li> <li><i>Coaching (E)</i></li> </ul> <p>Anatomical</p> <ul style="list-style-type: none"> <li><i>Foot pronation (I)</i></li> <li><i>Body composition and body mass index (I)</i></li> </ul> <p>Neuromuscular</p> <ul style="list-style-type: none"> <li><i>Muscle strength (I)</i></li> <li><i>Muscle activation patterns (I)</i></li> <li><i>Muscle stiffness (I)</i></li> <li><i>Physical fitness and muscle fatigue (I)</i></li> <li><i>Skill level (I)</i></li> </ul> <p>Hormonal</p>	<p>Environmental</p> <ul style="list-style-type: none"> <li><i>Playing situation (E)</i></li> <li><i>Opponent behavior (E)</i></li> <li><i>Unanticipated events during play (E)</i></li> </ul> <p>Anatomical</p> <ul style="list-style-type: none"> <li><i>Q angle (I)</i></li> <li><i>Navicular drop (I)</i></li> <li><i>Knee valgus (I)</i></li> <li><i>Postural alignment (I)</i></li> <li><i>Notch size, ACL geometry and properties (I)</i></li> <li><i>Tibial slope angle (I)</i></li> <li><i>Generalized joint hypermobility or laxity (I)</i></li> </ul> <p>Hormonal</p> <ul style="list-style-type: none"> <li><i>Menstrual cycle and hormone concentrations (I)</i></li> </ul> <p>Demographic</p> <ul style="list-style-type: none"> <li><i>Age (I)</i></li> <li><i>Injury history (I)</i></li> <li><i>Familial history and genetics (I)</i></li> <li><i>Sex (I)</i></li> <li><i>Height (I)</i></li> <li><i>Race (I)</i></li> </ul>

injury conceptualized risk factors by categorizing them into environmental, anatomical, hormonal, neuromuscular, and familial-tendency factors. Although these consensus statements<sup>10,16,17</sup> did not categorize risk factors as modifiable and nonmodifiable, they did recognize the importance of neuromuscular factors, primarily because of their modifiable nature. Risk factors from several consensus statements related to understanding and preventing ACL injuries are conceptualized as modifiable or nonmodifiable in the Table. It is important to note that some risk factors categorized as nonmodifiable may be modifiable through surgical (eg, tibial slope angle) or pharmacologic (eg, menstrual cycle and hormone concentrations) interventions, but such interventions may not be feasible or ethical. Conversely, risk factors categorized as modifiable (eg, meteorologic conditions, playing surface, rules) may not be financially or socially feasible to change, which would affect the successful implementation of subsequent injury prevention initiatives.<sup>9</sup>

Researchers<sup>10,17</sup> have recently been focusing more on modifiable risk factors for ACL injury, such as neuromuscular control and biomechanical factors, dynamic loading, movement variability, muscle strength, fatigue, and alignment during landing and cutting maneuvers. This information has been used to develop promising injury prevention programs to reduce the incidence of noncontact ACL injuries among athletes.<sup>18,19</sup> The JUMP-ACL project, led by Dr Stephen Marshall at the University of North Carolina at Chapel Hill and funded by the National Institute of Arthritis and Musculoskeletal and Skin Diseases, is an example of a research initiative that has conceptualized risk factors as modifiable and nonmodifiable in the context of noncontact ACL injuries.

The JUMP-ACL project is a prospective, multicenter cohort study designed to identify the modifiable and nonmodifiable risk factors for noncontact ACL injuries within the high-risk population attending the nation's 3 largest military academies. The project was initiated in the

summer of 2005 and is nearing completion. During the first several weeks of their academy career, incoming freshmen were asked to provide informed consent and, subsequently, to complete a baseline questionnaire (eg, injury history, age, activity history, menstrual history) along with a battery of anatomical (eg, height, weight, Q-angle, navicular drop, knee valgus) and neuromuscular (eg, muscle strength, kinetics and kinematics during a jump landing task) assessments. Participants were tracked through the closed health care systems at the academies, and regular injury surveillance activities aided in identifying all ACL injuries within the cohort until graduation. Participants who subsequently sustained an ACL injury were asked to complete a follow-up injury questionnaire that documented proximal factors associated with the injury. Injury information was also abstracted from the medical record. As of August 2008, 5686 participants had been enrolled in the study and had fully completed baseline testing.

The initial results of this project confirm that individuals who eventually tear their ACLs jump and land differently than those who are at low risk for subsequent ACL injury. This finding indicates that incoming cadets could be screened upon arrival, and those determined to be at greatest risk could be placed into a training program designed to correct their movement deficits. Previous authors<sup>18-22</sup> have reported that exercise programs could reduce the incidence of ACL injuries. Data from the JUMP-ACL project are being used by the research team to develop and validate risk profiles and field assessments to efficiently identify individuals at greatest risk of injury.<sup>23</sup> Using the scientifically validated risk profiles, the research team has also begun to further develop, refine, and evaluate the effectiveness of injury prevention interventions to target modifiable neuromuscular risk factors associated with noncontact ACL injury. Preliminary data indicate that based on an individual's neuromuscular risk profile, a targeted exercise program performed 2 to 3 times per week

(for 10 minutes at a time) may reduce the incidence of ACL injuries by as much as 70% and the incidence of lower extremity injury in general by as much as 50%. However, it is clear that close supervision is required in order to attain maximum benefit from such programs; intervention programs with higher levels of supervision appear to show stronger effects.<sup>24</sup> The future goals of the research team are to validate the effectiveness of these injury prevention programs, to better understand the role of the dose-response relationship, and to identify the factors affecting intervention fidelity as they try to transition their work from injury prevention research to injury prevention practice, consistent with the TRIPP framework described by Finch.<sup>9</sup>

Although the published sports medicine literature provides precedence for conceptualizing risk factors associated with injury as intrinsic and extrinsic or as grouped by domains, sports injury researchers should reexamine the utility of these conceptual models in light of the overarching goals of sports injury epidemiology, which are to reduce the incidence and mitigate the burden of preventable injuries among athletes. Within the sports medicine literature, research related to the understanding and prevention of ACL injuries has provided one of the most robust examples of how conceptualizing risk factors as modifiable and nonmodifiable has led to advances in injury prevention efforts. Conceptualizing risk factors as modifiable and nonmodifiable provides a framework that is more aligned with the overarching goals of injury prevention and one that has been used to develop and evaluate the effectiveness of intervention strategies. Considering the overarching goals of sports injury research, a paradigm shift in how risk factors are conceptualized seems justified in the context of sports injury research.

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