EDITOR'S CHOICE

Gender influences: the role of leg dominance in ACL injury among soccer players

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Accepted 25 February 2009
Published Online First 11 June 2010

ABSTRACT

Objective This study intends to look at the role of leg dominance in anterior cruciate ligament (ACL) injury risk among soccer (football) athletes. The purpose of this study was to test the hypothesis that soccer players rupture the ACL of their preferred support leg more frequently than the ACL in their preferred kicking leg, particularly in non-contact injuries, despite differences in gender.

Design Retrospective observational study.

Setting Outpatient orthopaedic practice.

Patients Subjects who had sustained an ACL injury due to direct participation in soccer. N=93 (41 male, 52 female).

Interventions These noncontact injuries were sustained while playing soccer.

Results For non-contact injuries, roughly half of the injuries occurred in the preferred kicking leg (30) and the contralateral leg (28). However, by gender, there was a significant difference in the distribution of non-contact injury, as 74.1% of males (20/27) were injured on the dominant kicking leg compared with 32% (10/31) of females ($p<0.002$).

Conclusions When limited to a non-contact injury mechanism, females are more likely to injure the ACL in their supporting leg, whereas males tend to injure their kicking leg. This research suggests that limb dominance does serve as an aetiological factor with regard to ACL injuries sustained while playing soccer. If follow-up studies confirm that females are more likely to injure their preferred supporting leg, future research should investigate the cause for this discrepancy, which could result from underlying gender-based anatomical differences as well as differences in neuromuscular patterns during cutting manoeuvres or kicking.

INTRODUCTION

Soccer is the most popular sport worldwide, with over 240 million active players.[1] The incidence of soccer related injuries is estimated to be 10–35 per 1000 playing hours in adult male players,[2 3] and often higher in younger and less skilled players.[4] Approximately 60–80% of severe injuries occur in the lower extremities,[2 5–7] most commonly at the knee or ankle.[2 5 6]

Kicking the soccer ball plays both a direct and indirect role in the aetiology of soccer player injuries. During an average 90 min game, a player has an average of 51 contacts with the ball, 26 of those with the foot.[8] An analysis of injury risk while playing soccer found that kicking accounted for 51% of potential actions that could lead to injury.[9] While other sports, particularly those involving throwing, have considerable investigation into the dominant extremity, extremity dominance in soccer has not been well described in the literature. Obviously, the fluidity of play in soccer does not put demand exclusively on one lower extremity like a throwing sport such as baseball puts on the dominant upper extremity. However, most soccer athletes definitely have a preferred kicking limb. This is likely to put differential demands on the lower extremities given the differences in muscle activation seen in the kicking limb compared with the supporting limb.[10]

This is particularly important in light of the significant gender discrepancy that exists with regard to the incidence of anterior cruciate ligament (ACL) injury among soccer athletes, with females sustaining an incidence rate 2–10 times greater than her male counterpart.[11 12] The mechanism of injury often involves faulty landing technique, deceleration, pivoting or cutting with excessive anterior shear forces. Numerous prevention programmes have been devised in order to address the pathokinematics surrounding the mechanism of injury which have been successful in reducing the rate of injury within the respective intervention groups.[12–18]

The literature did not frequently delineate between the side of injury with respect to lower-limb dominance and gender. Although a few studies have looked at the role of leg dominance in ACL injury,[19–21] the authors are not aware of any study in the literature looking at the potential relationship between leg dominance and ACL injury risk specifically in the soccer athlete. The purpose of this study was to test the hypothesis that soccer players rupture the ACL of their preferred support leg more frequently than the ACL in their preferred kicking leg, particularly in non-contact injuries, despite differences in gender. This study looked at the role of leg dominance in ACL injury risk among soccer athletes, particularly when adjusting for gender.

METHODS

Institutional Review Board approval was obtained through the St John's Internal Review Board Committee in Santa Monica, California, USA for this study protocol prior to initiating the investigation. The study reviewed all ACL reconstructions performed by a single orthopaedic surgeon affiliated with national, professional, collegiate and youth soccer teams to delineate those performed in soccer players. Inclusion criteria included athletes who had sustained a complete ACL tear

directly due to direct participation in soccer, in either a game or practice setting. All surgeries were completed within 4 months of the time of injury. The exclusion criteria included subjects under the age of 15, partial ACL injuries and those athletes who had sustained an ACL reoccurrences (ipsilateral limb). These individuals were then contacted via telephone (one interviewer) and asked directly if they would be willing to participate in this research study. If the subject agreed, informed consent was obtained via email or fax. After the informed consent was received, a second phone interview was conducted asking the subjects a number of questions regarding their preinjury level of play, preferred kicking limb and the mechanism of ACL injury. The preferred kicking limb was determined by asking which limb they prefer to kick a ball with (dominant limb), and the preferred stance or support leg was designated as the non-dominant limb based on a number of previous studies looking at the role of leg dominance in soccer player injury.[22–24] The mechanism of injury was divided into two categories: contact and non-contact. If there was any contact made with the player at the time of injury, this was considered a contact injury. The other injuries were considered non-contact. This information was then confirmed with information from the patient's chart.

A power analysis was performed to determine how many subjects would be necessary in order to demonstrate a difference in risk of injury to the dominant kicking leg compared with the dominant support leg. This showed that approximately 50 subjects would be needed to detect a statistically significant 70:30 dominant to non-dominant ratio with 80% power using a χ^2 test.

RESULTS

All subjects who were identified and contacted agreed to participate in this study. A total of 93 soccer players (N=41 male, 52 female) who had undergone ACL reconstruction were identified and consented to participate in this study.

The average age at the time of surgery was 26.8±1.6 years. Fifteen athletes played at the professional level, 23 at the college level, 55 at the high school/club level and 45 at the youth or recreational level. For the male cohort (n=41), the average age at the time of injury was 30.6±8.84. Twelve (12) male athletes were professional soccer players, 6 were collegiate players 4 at the high school/club level and 19 were recreational players. For the female cohort (n=52), the average age at the time of injury was 20.4±7.99 years. Three (3) were professional soccer athletes one sustaining two injuries; right and left, 17 were collegiate players 17 were at the high school/club level and 15 were recreational players (see table 1).

The ACL injured limbs were equally distributed between right (72) and left (73) when both contact and non-contact injuries were considered. The right lower extremity was the preferred kicking limb in 84 subjects while the left lower extremity was the preferred kicking limb in 9 (table 1). Slightly more than half of the ACL injuries occurred in the dominant lower extremity (53/99).

When the data were stratified to look at non-contact ACL injuries specifically, an interesting trend emerged. Roughly half of the injuries occurred in the preferred kicking (dominant) limb (30) and half occurred in the contra-lateral limb (28). However, when the data were stratified for gender, there was a significant difference in the distribution of non-contact injury with respect to dominance. Exactly 74.07% of males (20/27) were injured on the dominant kicking leg compared with 32.26% (10/31) of females, who were injured in (p<0.002).

Table 1 Non-contact anterior cruciate ligament (NC ACL) injury with respect to leg dominance

		Dominant leg		NC ACL injury	
Gender	**N**	**Right**	**Left**	**Right**	**Left**
Female (N=52)					
Professional	3	2	1	2	2
College	17	16	1	1	5
High school/club	17	16	1	2	7
Youth/recreational	15	13	2	5	7
	52	47	5	10	21
Average age (injury) =20.4±7.99				32.26%	67.74%
Total NC ACL injuries: 31					
Male (N=41)					
Professional	12	11	1	5	3
College	6	5	1	5	1
High school/club	4	3	1	2	1
Youth/recreational	19	18	1	7	2
	41	37	4	20	7
Average age (injury) =30.6±8.84				74.07%	25.93%
Total NC ACL injuries: 27					

DISCUSSION

This is the first study to our knowledge that suggests that leg dominance may play a gender based role in non-contact ACL injury in soccer athletes. In this cohort, male athletes were statistically more likely to injure their preferred kicking leg while females were more likely to injure their preferred support leg. Previous studies looking at the role of leg dominance in ACL injury have not found any consistent relationship. However, these studies did not stratify for sport.

A recent multicentre retrospective study of just over 300 subjects with non-contact ACL tears reported no significant correlation between the side of injury and the dominant limb for kicking.[19] There was no significant relationship between dominance and injury in male subjects but in females they found a strong trend (p=0.06) towards increased injury in the left lower extremity compared with the right lower extremity. This provides indirect support for the findings in our study since females were more likely to be injured in their dominant support leg, which was usually the left lower extremity. Of the 21 non-contact ACL injuries to the dominant support leg in female subjects in our study, 20 of them occurred in the left lower extremity.

A recent study of all injuries in the female German national soccer league actually reported more injuries in the dominant lower extremity (105) compared with the non-dominant lower extremity (71).[20] However, this relationship was based primarily on contact injuries, with a significantly greater number of contact injuries occurring on the dominant side (52) as opposed to the non-dominant side (29). Non-contact injuries did not show any significant difference between sides (37 dominant vs 36 non-dominant). When looking at ligament ruptures, 18 occurred in the dominant lower extremity while only 8 occurred in the non-dominant lower extremity. However, there was no breakdown limited to non-contact ACL injuries.

A retrospective study of acute, unilateral, non-contact ACL tears in 80 patients (44 male, 36 female) did not find any significant relationship between leg dominance and injury nor any gender effect on this relationship.[21] However, this was not a sport specific analysis as the cohort included athletes from over 10 sports or activities, including 13 soccer players. A study looking at the mechanism of ACL injuries in male

soccer players reported that 52/105 ACL injuries occurred in the dominant kicking leg.[25] While this study was did record and analyse the mechanism of injury, the breakdown of non-contact injuries by dominant kicking leg versus contralateral leg was not reported.

If leg dominance does affect the risk of non-contact ACL injury, what is the mechanism for that relationship? Neuromuscular studies have not reported consistent differences between the dominant and non-dominant lower extremity. A recent study of the single-leg hop for distance in nine uninjured subjects (six male, three female) demonstrated no relevant differences between the dominant and non-dominant side.[26] In a study that included healthy subjects as well as subjects with ACL injuries, the healthy subjects demonstrated limb symmetry indices of 95% or more on all functional performance and isokinetic tests.[27]

When identifying a mechanism of injury for ACL injury, the literature supports the notion of decreased lateral hip control, decreased hamstring activity (electromyography (EMG)), slower contraction times, decreased peak flexion angles upon jump-landing and decreased core stability within the female population. Valgus angles at the knee are often coupled with decreased knee and hip flexion, and pronation at the subtalar joint in the female population. Injury prevention programmes have successfully addressed the deficits commonly seen in the female cohort: actively addressing the hip abductors, external rotators of the hip, hip extensors, core/trunk control and proprioceptive deficits. Increasing attention has been paid to improving jump-landing kinematics by decreasing the propensity to decelerate in the sagittal plane; thus decreasing anterior shear forces, increase knee and hip flexion upon landing and to utilise the lateral hip musculature to avoid dynamic valgus. When we consider the aforementioned research with regard to the results of the lower-limb leg dominance results obtained in this study, we can infer that perhaps the deficits that preclude the ACL injury in females may be isolated to decreased lateral hip control, decreased hamstring activity due to a muscular imbalance with regard to the quadriceps and/or an altered length tension relationship of the hamstrings secondary to decreased hip and knee flexion.

Soccer, inherently, is a quadricep and adductor dominated sport. During baseline manual muscle testing during preseason physicals, professional male soccer athletes demonstrate a 2:1 ratio of quadricep to hamstring and a 2:1 ratio of adductor to abductor strength.[28] In this study, there was a preponderance of evidence to statistically support the dominant leg being most vulnerable to ACL injury in soccer in the male population. This may be due to the imbalance that exists between the quadriceps and the hamstring in the sagittal plane and the adductor to abductor in the frontal plane. In addition, pelvic positioning can perhaps contribute to this phenomenon. During striking, the pelvis assumes an anterior pelvic tilt on preswing, which transitions to a posterior pelvic tilt at the point of initial contact with the ball. At this point, the insertion for the biceps femoris musculature has migrated caudally, thus altering the length tension relationship of the biceps femoris of the hamstring group. The quadriceps has a mechanical advantage—and may impart a significant anterior shear force that precludes the ACL injury in the male. Further biomechanical analysis and EMG data are deemed necessary to confront this issue.

A number of studies have compared the dominant lower extremity to the non-dominant lower extremity specifically in soccer players. One study looked at the ground reaction forces on the support foot and found them higher in skilled players than unskilled players.[29] While some studies have reported greater strength in the dominant leg[30 31] or symmetry between players' dominant and non-dominant limbs,[32 33] non-dominant limb peak knee extension torque was greater than the dominant side in one study.[34] This was attributed to the role of the non-dominant quadriceps supporting the swing of the kicking leg. EMG analysis of the soccer kick in male players has demonstrated greater activity in the support limb quadriceps during the support phases of the kick.[10 33] Rahnama *et al*[35] found a significant difference between knee flexor and extensor strength in elite and subelite male soccer players in the sagittal plane. The dominant leg demonstrated both a diminished dynamic control ration during kicking (0.79±0.13 vs 0.84±0.16 Nm) and weaker knee flexors compared with the stance leg. Interestingly, no significant difference was demonstrated with regard to the quadriceps at any angular velocity tested.

Strength and muscle activation may not provide a complete picture, however. A longitudinal study of adolescent male and female athletes reported greater valgus in the non-dominant lower extremity on landing from a jump in female athletes after maturation.[36] This finding was supported by another study of high school basketball players which also demonstrated greater side-to-side differences in valgus knee angle at landing.[13] These studies suggest that subtle changes in neuromuscular control may contribute to the greater number of non-contact ACL injuries in the non-dominant limb of female soccer players.

There are some obvious limitations to the current retrospective study, including a selection bias in terms of looking only at athletes who underwent ACL reconstruction. Athletes who injured their ACL but did not undergo ACL reconstruction are not included in this cohort but there is no obvious reason to expect a difference in terms of injury mechanism or leg dominance between these populations. Furthermore, the retrospective study design allows for potential recall bias although data was checked against the written chart and no discrepancies were encountered. Finally, this retrospective series lacks any data on the relative exposure and no conclusions regarding incidence or relative risk can be made.

Nevertheless, this is an important study to look at the role of leg dominance in ACL injury among an isolated cohort of soccer players from all levels of the game. When limited to a non-contact injury mechanism, female soccer athletes are more likely to injure the ACL in their preferred supporting leg whereas male soccer athletes tend to injure the ACL in their preferred kicking leg. This retrospective research suggests that lower-limb dominance does serve as an etiological factor with regard to ACL injured athletes that were sustained while playing soccer. Prospective studies should look at the relationship between leg dominance, gender and ACL injury to confirm the findings in this retrospective cohort. If follow-up studies confirm that females are more likely to injure their preferred supporting leg, future research should investigate the cause for this discrepancy, which could result from underlying gender based anatomical differences as well as differences in neuromuscular patterns during cutting manoeuvres or kicking. This could also play a role in the higher rate of non-contact ACL injury in female soccer athletes compared with male soccer athletes.

Competing interests None.

Patient consent Obtained.

Ethics approval Ethics approval was provided by the St John's Medical Center, Santa Monica, California, USA.

Provenance and peer review Not Commissioned; externally peer reviewed.

Contributors All of the authors listed on this manuscript contributed fully to the research process.

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