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Anatomical Characteristics of Notch Width Index and Femoral Notch Shape in Patients with Anterior Cruciate Ligament Injury

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ABSTRACT

I Background: Anterior Cruciate Ligament (ACL) injury is a significant orthopedic problem, particularly among young, active individuals. Anatomical factors, such as a narrow intercondylar notch, are considered intrinsic risks. However, findings on the association between the Notch Width Index (NWI) and femoral notch shape with ACL tears vary across populations. This study aimed to describe these anatomical characteristics in patients diagnosed with ACL injury at H. Adam Malik General Hospital, Medan.

Methods: A descriptive observational study was conducted using medical records and Magnetic Resonance Imaging (MRI) data of patients treated between January 2023 and December 2024. A total of 64 patients with confirmed ACL injuries who met the inclusion criteria were included. Data on demographics, mechanism of injury, NWI, and femoral notch shape (classified as Type A, U, or W) were collected and analyzed descriptively.

Results: The majority of patients were male (71.9%), with a mean age of 27.75 ± 8.35 years. The most common occupations were student (35.9%) and private employee (32.8%). The primary mechanism of injury was sports-related activities (64.1%), with the left knee being more commonly affected (64.1%). The mean NWI for the cohort was 0.28 ± 0.032. The most prevalent femoral notch morphologies were Type W (46.9%) and Type U (42.2%), while Type A was the least common (10.9%).

Conclusion: In this cohort, ACL injuries predominantly affect young adult males involved in sports. The average NWI suggests a tendency towards a narrower intercondylar notch. Contrary to some studies, wider notch shapes (Type W and U) were more frequent than the stenotic Type A, indicating potential population-specific anatomical variations.

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INTRODUCTION

Anterior Cruciate Ligament (ACL) injury is one of the most common and debilitating knee injuries, leading to significant joint instability, chronic pain, and an increased risk of premature osteoarthritis.[1] The incidence is particularly high in young, physically active populations, with over 200,000 cases reported annually in the United States alone.[2] While comprehensive epidemiological data for Indonesia is limited, a national rise in participation in high-risk sports such as football, basketball, and volleyball is believed to correspond with a higher incidence of these injuries.

Risk factors for ACL tears are broadly categorized as extrinsic (e.g., sport type, movement technique) and intrinsic (e.g., anatomical, biomechanical).[3] Among intrinsic factors, the morphology of the distal femur, specifically the intercondylar notch, has been a major focus of research.[4] The intercondylar notch houses the ACL, and its geometry plays a crucial biomechanical role. It is hypothesized that a narrow notch can cause mechanical impingement on the ligament during rotational and hyperextension movements, thereby increasing the risk of a tear.[5]

Two key parameters are used to evaluate this morphology: the Notch Width Index (NWI), a quantitative ratio of the notch width to the femoral condylar width, and the qualitative shape of the femoral notch, typically classified as Type A (stenotic), Type U (parallel walls), or Type W (wider base).[4],[6]

However, the existing literature presents conflicting evidence. While some studies report a significant correlation between a low NWI and ACL tears, others have failed to establish a definitive link.[7],[8] For instance, a meta-analysis by Li et al. confirmed that NWI was significantly smaller in ACL injury cases, yet other individual studies found no significant difference.[6] This disparity may be due to variations in measurement techniques (MRI vs. radiography), population heterogeneity (race, sex, age), and inconsistent definitions for a "narrow" notch. This study aims to describe the anatomical characteristics of the NWI and femoral notch shape in patients with ACL injuries at H. Adam Malik General Hospital in Medan, Indonesia, to provide valuable data specific to this local population and contribute to the broader understanding of these anatomical risk factors.

METHOD

Study Design and Population

This study was a descriptive observational study with a retrospective design. Data was sourced from patients who underwent knee Magnetic Resonance Imaging (MRI) at the Radiology and Medical Records Installation of H. Adam Malik General Hospital between January 2023 and December 2024. The study population consisted of all patients with an MRI-confirmed diagnosis of an ACL injury. Using a consecutive sampling technique, a total of 64 patients who met the predefined criteria were included.

Inclusion and Exclusion Criteria

Inclusion criteria were an age over 18 years and the availability of complete and evaluable medical records and MRI scans confirming an ACL tear. Patients were excluded if they had a history of previous surgery on the affected knee, congenital bone deformities impacting femoral notch morphology, poor quality or unevaluable MRI images, or concomitant major ligamentous injuries (e.g., PCL, MCL, LCL) that could confound interpretation.

Data Collection and Measurements

Data retrieved from patient medical records included demographic information (age, sex, occupation) and the reported mechanism of injury. All anatomical measurements were performed by evaluators on T1-weighted coronal and sagittal MRI sequences. The NWI was calculated as the ratio of the intercondylar notch width to the total width of the femoral condyles at the level of the popliteal groove.

The femoral notch was morphologically classified based on the relationship between the notch width at the popliteal level (NWP) and the notch width at the joint line (NWJ):

- Type A (Stenotic): Occurs when NWP < NWJ.
- Type U (Parallel): Occurs when the difference between NWP and NWJ is less than or equal to 1 mm.
- Type W (Wide Base): Occurs when NWP > NWJ.

Statistical Analysis

All collected data were analyzed using descriptive statistics with SPSS version 29. Numerical data, including age and NWI values, were presented as mean and standard deviation (SD). Categorical data, such as sex, occupation, side of injury, and femoral notch shape, were presented as frequencies and percentages.

RESULTS

Demographic and Clinical Characteristics

The study included 64 patients with confirmed ACL injuries. The majority of subjects were male (n=46, 71.9%), with 18 female patients (28.1%). The mean age of the cohort was 27.75 ± 8.35 years. The most represented occupational groups were students (n=23, 35.9%) and private sector employees (n=21, 32.8%). The left knee was more commonly affected (n=41, 64.1%) than the right knee (n=23, 35.9%). The most frequent mechanism of injury was sports-related activity, accounting for 41 cases (64.1%), followed by falls (n=12, 18.8%) and accidents (n=11, 17.2%).

Anatomical Measurements

The mean NWI for the patient cohort was 0.28 ± 0.032. The mean notch width at the popliteal level (NWp) was 19.08 ± 2.4 mm, and the mean notch width at the joint line (NWj) was 18.43 ± 2.73 mm (table 1).

Table 1. Notch Width Index in ACL Injury Group

Variable	ACL Injury (n = 64) Mean ± SD (Range)
Notch Width Index	0.284 ± 0.032 (0.14)
NFP	19.08 ± 2.4 (10.45)
NFW	18.43 ± 2.73 (13.74)

Regarding the femoral notch morphology, the most common shapes observed were Type W (n=30, 46.9%) and Type U (n=27, 42.2%). The stenotic Type A notch was the least frequent, identified in only 7 patients (10.9%).

DISCUSSION

This study provides a detailed descriptive overview of the demographic and anatomical characteristics of patients with ACL injuries in a specific Indonesian population. The finding that injuries are most prevalent in young, active males is consistent with global epidemiological data, which identifies this group as being at the highest risk, largely due to greater participation in high-impact and pivoting sports.[9],[10]

The mean NWI in our cohort was 0.28. This value is comparable to findings from some international studies on patients with ACL tears, such as a study in India that reported a mean NWI of 0.27 in ACL-injured patients versus 0.31 in controls.[3] Our result falls within a range often considered narrower than that of uninjured control groups, supporting the general hypothesis that a relatively smaller intercondylar notch width is a predisposing factor for ACL injury by potentially causing mechanical impingement.

Interestingly, and in contrast to several other studies, our research found that the wider femoral notch shapes, Type W (46.9%) and Type U (42.2%), were far more common than the stenotic Type A (10.9%). This finding differs from reports by Al-Saeed et al. and Akgün et al., who reported a higher prevalence of Type A notches in ACL-injured cohorts and strongly associated this stenotic shape with tear risk.[6],[11] This notable discrepancy could suggest the influence of ethnic or population-specific anatomical variations that have yet to be fully explored. It may also imply that while the NWI provides a quantitative measure of stenosis, the overall geometry and biomechanics related to Type W and U shapes could still contribute to ACL strain in this population, a factor not captured by NWI alone. For example, the specific angles and contours of these "wider" notch types could still create impingement under certain loading conditions.

This research has several limitations. The primary limitation is its descriptive, retrospective design without a control group of healthy individuals, which prevents direct statistical comparison and the calculation of risk ratios. Furthermore, as a single-center study with a modest sample size, the generalizability of the findings to the broader Indonesian population may be limited. Finally, inherent variability in MRI measurements, despite standardized protocols, can exist. Future research should aim to conduct a larger, multi-center prospective study that includes a matched control group to establish a more definitive relationship between these anatomical parameters and ACL injury risk in this population.

CONCLUSION

This study confirms that ACL injuries at H. Adam Malik General Hospital predominantly affect young, physically active males, with sports being the leading cause. Patients with ACL tears in this cohort presented with a mean NWI of 0.28, supporting the notion of a narrow intercondylar notch as a risk factor. However, the high prevalence of Type W and U femoral notch shapes, rather than the stenotic Type A, suggests that anatomical risk profiles may vary across different populations. This highlights the need for further research,

including comparative studies with local control groups, to better understand population-specific anatomical predispositions to ACL injury and to develop more targeted screening and prevention strategies.

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