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Risk factors for noncontact anterior cruciate ligament injury: Analysis of parameters in proximal tibia using anteroposterior radiography

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Abstract

Objective: To investigate the relationship between the proximal tibial parameters of tibia width (TW), eminence width (EW), and eminence width index (EWI), and noncontact anterior cruciate ligament (ACL) injury, in a Chinese population.

Methods: A retrospective case–control study was conducted of all ACL reconstructions (ACL group) and meniscal surgeries (control group) undertaken at two Chinese hospitals. Patients in the ACL group were age- and sex-matched with controls. Anteroposterior knee radiographs were used to measure the TW, EW and EWI.

Results: A total of 73 pairs of patients who were verified by knee arthroscopy, magnetic resonance imaging and physical examination were included in the study. There was no significant difference between the ACL group and the control group in terms of TW in the total population and in the two sex subgroups. The ACL group had a significantly smaller EW and EWI compared with the control group in the total population and in the two sex subgroups.

Conclusion: Decreased EW and EWI are associated with increased risk of noncontact ACL injury in a Chinese population.

Keywords

Anterior cruciate ligament injury, tibia width, eminence width, risk factor

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Introduction

Anterior cruciate ligament (ACL) injury is a commonly occurring orthopaedic problem with ~200 000 cases per year occurring in the United States.[1] Causes of ACL injuries can be divided into two categories: (i) extrinsic, e.g. access to training facilities[2] and high levels of competition;[3] (ii) intrinsic, e.g. ligament laxity,[4] increased Q angle,[5] narrow femoral intercondylar notch dimensions[6–9] and increased tibia plateau slope.[10–16] Narrow femoral intercondylar notch dimensions and increased tibia plateau slope are risk factors for ACL injury that have been confirmed by two meta-analyses.[17,18] Uhorchak et al.[19] in 2003, were the first to demonstrate that a narrow eminence width (EW) and a decreased eminence width index (EWI) are two of several risk factors that may predispose young athletes to noncontact ACL injury. Since then, however, no subsequent studies have evaluated the role of these two parameters in the presence of ACL injury in other populations. The objective of this study was to investigate further the relationship between proximal tibia parameters (EW, EWI and tibia width [TW]) and ACL injury in a Chinese population.

Patients and methods

Study population

This case–control study was a retrospective review of all ACL reconstructions (ACL group) and meniscal surgeries (control group) performed at the Department of Orthopaedics, Xiangya Hospital, Central South University, Changsha, Hunan Province, China between May 2010 and December 2013 and at the Department of Orthopaedics, Third Xiangya Hospital, Central South University, Changsha, Hunan Province, China between July 2008 and December 2013. Pairs of patients and controls (age- and sex- matched, and verified by arthroscopy, magnetic resonance imaging [MRI] and physical examination, according to the inclusion and exclusion criteria) were identified. Inclusion criteria were as follows: for the ACL group, noncontact, isolated, complete rupture of the ACL; for the control group, meniscal pathology. Exclusion criteria were as follows for both groups: other ligament or capsular injury or fractures of the knee, bone or soft-tissue tumour of the lower limbs, grade II or greater osteoarthritic changes (according to Kellgren–Lawrence radiographic atlas), history of knee ligament injury or knee surgery or an abnormal knee examination consistent with ligamentous instability, family history of inheritable musculoskeletal disorders, low-quality radiograph, and the patient could not remember the extent of the weight that was on the leg during injury. In addition, patients in the ACL group were excluded if they could not remember the exact mechanism of injury. Approval for the study was obtained from the Institutional Review Board at Xiangya Hospital of Central South University (no. 201212057). All study participants provided written informed consent.

Knee measurements

All patients had a minimum of two radiographic views of the injured knee: anteroposterior and lateral. Two sports medicine-trained orthopaedic doctors (W.-F. X. and T. Y.) independently evaluated the anteroposterior knee radiographs to establish the TW, EW and EWI for all patients according to the method described previously (Figure 1).[19] These three parameters were measured using a Rogan-Delft View Pro-X System Version 4.0.2.4 (Rogan-Delft, Utrecht, the Netherlands).

Statistical analyses

The sample-size power analysis was conducted with reference to a previous study.[12] The sample size was set based on the following parameters: difference of TW, 2.92; SD, 5.00; power, 0.10; α-error, 0.05. The analysis result showed that a sample size

Figure 1. Measurements were undertaken on anteroposterior knee radiographs by two sports medicine-trained orthopaedic doctors in order to independently establish the tibia width (A–B), the eminence width (A′–B′) and the eminence width index (A′–B′/A–B) according to the method described previously.[19]

of 50 for each group would be sufficient to detect the difference. The reliability of the measurement performance was assessed by intra- and inter-rater correlation coefficient (ICC) analyses. Analysis of intra- and inter-rater reliability showed that the ICCs of the three knee indices were all above 0.85, suggesting an excellent reliability. Data were presented as mean ± SD. All statistical analyses were performed using the SPSS® statistical package, version 17.0 (SPSS Inc., Chicago, IL, USA) for Windows®. Student's *t*-test or χ^2-test were used to compare demographic and clinical characteristics between the two groups. The differences between the three knee indices between the ACL and control group in the total, male and female populations were evaluated using two-tailed paired Student's *t*-test. A P-value < 0.05 was considered statistically significant.

Results

A total of 73 age- and sex-matched pairs of patients who were verified by arthroscopy, MRI and physical examination were identified and their data were retrospectively reviewed. Demographic and clinical data are presented in Table 1. There were no statistically significant differences between the ACL and control groups either in the total population or in the male and female subgroups (data not shown).

The knee anatomical measurements of TW, EW, and EWI for the ACL and control groups are presented in Table 2. There were no statistically significant differences in the TW between the ACL group and the control group for the total population or in the male and female subgroups. The ACL group had significantly smaller EW and EWI values compared with the control group ($P < 0.001$ for both comparisons). Similar significant

Table 1. Demographic and clinical characteristics of patients with anterior cruciate ligament (ACL) injury and the age- and sex-matched control group who had meniscal pathologies.

	ACL injury group			Control group		
Characteristic	Total $n = 73$	Male $n = 53$	Female $n = 20$	Total $n = 73$	Male $n = 53$	Female $n = 20$
Age, years	28.2 ± 8.6	26.7 ± 7.7	32.4 ± 9.6	28.1 ± 8.7	26.3 ± 7.6	32.8 ± 9.8
Height, cm	170.5 ± 7.4	174.2 ± 4.1	160.8 ± 4.9	170.2 ± 6.3	172.7 ± 4.2	163.4 ± 6.1
Weight, kg	67.7 ± 11.3	71.9 ± 9.5	56.6 ± 7.3	65.5 ± 9.9	68.7 ± 8.2	57.0 ± 9.3
Body mass index, kg/m^2	23.3 ± 2.9	23.8 ± 3.0	21.9 ± 2.3	22.5 ± 2.6	23.0 ± 2.6	21.2 ± 2.4
Side of injury, right/left	37/36	28/25	9/11	36/37	25/28	11/9

Data presented as mean ± SD or *n* patients.
No statistically significant between-group differences (Student's *t*-test or χ^2-test; $P \geq 0.05$).

differences in EW and EWI between the ACL and control groups were observed in the male and female subgroups ($P < 0.05$ for all comparisons).

Discussion

This present study demonstrated that the ACL group had significantly decreased EW and EWI compared with the control group. When the sample was stratified by sex, the significant differences still existed in both the male and female subgroups. These findings may have some important implications for public health and clinical care (for example, in helping to identify members of the population at heightened risk of ACL injury, or to serve as a potential reference index for athlete selection).

The present findings are supported by a prospective cohort study,[19] which also reported a decreased EW and EWI in the ACL injury group; and an insignificant difference in the TW between patients with an ACL injury and the control group. Their findings also indicated that the ACL injury group had decreased EW and EWI for both male and female subgroups, which was consistent with this present study.[19] The EW (the distance between the lines bisecting the tibia eminences) and the EWI could potentially be simple indicators to estimate the ACL diameter.[19] In particular, similar to the notch width index, the EWI aims to represent the estimated size of the ACL.[19] Furthermore, Jamison et al.[20] suggested that the ACL volume could be regarded as a screening tool for assessing the risk of injury. A cadaveric study also indicated that smaller ligament size may explain why women have a higher rate of ACL injury than men.[21] This was also supported by an anatomical study using MRI, which revealed significant differences between male and female subjects, but that these differences no longer existed when adjusting for body height.[22] Therefore, just like patients with narrower notches having a higher incidence of ligament rupturing,[23] the present study results demonstrated that people with decreased EW and EWI were naturally more inclined to ACL injury during intense exercise.

A major strength of the present study was that arthroscopic surgery, which is the gold standard for diagnosing ACL injury, was used as an inclusion criterion for both the ACL group and the control group. Although MRI is thought to be the best imaging modality for the diagnosis of ACL injury, it still has highly variable sensitivity (range, 64–98%) and specificity (range, 87–100%).[24–32] In addition, this present study confirmed that arthroscopic surgery can guarantee the absence of any visible pathological changes that may impact

Table 2. The tibia width, eminence width and eminence width index values for patients with anterior cruciate ligament (ACL) injury, and the age- and sex-matched control group (who had meniscal pathologies) stratified according to sex.

	Total			Male			Female		
Parameter	ACL group $n=73$	Control group $n=73$	Statistical significance[a]	ACL group $n=53$	Control group $n=53$	Statistical significance[a]	ACL group $n=20$	Control group $n=20$	Statistical significance[a]
Tibia width	81.5 ± 6.2	80.5 ± 5.4	NS	84.2 ± 5.0	82.5 ± 4.3	NS	74.5 ± 2.9	75.1 ± 4.3	NS
Eminence width	11.3 ± 1.9	13.0 ± 1.8	$P < 0.001$	11.5 ± 1.9	13.3 ± 1.8	$P < 0.001$	10.7 ± 1.7	12.1 ± 1.5	$P = 0.01$
Eminence width index	0.14 ± 0.02	0.16 ± 0.02	$P < 0.001$	0.14 ± 0.02	0.16 ± 0.02	$P < 0.001$	0.14 ± 0.02	0.16 ± 0.02	$P = 0.02$

Data presented as mean ± SD.
[a]Two-tailed paired Student's *t*-test.
NS, no statistically significant between-group differences ($P \geq 0.05$).

the research accuracy. Furthermore, the ACL group and the control group in the present study were matched for age and sex, which may improve the comparability between the two groups.

This study had a number of limitations. First, it had a relatively small sample size, particularly in the female subgroup, so it remains unclear whether the association between decreased EW and EWI and the risk of noncontact ACL injury only exists in the male subgroup. In terms of other studies examining anatomical risk factors of ACL injury,[6–9,11–16,19] to our knowledge this study is the only one that has used arthroscopy, MRI and physical examination to confirm the injury and the control group pathology after matching for age and sex. Secondly, there was an unequal sports activity level between the two groups and future studies should pay more attention to this issue. Thirdly, arthroscopic notch shape, size of the tibial footprint and type of ACL injury were not recorded in the present study.

In conclusion, the results of this present study suggest that decreased EW and EWI are associated with the increased risk of noncontact ACL injury in a Chinese population.

Declaration of conflicting interest

The authors declare that there are no conflicts of interest.

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