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Anatomic Alignment, Menstrual Cycle Phase, and the Risk of Anterior Cruciate Ligament Injury

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The fundamental basis for knee trauma prevention research is that injuries occur in patterns reflecting the underlying causes. Understanding the underlying causes or risk factors for one of the more severe sport-related knee injuries, an anterior cruciate ligament (ACL) disruption, is important for developing intervention strategies, identifying those at increased risk of this injury, and allowing targeted interventions. The risk factors for ACL injury have been considered either internal or external to an individual. In the following review, we focus on what is known about 2 categories of internal risk factors: an athlete's anatomy and menstrual cycle phase.

THE ASSOCIATION AMONG ANATOMY, ALIGNMENT, AND THE RISK OF AN ANTERIOR CRUCIATE LIGAMENT INJURY

Abnormal posture and lower extremity alignment (eg, the hip, knee, and ankle) may predispose an individual to ACL injury by contributing to increased ACL strain values. From this perspective, alignment of the entire lower extremity should be considered when assessing risk factors for ACL injury. Unfortunately, very few authors investigated alignment of the entire lower extremity and determined its relationship to ACL injury risk. Most of what we know has come from investigations of relatively small sample sizes and isolated or limited sets of anatomic measures; therefore, consensus is lacking among these studies.

Three groups[1–3] have reported that athletes with a decreased intercondylar notch width, as measured radiographically on a standard notch view, are at increased risk of a noncontact ACL injury. In contrast, Lombardo et al[4] noted that the risk of a noncontact ACL injury was not related to the intercondylar notch width among professional basketball athletes. This finding may be unique to the musculoskeletal system of professional basketball players; how it transfers to athletes with different body types who take part in other sports is unclear. Recent evidence suggests that females with smaller femoral notches also have smaller ACLs, with inferior structural properties compared with males. The complex mechanism by which a smaller femoral notch is associated with increased risk of ACL injury is uncertain and requires further investigation.

Uhorchak et al[3] prospectively studied ACL injury risk factors among US military academy cadets. Men with a narrower femoral notch and greater generalized joint laxity had a 7.8-fold increased risk of an ACL injury. For females, a narrower notch, higher-than-average body mass index, and general joint laxity predicted ACL injury risk with high specificity and sensitivity. Uhorchak et al[3] also found that the risk of an ACL injury was 2.7 times higher in women whose knee laxity values were more than 1 SD from the mean compared with women with decreased knee laxity values. For the men, no relationship was noted between knee laxity and the risk of an ACL injury. These findings suggest that, at least to some degree, the anatomical risk factors for ACL injury may be sex specific.

THE ASSOCIATION BETWEEN MENSTRUAL CYCLE PHASE AND THE RISK OF AN ANTERIOR CRUCIATE LIGAMENT INJURY

A consensus emerging from the literature suggests that the likelihood of an ACL injury does not remain constant during the menstrual cycle. Instead, the risk of an ACL disruption is greater during the preovulatory phase of the menstrual cycle than the postovulatory phase. Wojtys et al[5] used self-reported menstrual history data to characterize a participant's menstrual status at the time of injury and demonstrated a greater incidence of noncontact ACL injuries among women athletes during the preovulatory phase. In a subsequent study, Wojtys et al[6] used urine levels of estrogen, progesterone, and luteinizing hormone metabolites to characterize a participant's menstrual status at the time of injury. The incidence of ACL injuries was greater during days 9 to 14 of a 28-day cycle and lower during the postovulatory phase (defined as day 15 thorough the end of the cycle). Arendt et al[7] reported that female athletes were at increased risk of ACL injury during the preovulatory phase when compared with the postovulatory phase. Similarly, Slauterbeck et al[8] noted that a disproportionally greater number of ACL injuries occurred during the preovulatory phase and that fewer injuries occurred as the cycle progressed. In a study of recreational alpine skiers, serum concentrations of progesterone and estradiol were used to stage the phase of a skier's menstrual cycle at the time of ACL injury.[9] Skiers in the preovulatory phase were more likely to tear their ACLs than skiers in the postovulatory phase (odds ratio, 3.22).[9] A comparison between this investigation and that of Wojtys et al[6] revealed a striking similarity. Among the skiers, 74% of the women with ACL injuries were in the preovulatory phase, whereas 26% were in the postovulatory phase. Wojtys et al[6] noted that 72.5% and 27.5% of the women not using oral contraception experienced ACL injuries during the preovulatory and postovulatory phases, respectively. In contrast, Myklebust et al[10] studied competitive European team handball players over 3 years and found an increased risk of ACL injury during the week before or just after the onset of menstruation.

The underlying mechanism that increases the likelihood of sustaining an ACL injury during the preovulatory phase of the menstrual cycle has not been determined. It may well be that the increased risk of injury is the result of an unopposed increase in estradiol that occurs during the preovulatory phase of the menstrual cycle (ie, an increased concentration of estradiol and a decreased concentration of progesterone). In the study of recreational alpine skiers,[9] post hoc analyses of serum concentrations of estradiol were similar between control and ACL-injured participants. However, serum concentrations of progesterone tended to be elevated by a mean of 70% for participants in the uninjured control group compared with those sustaining ACL injuries. In a larger sample size, this relationship may become significant. Although it remains unclear whether estradiol and progesterone act directly on the ACL in humans and increase the likelihood that a participant will be injured, other hormones associated with the menstrual cycle may modulate injury risk. Alternatively, hormones may act on structures other then the ACL. For example, hormones may have a direct effect on the sequence and magnitude of muscle contraction and corresponding stiffness of the knee, predisposing an individual to increased risk of injury.

FUTURE DIRECTIONS

The evidence regarding an athlete's complete external and internal risk factor profile for ACL injury is unclear, because most investigators have studied isolated variables. Only Uhorchack et al[3] took a multivariate approach to establishing risk factors that increase an athlete's chance of tearing the ACL. Females are at increased risk of sustaining an ACL injury in comparison with males when they compete in the same sport at the same level of competition, and growing evidence suggests that females are at significantly greater risk of ACL injury during the preovulatory phase than the postovulatory phase. Further, females with an increased knee abduction moment when landing from a jump are at increased risk of sustaining an ACL injury.[11] Many sex differences have been identified with regard to anatomic alignment of the lower limb: increased hip anteversion, tibiofemoral angle, Q-angle, and hyperextension of the knee in females.[12] Yet very little is known about how these alignment variables are related to the likelihood of sustaining a knee ligament injury. Also, not much is known about the effects of sport-specific factors (eg, rules, referees, and coaching), meterologic conditions (eg, the traction at the shoe-playing surface interface), playing surfaces, and protective equipment on the risk of sustaining an ACL injury. These potential risk factors merit further investigation. Very little is known about the effects of age, athleticism, skill level, psychologic characteristics, and prior knee injury as risk factors for ACL injury. For example, almost everything we know with regard to the incidence rate of ACL injuries in specific sports has come from studies performed in precollegiate (high school) and collegiate athletes. Limited data address the incidence rate of ACL disruptions in those who are either younger or older then this narrow age window and, consequently, the effect of age on the likelihood of sustaining an ACL tear is not well understood.

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