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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.
GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.
ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ,რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

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Содержание:

TYPE A INTERCONDYLAR FOSSA CONFIGURATION SIGNIFICANTLY INCREASES ACL RUPTURE RISK: A MORPHOMETRIC MRI STUDY

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Abstract.

Background: Anterior cruciate ligament (ACL) rupture is a prevalent and debilitating injury, particularly among active individuals. Morphological characteristics of the femoral intercondylar fossa have been hypothesized to influence susceptibility to ACL injury, with specific shapes such as the Type A (narrow, steep-sided) notch potentially predisposing the ligament to mechanical impingement and rupture.

Purpose: To evaluate the association between intercondylar fossa morphology and the presence of ACL rupture using MRI-based morphometric assessment.

Methods: This retrospective cross-sectional study included 80 participants (40 with confirmed ACL rupture and 40 controls with intact ACL) who underwent knee MRI at the University Clinical Center of Kosovo. Intercondylar fossa shape was classified into three types—A, U, and W—based on standardized coronal and axial MRI views analyzed using Mimics software. Statistical analysis was conducted using SPSS, including chi-square testing, logistic regression, and ROC curve analysis.

Results: Type A fossa morphology was significantly more prevalent among ACL-ruptured patients ($p < .001$). Binary logistic regression revealed that individuals with a Type A fossa had an 8.76-fold increased risk of ACL rupture ($OR = 8.76$; $p < .001$). ROC curve analysis demonstrated acceptable discriminative ability ($AUC = 0.738$), with 82.5% sensitivity and 65% specificity for predicting ACL rupture based on fossa shape.

Conclusion: The morphology of the intercondylar fossa, particularly Type A configuration, is significantly associated with increased ACL rupture risk. These findings underscore the potential utility of morphological MRI assessments in screening high-risk individuals and guiding preventative strategies.

Key words. Anterior Cruciate Ligament (ACL), intercondylar fossa morphology, MRI morphometry, knee anatomy, ACL injury.

Introduction.

The anterior cruciate ligament (ACL) is a critical stabilizing structure within the knee joint, playing a central role in maintaining anteroposterior and rotational stability. Functionally, the ACL restrains anterior translation of the tibia relative to the femur and limits internal rotation, particularly during high-demand activities such as pivoting, jumping, and sudden directional changes [1,2]. Given its biomechanical importance, injury to the ACL not only compromises knee function but also predisposes individuals to long-term consequences, including meniscal damage, chondral injury, and early-onset osteoarthritis [3].

ACL rupture is one of the most common and debilitating injuries in both athletic and general populations. Epidemiologically, it is particularly prevalent among young, active individuals, with an estimated incidence ranging from 68.6 to 80 per 100,000 person-years [4]. Female athletes have shown a disproportionately higher risk compared to males in similar sporting contexts, suggesting a multifactorial etiology involving hormonal, neuromuscular, and anatomical factors [4,5].

A growing body of evidence has highlighted various risk factors contributing to ACL injury, including extrinsic elements such as playing surface and footwear, as well as intrinsic factors like ligament laxity, neuromuscular control, and lower limb alignment. Among these, anatomical morphology—particularly of the intercondylar notch—has emerged as a potentially significant predictor of injury [6]. Morphometric parameters such as notch width, notch shape, and notch width index have been associated with ACL injury risk, with narrower notches and certain notch shapes (notably the A-shaped notch) postulated to predispose the ligament to impingement and subsequent rupture [6-9]. Despite these associations, the relationship between intercondylar notch morphology and ACL injury remains controversial, partly due to heterogeneity in measurement techniques and classification systems across studies [7,10].

As summarized in Table 1, previous meta-analyses by Zeng et al. (2013) demonstrated a clear link between narrow notch dimensions and ACL rupture, whereas Andrade et al. (2016) reported similar associations but emphasized inconsistencies in measurement techniques across studies, underscoring the need for standardized methods employed in the current study [5-7,9].

A key strength of this study is its use of standardized 3D MRI-based methods (as described by Park et al. and van Eck et al.), which directly address the inconsistencies in measurement techniques noted in previous research.

The primary aim of this study is to investigate the morphological characteristics of the intercondylar notch, with a specific focus on evaluating whether the A-shaped intercondylar fossa is an independent risk factor for ACL rupture. This hypothesis is grounded in the premise that specific notch configurations may contribute to mechanical impingement or reduced spatial accommodation for the ACL, thereby increasing susceptibility to injury. By refining the understanding of anatomical risk factors, this study seeks to contribute to injury prevention strategies and improve clinical assessment of ACL injury risk.

Materials and Methodology.

This retrospective cross-sectional study was conducted at the University Clinical Center of Kosovo and included a total of 80 participants who underwent knee magnetic resonance imaging (MRI) between 2022 and 2023. Participants were divided into two equal groups: 40 patients diagnosed with anterior cruciate

Table 1. Summary of prior systematic reviews and meta-analyses on intercondylar notch morphology as a risk factor for ACL rupture.

Study (Year)	Type	Sample & Methods	Key Findings	Agreement / Discrepancies
Zeng et al. (2015)	Meta-analysis	23 studies, n ≈ 3,452; assessed ICN width, NWI, tibial slopes	ACL-injured group had significantly narrower notch width, lower notch width index, and steeper tibial slopes.	Supports narrow notch → higher ACL risk.
Andrade et al. (2016)	Systematic review + meta-analysis	23 studies; analysed ICN width, NWI, notch shape, tibial slope	Narrow ICN widths, smaller NWI, and steeper tibial slopes were associated with ACL rupture. Noted methodological heterogeneity.	Agrees overall but calls for standardization; heterogeneity noted.
Hamdy Abdel Reheem et al. (2025)	MRI case-control	187 knees; correlated NW, NWI, notch angle, shape (A-type)	Smaller NW/NWI and A-shaped notch showed higher ACL rupture incidence.	Aligns with notch stenosis hypothesis.
Park et al. (2012)	MRI comparative cohort study	150 ACL-rupture vs. 150 controls; used 3D MRI notch classification	Inlet-and-outlet stenosis notch type had smaller 3D volume and significantly higher ACL injury risk ($P < 0.001$) ().	Underscores value of 3D notch evaluation.
Chen et al. (2016)	MRI retrospective cohort	>300 subjects; MRI volume-based assessments	Narrower notch width and smaller ACL volume correlated with ACL tears ().	Supports the 3D volume approach.
Jha et al. (2020)	Meta-analysis	Focus on notch volume and sex differences	Notch volume significantly smaller (men: –1.40 cm³; women: –0.38 cm³). Noted heterogeneity in 2D measures ().	Heterogeneity resolved via volume metrics.

ligament (ACL) rupture (ACL group) and 40 individuals with no evidence of ACL injury (control group). All participants underwent MRI imaging using a 1.5 Tesla Philips Intera (Philips Medical Systems, Eindhoven, The Netherlands) for precise diagnostic assessment. The MRIs were sourced from the Department of Orthopedics and the Department of Radiology at the University Clinical Center. Inclusion criteria were: (1) patients aged between 15 and 45 years, (2) availability of high-quality sagittal, frontal and axial MRI images, and (3) no history of prior knee surgery or multi-ligamentous injury. Exclusion criteria included low-resolution imaging, previous knee surgery, or comorbid osseous deformities.

MRI Acquisition and Morphological Analysis:

MRI evaluations were performed using standardized clinical imaging protocols. Intercondylar fossa morphology was analyzed using Mimics software (Materialise, Leuven, Belgium), a specialized 3D image processing platform. MRI DICOM files were imported into Mimics, where segmentation and multiplanar reconstruction enabled accurate assessment of femoral intercondylar notch morphology. Each participant's intercondylar fossa was classified into one of three morphotypes:

Type A: Characterized by a narrow intercondylar space with steep, converging walls, forming a sharply pointed, triangular configuration.

Type U: Defined by moderate concavity with gently sloping walls and a relatively flattened base, producing a U-shaped appearance.

Type W: Distinguished by a broader intercondylar notch with widely spaced walls and a flat or slightly concave floor, resulting in a widened W-like contour.

These classifications were based on sagittal and axial visualizations, consistent with previously established morphologic criteria. To ensure standardized measurement, the methodology described by Park et al. was adopted (Figure 1 2D and 3D reconstructed MRI). Specifically, on T1-weighted coronal MRI views, a baseline was drawn along the most inferior aspects of the femoral condyles. A second line was drawn parallel to this reference at the level where the popliteal grooves were clearly visible—typically at the intermediate coronal slice among the acquired images [11]. Morphometric measurements, including notch width and notch shape classification, were recorded at this level to ensure consistency and comparability across participants.

Figure 1 Sagittal and axial 2D and 3D MRI reconstructions demonstrating intercondylar notch morphology types: Type A (narrow, triangular) classified according to established morphologic criteria and measured using the methodology of Park et al.

The inclusion age range of 15 to 45 years was chosen to ensure skeletal maturity, as the distal femoral physis typically closes by age 14–16, eliminating confounding from open growth plates that could affect notch morphology. The upper limit of 45 was selected to minimize the influence of age-related degenerative changes, such as osteophyte formation, which could distort intercondylar fossa measurements or affect ACL integrity. The ACL rupture and control groups were frequency-matched for age and exhibited similar gender distributions (82.5% vs. 72.5% male, respectively), supporting approximate demographic balance between groups. Consequently, age and gender were excluded as covariates from logistic regression to avoid overfitting, as their inclusion would not add predictive value in the context of matched groups and could introduce collinearity into the mode.

Intercondylar fossa morphology was independently classified by two observers—one orthopedic surgeon and one musculoskeletal radiologist—who categorized all 80 MRI cases

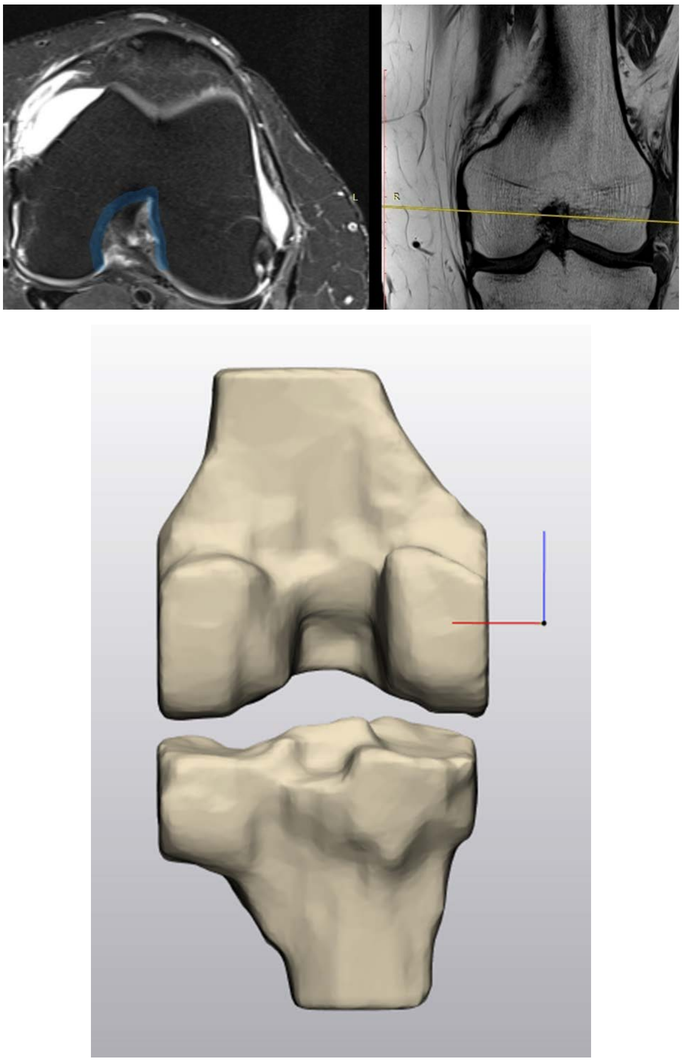

Figure 1. *Sagittal and axial 2D and 3D MRI reconstructions demonstrating intercondylar notch morphology types.*

into Types A, U, or W using standardized imaging criteria. Inter-rater reliability was assessed by calculating Cohen's kappa, which demonstrated near-perfect agreement (κ=0.976, p<0.001) across the dataset.

Data Management and Statistical Analysis:

Morphological data extracted from Mimics were compiled and exported to IBM SPSS Statistics version 23.0 (IBM Corp., Armonk, NY, USA) for statistical processing. Descriptive statistics were used to summarize participant demographics and distribution of intercondylar fossa types. Chi-square tests were applied to assess the association between fossa morphology and ACL rupture status. Pearson's R and Spearman's rho were used to determine correlation strength. To further evaluate the predictive capacity of fossa morphology—particularly Type A configuration—on ACL injury risk, binary logistic regression analysis was performed, calculating odds ratios (OR) and 95% confidence intervals (CI). Additionally, a receiver operating characteristic (ROC) curve analysis was conducted to assess diagnostic performance and determine sensitivity and specificity at a threshold probability of 0.50.

Results.

Participant Characteristics:

The study comprised 80 participants, equally divided between those diagnosed with anterior cruciate ligament (ACL) rupture (n = 40) and a control group with no rupture (n = 40). Participants were aged between 15 and 45 years and predominantly male (77.5%, n = 62). Laterality of the assessed knee showed a near-even distribution: 52.5% right-sided (n = 42) and 47.5% left-sided (n = 38). Intercondylar fossa shapes were categorized into three types based on MRI: Type A (58.8%, n = 47), Type U (36.3%, n = 29), and Type W (5%, n = 4). All descriptives are shown in Table 2.

Fossa Type and ACL Rupture Association:

A Pearson Chi-square test revealed a statistically significant association between fossa type and ACL rupture status ($\chi^2(2)$ = 18.646, p < .001), indicating that the distribution of rupture risk differed by intercondylar notch shape. The linear-by-linear association was also significant ($\chi^2(1)$ = 15.616, p < .001), suggesting a gradient relationship across the fossa types. Symmetric measures confirmed this finding, with moderate negative correlations observed between fossa type and ACL rupture using Pearson's R (r = -0.445, p < .001) and Spearman's rho (ρ = -0.472, p < .001). These results indicate that as the fossa shape progresses from Type A to U and W, the incidence of ACL rupture decreases.

Logistic Regression Analysis:

To quantify the predictive strength of Type A fossa on ACL rupture risk, a binary logistic regression was performed. A dichotomous variable compared Type A (coded as 1) against Types U and W combined (coded as 0). The model was statistically significant ($\chi^2(1)$ = 19.547, p < .001), accounting for 28.9% of the variance in ACL rupture status (Nagelkerke R^2 = 0.289). The model correctly classified 73.8% of cases, with a high sensitivity for detecting ruptures (82.5%) and moderate specificity (65.0%). Notably, the odds ratio for Type A fossa was 8.76 (B = 2.170, p < .001), indicating that individuals with a Type A fossa were nearly nine times more likely to sustain an ACL rupture compared to those with other fossa shapes.

Type A femoral fossa morphology significantly increases the likelihood of ACL rupture.

The effect size is substantial, and the model has solid predictive power.

"A multinomial logistic regression treating fossa type as a three-level categorical variable confirmed the trend of increased rupture risk associated with Type A morphology (OR = 0.141), though this did not reach statistical significance (p = .103), potentially due to the small number of Type W cases."

To assess the discriminative ability of intercondylar fossa shape (Type A vs. U/W) in predicting ACL rupture, an ROC curve analysis was performed. The model achieved an area under the curve (AUC) of 0.738, indicating acceptable diagnostic accuracy and suggesting that fossa morphology can correctly distinguish between rupture and non-rupture cases approximately 74% of the time.

Table 2. Participants characteristics depending on laterality, gender and the type of intercondylar fossa.

Variable	Category	ACL Rupture Group (n=40)	Control Group (n=40)	Total Count	Total Percentage (%)
Laterality	Left	21	17	38	47.5
	Right	19	23	42	52.5
	Type A	33 (82.5%)	14 (35.0%)	47	58.8
Intercondylar Fossa Type	Type U	6 (15.0%)	23 (57.5%)	29	36.3
	Type W	1 (2.5%)	3 (7.5%)	4	5.0
Gender	Male	33	29	62	77.5
	Female	7	11	18	22.5

The optimal cutoff probability, determined using the Youden index, was 0.50, which provided the highest combined sensitivity (82.5%) and specificity (65.0%), corresponding to a Youden index of 0.475. This threshold offers a clinically relevant decision point for identifying individuals at elevated risk of ACL rupture based on intercondylar notch morphology, particularly the presence of a Type A configuration.

Discussion.

The current study investigated the association between intercondylar fossa morphology and anterior cruciate ligament (ACL) rupture, with findings revealing a statistically significant correlation. Specifically, Type A fossa was found to be disproportionately associated with ACL ruptures compared to Types U and W. Logistic regression analysis indicated that individuals with a Type A fossa were nearly nine times more likely to sustain an ACL rupture (OR = 8.76), strongly reinforcing the hypothesis that femoral morphology contributes significantly to ligament vulnerability.

These results are consistent with previous MRI-based morphometric investigations. Misbah et al. observed that a narrower, A-shaped femoral notch was significantly more common in patients with complex bicruciate injuries [12]. Likewise, Kacem et al. emphasized that reduced notch width index (NWI) and a more acute notch angle are reliable predictors of ACL rupture, suggesting biomechanical impingement within constricted femoral architecture [13]. Van Kuijk et al. further supported this premise by demonstrating that individuals with smaller intercondylar notches and ACL volumes exhibited increased rates of posterior cruciate ligament injuries, implying a broader anatomical susceptibility rooted in joint morphology [14].

Our results are consistent with prior MRI-based findings by Chen et al. (2016), who reported that narrowed intercondylar notch width and reduced notch volume are significantly associated with ACL rupture, and with the meta-analysis by Jha et al. (2021), which confirmed that smaller femoral notch volumes substantially increase the risk of ACL injury [15,16].

Similarly, recent MRI research by Hamdy Abdel Reheem et al. (2025) demonstrated that patients with A-shaped intercondylar notches and reduced notch width index had a significantly higher incidence of ACL rupture, further reinforcing the role of notch morphology as a key anatomical risk factor [17].

In our study, 59% of participants exhibited Type A morphology, compared to a prevalence of 35% in asymptomatic controls reported by Al-Saeed et al. and Cernat et al., suggesting our sample may overrepresent high-risk morphologies relative to the general population. However, consistent with our findings, Al-Saeed et al. demonstrated that individuals with Type A had a markedly higher ACL tear incidence (73%) than those with Type U/W (32%), reinforcing the strong association between Type A morphology and ACL rupture risk [18,19].

Pediatric data also mirror these trends. Pękala et al. and Silva et al. independently reported that narrowed notch shapes and reduced notch opening angles in immature skeletons were associated with increased ACL rupture rates [20,21]. These findings highlight the possibility that anatomical predispositions may begin early in musculoskeletal development.

Further anatomical validation is found in the work of Bouras et al. [8], who used MRI imaging to confirm that a stenotic Type A notch correlates with higher ACL injury incidence in young females [16]. Bayer et al. also emphasized the predictive value of intercondylar morphology in ACL injury risk, particularly when combined with other geometric indicators such as alpha angle and tibial slope [5]. Zeng et al. consolidated these associations in a meta-analysis, confirming that decreased notch width and volume significantly elevate rupture risk [7].

Moreover, Van Eck et al. conducted in vivo arthroscopic evaluations of notch shapes, noting that Type A notches were significantly more prevalent in ACL-deficient knees [9]. A large prospective cohort by Whitney et al. echoed this, identifying a correlation between femoral notch narrowing and first-time ACL rupture, particularly among female athletes [22].

Taken together, this growing body of evidence reinforces the anatomical theory that stenosis of the intercondylar notch—whether through decreased width, altered angle, or A-type morphology—places the ACL at mechanical disadvantage, rendering it more susceptible to injury.

Despite the robustness of our findings, certain limitations must be acknowledged. The sample was predominantly male, which may limit generalizability to female and pediatric populations. The classification of intercondylar notch shapes (A, U, W) remains a qualitative system and could be further enhanced by 3D morphometric modelling and automated imaging segmentation in future studies. Additionally, future work should explore the interaction between static anatomical risk factors and dynamic neuromuscular control to develop comprehensive injury prediction models.

Conclusion.

This study provides compelling evidence that the morphology of the intercondylar femoral fossa significantly influences the likelihood of anterior cruciate ligament (ACL) rupture. Specifically, individuals with a Type A fossa were found to have a markedly higher risk of ACL injury compared to those with U or W-shaped fossae. The strong association was supported by multiple statistical methods, including chi-square analysis, binary and multinomial logistic regression, and ROC curve analysis, with the latter yielding an area under the curve (AUC) of 0.738—indicating acceptable diagnostic accuracy. These findings underscore the clinical relevance of incorporating fossa shape assessment into routine MRI evaluations, especially in athletic or high-risk populations. Early identification of high-risk anatomical patterns could enable targeted prevention strategies, such as neuromuscular training or activity modification, potentially reducing the burden of ACL injuries. However, despite the observed association, the moderate sensitivity (82.5%) and specificity (65.0%) of Type A morphology at the optimal threshold highlight the limitations of relying on this parameter alone as a screening tool. Given its substantial prevalence in the general population, sole dependence on Type A identification could lead to overdiagnosis and unnecessary interventions. Therefore, fossa morphology should be integrated into a comprehensive assessment that includes additional anatomical, biomechanical, and clinical factors to guide individualized ACL injury risk stratification. Future research with larger, more diverse cohorts is warranted to further validate these findings and explore underlying biomechanical mechanisms.

Authors' contributions.

Premtim Rashiti – writing
Jeton Shatri – radiologic scanning and evaluation
Ardita Kafexholli – writing
Leotrim Berisha – data gathering
Dijon Musliu – 3D reconstruction and statistical analysis

Consent.

Yes

Ethical Considerations.

This study was approved by the institutional ethics board of the University Clinical Center of Kosovo. All data were anonymized prior to analysis to ensure participant confidentiality. Informed consent was waived due to the retrospective and non-interventional nature of the study.

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