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Lower Lateral Femoral Index as a Significant Risk Factor for Non-Contact Anterior Cruciate Ligament Rupture: A Case-Control Study

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ABSTRACT

Introduction: Anterior Cruciate Ligament (ACL) injury is one of the most common knee ligament injuries, particularly in the athletic population. Anatomical risk factors, such as knee bone morphology, are thought to play a crucial role in injury susceptibility. One parameter under investigation is the Lateral Femoral Index (LFCI), which describes the shape of the lateral femoral condyle. This study aimed to analyze the difference in LFCI in patients with ACL rupture compared to normal individuals as a potential risk factor.

Methods: This study employed an observational analytic design with a case-control approach, conducted at H. Adam Malik General Hospital, Medan. The sample consisted of 50 subjects divided into two groups: 25 patients with an arthroscopically confirmed diagnosis of ACL rupture (case group) and 25 healthy individuals with no history of knee injury (control group). The LFCI was measured from true lateral projection knee radiographs. An independent T-test was used for statistical analysis to compare the mean LFCI difference between the two groups.

Results: The mean age of the study subjects was 30.68 ± 5.35 years. The measurements revealed that the mean LFCI in the ACL rupture group was significantly lower (0.68 ± 0.56) compared to the control group (0.74 ± 0.56). This difference was statistically significant ($p < 0.001$).

Conclusion: There is a significant difference in the Lateral Femoral Index (LFCI) between patients with ACL rupture and normal individuals. A lower LFCI value can be considered an anatomical risk factor for ACL rupture.

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INTRODUCTION

Anterior Cruciate Ligament (ACL) injuries are among the most prevalent and debilitating traumatic knee injuries, frequently affecting young, active individuals and athletes.1 A significant majority, over 70%, of these injuries occur via non-contact mechanisms, such as sudden deceleration, pivoting, or landing maneuvers.2 These events can lead to long-term consequences, including prolonged rehabilitation, decreased quality of life, and an increased risk of premature knee osteoarthritis.3-4

Numerous intrinsic and extrinsic risk factors have been implicated in the etiology of non-contact ACL tears. While neuromuscular control, hormonal influences, and environmental factors are well-studied, there is growing interest in the role of anatomical morphology of the knee joint.5 Variations in tibial slope, intercondylar notch width, and tibiofemoral articular geometry have been identified as potential predisposing factors.6-8

Recently, the morphology of the distal femur, specifically the shape of the lateral femoral condyle (LFC), has emerged as a significant area of investigation. The Lateral Femoral Index (LFCI), a radiographic parameter, quantifies the roundness or asymmetry of the LFC. It is hypothesized that a less spherical or more asymmetric LFC may alter knee biomechanics, increasing anterior tibial translation and internal rotation, thereby placing greater strain on the ACL during dynamic activities.[4] Several studies have suggested a link between a flattened LFC and a higher risk of ACL injury.6-13 However, this data is limited, especially within the Indonesian population. This study aims to investigate the difference in the Lateral Femoral Index between patients with non-contact ACL ruptures and a healthy control group to determine its viability as an anatomical risk factor.

METHODS

Study Design and Participants

This observational analytic study utilized a case-control design. The research was conducted at the Orthopaedics and Traumatology Clinic of H. Adam Malik General Hospital in Medan, Indonesia, after receiving approval from the institutional ethics committee. A total of 50 subjects were enrolled and divided into two groups. The case group consisted of 25 consecutive patients (aged 18-40 years) diagnosed with a primary, non-contact ACL rupture, with the diagnosis confirmed by arthroscopic surgery. The control group comprised 25 age-matched healthy volunteers with no history of knee injury, pain, or instability, and who had negative findings on physical examination tests for ACL integrity (Anterior Drawer, Lachman, and Pivot Shift tests).

Exclusion criteria for the case group were a history of contact injury, concomitant injuries to other knee ligaments or structures, and a history of congenital, developmental, degenerative, or neoplastic musculoskeletal disorders. Exclusion criteria for the control group included any abnormal findings on knee radiographs.

Data Collection and Measurement

Demographic data, including age, sex, and mechanism of injury, were collected for all participants. For radiographic analysis, all subjects underwent a standardized true lateral X-ray of the affected or corresponding knee, with the knee held in 20-30° of flexion.

The Lateral Femoral Index (LFCI) was measured on the radiographs using a standardized method. First, the longitudinal axis of the distal femoral shaft was determined (Line 1). Second, a line was drawn tangential to the most anterior and posterior points of the lateral femoral condyle, defining its total anteroposterior length (Line 2). The LFCI was calculated as the ratio of the distance from the intersection of these two lines to the posterior point of the condyle, divided by the total anteroposterior length of the condyle.

Statistical Analysis

All statistical analyses were performed using SPSS version 22.0. Descriptive statistics were used to summarize the demographic characteristics of the subjects. An independent samples t-test was conducted to compare the mean LFCI between the ACL rupture group and the control group. A p-value of <0.05 was considered statistically significant.

RESULTS

The study included 50 participants, with 25 in the ACL rupture group and 25 in the control group. The overall mean age was 30.68 ± 5.35 years. The ACL rupture group was predominantly male (19 males, 76%), while the control group had a more balanced distribution (16 males, 64%). The most common mechanism of injury in the case group was sports-related activities (48%). Demographic characteristics are detailed in Table 1.

Table 1. Subject Demographic Characteristics

Variable	ACL Injury (n=25)	Control (n=25)	Total (n=50)
Gender			
Female	6 (24%)	9 (36%)	15

Variable	ACL Injury (n=25)	Control (n=25)	Total (n=50)
Male	19 (76%)	16 (64%)	35
Age (years, mean ± SD)	30.40 ± 5.69	30.96 ± 5.09	30.68 ± 5.35
Affected Knee Side			
Right	17 (68%)	15 (60%)	32
Left	8 (32%)	10 (40%)	18
Mechanism of Injury			
Fall	8 (32%)		
Sport injury	12 (48%)		
Accident	5 (20%)		

The primary finding of this study was a statistically significant difference in the mean LFCI between the two groups. The mean LFCI in the ACL rupture group was 0.68 ± 0.56, which was significantly lower than the mean LFCI of 0.74 ± 0.56 in the control group ($p < 0.001$).

DISCUSSION

This study demonstrates a significant association between a lower Lateral Femoral Index and the incidence of non-contact ACL ruptures. Our finding that patients with ACL tears have a smaller LFCI aligns with a growing body of evidence suggesting that the anatomical morphology of the distal femur is a key intrinsic risk factor for this injury.11,12

A lower LFCI signifies a more prominent posterior condyle relative to the anterior condyle, resulting in a more asymmetric or "flatter" articular surface. From a biomechanical perspective, this asymmetry can profoundly influence knee kinematics. During dynamic movements involving deceleration and pivoting, a flattened LFC may fail to provide adequate bony constraint, facilitating greater anterior tibial translation and excessive internal tibial rotation. This altered joint mechanics increases the tensile and rotational strain experienced by the ACL, rendering it more susceptible to failure under physiological loads.9,10

The results of our study are consistent with the findings of Hodel et al., who first introduced the Lateral Femoral Condyle Index (a similar measurement) and reported significantly lower values in ACL-injured individuals compared to controls.[5] Similarly, Li et al. found that a smaller condylar index was a strong predictor of non-contact ACL rupture.[3] Our study validates these findings in an Indonesian population, suggesting that this anatomical trait is a consistent risk factor across different ethnic groups.14

The clinical implications of this finding are substantial. The LFCI can be measured reliably and cost-effectively from a standard true lateral knee radiograph, an imaging modality that is widely available. This presents an opportunity to incorporate LFCI measurement into pre-participation screening programs for athletes and other high-risk populations. Identifying individuals with a lower LFCI could allow for the implementation of targeted injury prevention strategies. Such programs may include targeted neuromuscular training to improve dynamic knee stability, proprioceptive exercises, and strengthening protocols designed to counteract adverse biomechanics and reduce injury risk.15,16

LIMITATION

This study has several limitations. First, its case-control design establishes an association but cannot prove causation. A prospective cohort study would be required to confirm LFCI as a predictive risk factor. Second, the study was conducted at a single institution, which may affect the generalizability of the findings to a broader population. Third, our study was restricted to non-contact injuries; therefore, the results may not be

applicable to ACL ruptures resulting from direct trauma. Finally, while a standardized protocol was used, radiographic measurements are subject to inter-observer and intra-observer variability.

CONCLUSION

A lower Lateral Femoral Index is significantly associated with an increased risk of non-contact Anterior Cruciate Ligament rupture. This anatomical parameter, easily measured on standard lateral knee radiographs, represents a valuable and accessible tool that may aid in screening and identifying individuals at a higher risk of ACL injury.

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