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MRI Assessment of Patellofemoral Morphology and Chondromalacia Severity in Young Soccer Players: A Case-Control Study

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Abstract

Introduction:

Patellofemoral chondromalacia is an important cause of anterior knee symptoms in physically active individuals. Repetitive loading during football may interact with patellofemoral anatomical variations and contribute to cartilage damage. This study investigated the association between MRI-defined patellofemoral chondromalacia, anatomical variations, and demographic characteristics in young footballers.

Methods

This case-control study included 70 footballers aged 18–30 years with knee pain who underwent MRI between 2024 and 2025. Thirty-five participants with symptomatic anatomical variations constituted the case group, and 35 without anatomical variations constituted the control group. TT–TG distance, Insall–Salvati ratio, lateral trochlear inclination, trochlear facet asymmetry, and trochlear depth were evaluated. Chondromalacia was graded using the Modified Outerbridge system. Data were analyzed using SPSS version 25 with parametric or non-parametric tests as appropriate, and $P < 0.05$ was considered statistically significant.

Results

Age and BMI did not differ significantly between groups. TT–TG distance was greater in the anatomical-variation group (11.50 ± 4.71 vs 9.38 ± 3.25 mm; $P = 0.032$), whereas the Insall–Salvati ratio (0.82 ± 0.10 vs 0.88 ± 0.07; $P = 0.003$) and trochlear facet asymmetry (0.63 ± 0.14 vs 0.73 ± 0.13; $P = 0.002$) were both lower. Patella baja occurred in 54.3% of participants with anatomical variations and none of the controls ($P < 0.001$), and trochlear depth was significantly lower in the variation group (2.73 ± 1.08 vs 3.84 ± 1.53 mm; $P < 0.001$). Chondromalacia grades differed significantly between groups ($P < 0.001$), with grade 3–4 disease affecting 65.7% versus 8.6% of the variation and control groups, respectively.

Conclusion

Patellofemoral anatomical variations were strongly associated with a greater burden and severity of MRI-defined chondromalacia in young footballers, particularly increased TT–TG distance, patella baja, reduced trochlear facet asymmetry, and shallower trochlear depth.

Introduction

Football is one of the most physically demanding sports, requiring repeated high-intensity activities such as sprinting, jumping, kicking, and rapid changes in direction. These movements expose the knee joint to

repetitive mechanical loading and increase the risk of patellofemoral disorders among football players (1). Knee injuries are among the most common musculoskeletal problems in football athletes and are associated with reduced participation, impaired performance, and prolonged recovery periods (2). Patellofemoral pain and cartilage abnormalities represent important causes of anterior knee symptoms(3), particularly in physically active young individuals.

The patellofemoral joint is particularly vulnerable to repetitive mechanical loading, and abnormalities of patellar tracking or trochlear morphology may alter contact mechanics and contribute to progressive cartilage deterioration (4). This issue is clinically relevant in footballers, who are repeatedly exposed to high-load running, acceleration, deceleration, cutting, kicking, and rotational movements of the knee. A recent MRI study of 85 active male professional soccer players encompassing 170 knees identified cartilage abnormalities in 141 knees, while structural cartilage defects were present in 54% of knees (5).

Patellofemoral morphology appears to influence the presence and severity of chondral abnormalities. Öztürk and Güngör evaluated 136 knees and demonstrated that chondromalacia was significantly more frequent and severe in knees with abnormal patellofemoral morphology; trochlear depth, Insall–Salvati index, and trochlear and patellar facet asymmetry differed significantly between patients with and without chondromalacia (6). Similarly, Soufi et al. reported significant associations of patellofemoral OA with TT–TG distance, trochlear dysplasia, patellar position, and the Insall–Salvati ratio in a case-control study of 400 participants (7).

Magnetic resonance imaging is particularly suitable for this purpose because it enables simultaneous assessment of articular cartilage and patellofemoral morphology without ionizing radiation (8). A systematic review and meta-analysis including 3,534 participants reported an overall MRI sensitivity of approximately 0.80, specificity of 0.90, and an area under the summary receiver-operating-characteristic curve of 0.90 for detecting patellofemoral cartilage injuries compared with arthroscopy (9). Accordingly, the present study aimed to investigate the association between MRI-defined patellofemoral chondromalacia, anatomical variations, and demographic characteristics in young footballers with knee pain.

METHODS

Study Design and Participants

This case-control study was conducted between 2024 and 2025 at Poursina Hospital and the Medical Imaging Center affiliated with Guilan University of Medical Sciences, Rasht, Iran. The study population consisted of male football players aged 18–30 years who were evaluated for patellofemoral abnormalities and knee symptoms. A total of 70 participants were included and categorized into two groups: 35 football players with symptomatic patellofemoral anatomical variations (case group) and 35 football players without anatomical variations (control group).

Participants were eligible if they were active football players aged between 18 and 30 years, had knee pain, and underwent knee magnetic resonance imaging (MRI). Participants were excluded if they had a history of previous knee surgery, significant knee trauma, or other known knee joint disorders that could affect patellofemoral assessment. Participants with incomplete clinical or imaging data were also excluded from the final analysis.

The sample size was determined using G*Power software based on previously reported differences in the Insall–Salvati ratio between groups (7). Considering an effect size of 0.83, a two-sided α level of 0.05, statistical power of 90%, and an allocation ratio of 1:1, the minimum required sample size was estimated as 64 participants (32 participants per group). Finally, 70 football players were enrolled, with 35 participants included in each group.

All participants provided written informed consent before inclusion in the study. The study was conducted in accordance with the principles of the Declaration of Helsinki (10). Ethical approval was obtained from the Ethics Committee of Guilan University of Medical Sciences. (IR.GUMS.REC.1404.253)

Data Collection and MRI Assessment

Demographic and clinical characteristics, including age, sex, height, weight, body mass index (BMI), dominant leg, and affected knee, were collected for all participants. MRI examinations were evaluated to assess patellofemoral anatomical parameters and cartilage status. The evaluated morphological parameters included tibial tubercle–trochlear groove (TT–TG) distance, patellar height based on the Insall–Salvati ratio, trochlear morphology parameters, and patellofemoral cartilage abnormalities.

The TT–TG distance was measured as the horizontal distance between the tibial tubercle and the deepest point of the trochlear groove and was used as an indicator of patellar alignment. Patellar height was assessed using the Insall–Salvati ratio, calculated as the ratio between patellar tendon length and patellar length. Based on the study protocol, values were categorized into patella baja, normal patellar height, and patella alta.

Trochlear morphology was assessed using measurements including lateral trochlear inclination (LTI), trochlear depth, and trochlear facet asymmetry. LTI was defined as the angle between the lateral trochlear facet and the posterior condylar reference line. Trochlear depth was calculated based on the relationship between the deepest point of the trochlear groove and the anterior aspects of the medial and lateral trochlear facets. These parameters were used to identify morphological abnormalities associated with patellofemoral dysfunction.

The severity of patellofemoral cartilage damage was evaluated using the Modified Outerbridge classification system. Cartilage lesions were graded from grade 0 to grade 4, where grade 0 represented normal cartilage, grade 1 represented cartilage signal abnormalities without surface disruption, grade 2 represented superficial cartilage defects, grade 3 represented partial-thickness cartilage loss with focal

ulceration, and grade 4 represented full-thickness cartilage loss with associated subchondral bone changes.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were assessed for normal distribution using the Shapiro–Wilk test. Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR), according to data distribution, while categorical variables were presented as frequencies and percentages. Comparisons of demographic characteristics between the two groups were performed using appropriate statistical tests. The independent-samples t-test was applied for normally distributed continuous variables, whereas the Mann–Whitney U test was used for variables that did not meet normality assumptions. Categorical variables were compared using Pearson's chi-square test or Fisher's exact test when appropriate. Between-group comparisons were performed for MRI-derived continuous parameters, including TT–TG distance, Insall–Salvati ratio, lateral trochlear inclination angle, trochlear depth, and trochlear facet asymmetry. Categorical MRI findings, including patellar height categories, TT–TG classification, trochlear abnormalities, and Modified Outerbridge cartilage grades, were compared between groups using chi-square or Fisher's exact tests. A two-tailed P value < 0.05 was considered statistically significant.

Results

A total of 70 patients were included, with 35 patients presenting with anatomical variation and 35 serving as the control group without such variation. The mean age of the overall cohort was 25.79 ± 4.28 years, and the mean BMI was 20.43 ± 1.10 kg/m², indicating a young, normal-weight population. No statistically significant differences were observed between the two groups regarding age ($p = 0.459$), BMI ($p = 0.310$), or side dominance/involvement ($p > 0.05$ for both), confirming that the groups were well-matched for these potential confounders. The baseline demographic and clinical characteristics of the study population are summarized in Table 1.

Table 1
Baseline demographic and clinical characteristics of the study population

Variable	Total (n = 70)	Anatomical variation (n = 35)	No anatomical variation (n = 35)	P value
Age, years, mean ± SD	25.79 ± 4.28	26.17 ± 4.23	25.40 ± 4.35	0.459
BMI, kg/m², mean ± SD	20.43 ± 1.10	20.29 ± 1.07	20.57 ± 1.12	0.310
Right dominant knee, n (%)	36 (51.4)	18 (51.4)	18 (51.4)	0.999
Right involved knee, n (%)	35 (50.0)	18 (51.4)	17 (48.6)	0.811

MRI Morphometric Measurements

Continuous MRI-based morphometric parameters are presented in Table 2. Patients with anatomical variation demonstrated significantly greater TT–TG distance (11.50 ± 4.71 mm vs. 9.38 ± 3.25 mm, p = 0.032) and a lower Insall–Salvati ratio (0.82 ± 0.10 vs. 0.88 ± 0.07, p = 0.003), indicating increased lateralization of the tibial tubercle and a higher prevalence of patella baja, respectively. Trochlear facet asymmetry was significantly reduced in the anatomical variation group (0.63 ± 0.14 vs. 0.73 ± 0.13, p = 0.002), and trochlear depth was markedly shallower (2.73 ± 1.08 mm vs. 3.84 ± 1.53 mm, p < 0.001). Conversely, lateral trochlear inclination did not differ significantly between groups (p = 0.196).

Table 2
Comparison of continuous magnetic resonance imaging (MRI) morphometric parameters between patients with and without patellofemoral anatomical variation

MRI parameter	Anatomical variation (n = 35)	No anatomical variation (n = 35)	P value
TT–TG distance, mm, mean ± SD	11.50 ± 4.71	9.38 ± 3.25	**0.032**
Insall–Salvati ratio, mean ± SD	0.82 ± 0.10	0.88 ± 0.07	**0.003**
Lateral trochlear inclination, °	24.17 ± 6.73	26.03 ± 5.01	0.196
Trochlear facet asymmetry, mean ± SD	0.63 ± 0.14	0.73 ± 0.13	**0.002**
Trochlear depth, mm, mean ± SD	2.73 ± 1.08	3.84 ± 1.53	**< 0.001**

Distribution of categorical MRI abnormalities

Table 3 reports the distribution of categorical MRI abnormalities. Regarding TT–TG distance, all controls (100%) had normal values, whereas 20.0% of patients with anatomical variation had borderline measurements and 2.9% had increased values ($p = 0.005$). Patella baja was observed exclusively in the anatomical variation group, affecting 54.3% of patients ($p < 0.001$). Abnormal trochlear depth was present in 82.9% of patients with anatomical variation, compared to only 2.9% of controls ($p < 0.001$). Notably, trochlear facet asymmetry was universally abnormal (100%) in both groups, suggesting this may be a pervasive feature rather than a distinguishing marker.

Table 3
Distribution of categorical MRI abnormalities in patients with and without patellofemoral anatomical variation

Variable		Anatomical variation, n (%)	No anatomical variation, n (%)	P value
TT–TG				**0.005**
	Normal	27 (77.1)	35 (100.0)	
	Borderline	7 (20.0)	0	
	Increased	1 (2.9)	0	
Patellar height (Patella baja)		19 (54.3)	0	**< 0.001**
Lateral trochlear inclination (Abnormal)		1 (2.9)	0	0.999
Trochlear Facet Asymmetry (Abnormal)		35(100.0)	35(100.0)	-
Trochlear depth (Abnormal)		29 (82.9)	1 (2.9)	**< 0.001**

Distribution of Modified Outerbridge chondromalacia grades

Patients with anatomical variation exhibited a significantly more severe cartilage damage profile compared to controls ($p < 0.001$). In the anatomical variation group, the majority demonstrated advanced degeneration, with 48.6% classified as grade 4 and 17.1% as grade 3, whereas only 11.4% had no evidence of chondromalacia (grade 0). Conversely, the control group predominantly exhibited mild or no cartilage damage, with 51.4% grade 0 and 37.1% grade 1; only 8.6% reached grade 4. These findings suggest a strong association between patellofemoral anatomical variation and progressive cartilage deterioration. The distribution of Modified Outerbridge chondromalacia grades is displayed in Table 4.

Table 4
Distribution of Modified Outerbridge chondromalacia grades in patients with and without patellofemoral anatomical variation

Chondromalacia grade	Anatomical variation (n = 35)	No anatomical variation (n = 35)
Grade 0	4 (11.4%)	18 (51.4%)
Grade 1	5 (14.3%)	13 (37.1%)
Grade 2	3 (8.6%)	1 (2.9%)
Grade 3	6 (17.1%)	0
Grade 4	17 (48.6%)	3 (8.6%)
Overall P value	**< 0.001**	

Discussion

In this case–control study of 70 symptomatic male football players aged 18–30 years, patellofemoral anatomical variation was associated with a distinctly adverse magnetic resonance imaging (MRI) phenotype: greater tibial tubercle–trochlear groove (TT–TG) distance, a lower Insall–Salvati ratio, reduced trochlear facet asymmetry, and substantially shallower trochlear depth. Importantly, 65.7% of players with anatomical variation had grade 3–4 chondromalacia compared with 8.6% of controls, whereas lateral trochlear inclination (LTI) did not differ significantly. These findings suggest that, among young footballers presenting with knee pain, patellofemoral geometry may identify a subgroup with disproportionately severe cartilage injury; however, the observational design does not establish that anatomical variation preceded or caused cartilage deterioration.

The strong association between abnormal morphology and chondromalacia severity is consistent with Öztürk and Güngör (2024), who reported a significantly greater incidence and grade of chondromalacia in knees with abnormal patellofemoral morphology and identified differences in trochlear depth, trochlear facet asymmetry, and the Insall–Salvati index (6). Similarly, Duran and Günaydin (2021) found that flatter trochlear morphology was associated with medial patellar cartilage defects, with lower trochlear inclinations accompanying increasing cartilage loss (11). Collectively, these observations and the markedly shallower trochlea in the present study support a plausible biomechanical explanation: diminished trochlear containment may alter patellar tracking and reduce effective articular congruence, potentially concentrating repetitive contact stresses during football-specific loading. This interpretation remains mechanistic rather than causal and requires longitudinal confirmation.

The findings concerning TT–TG distance and patellar height are more nuanced. Soufi et al. (2023), in a case–control study including 200 patients with patellofemoral osteoarthritis and 200 controls, found greater TT–TG distance, more frequent trochlear dysplasia, and a higher Insall–Salvati ratio/patella alta in affected knees (7). Their TT–TG findings therefore support the present results, whereas the direction of patellar-height abnormality differs. Namiri et al. (2023), analyzing 2,461 knees from the multicenter Osteoarthritis Initiative, likewise demonstrated relationships between patellofemoral degeneration and

joint geometry, including reduced trochlear depth and altered tibial-tubercle position (12). Notably, Kim et al. (2026) found that high-grade chondromalacia was associated with significantly lower Insall–Salvati and modified Insall–Salvati values, providing contemporary support for the direction observed in our cohort despite substantial differences in population characteristics (13).

The football-specific context further strengthens the clinical relevance of these observations. Welsch et al. (2026) evaluated 170 knees from 85 active professional soccer players with a mean age of 24 years and found cartilage abnormalities in 141 knees, with structural cartilage lesions present in 54% (5). The concentration of advanced cartilage damage among anatomically variant players in the present study suggests that morphology may partly explain heterogeneity in cartilage burden among athletes exposed to broadly similar sporting demands. MRI is also a defensible modality for this phenotype: Xará-Leite et al. (2023), in a systematic review and meta-analysis of 3,534 participants, reported approximately 0.80 sensitivity, 0.90 specificity, and a summary receiver-operating-characteristic area of 0.90 for detecting patellofemoral cartilage injury compared with arthroscopy (14).

Clinical implications

Clinically, these findings support systematic assessment of trochlear depth, TT–TG distance, patellar height, and cartilage grade when evaluating young footballers with persistent patellofemoral symptoms, rather than interpreting cartilage abnormalities independently of joint morphology. Imaging abnormalities should, however, inform risk stratification rather than independently determine treatment. The ICRS–FIFA–Aspetar consensus reported by Kon et al. (2025) considered surgery appropriate in only 32% of modeled scenarios for symptomatic cartilage lesions in competitive footballers, with decisions primarily influenced by symptom severity, lesion size, subchondral bone involvement, and player priorities (15). Accordingly, advanced cartilage loss combined with adverse morphology should prompt comprehensive sports-medicine or cartilage-specialist assessment and individualized load and return-to-play decision-making rather than automatic corrective surgery.

Unexpected findings

Three observations warrant particular attention: the predominance of patella baja rather than patella alta, the absence of a significant LTI difference, and the classification of trochlear facet asymmetry as abnormal in 100% of both groups. The low patellar-height finding is directionally supported by Kim et al. (2026) (13) but contrasts with Banach et al. (2024), who associated isolated advanced patellar chondromalacia with patella alta (16). These discrepancies may reflect differences in age, athletic exposure, case definition, MRI positioning, or measurement thresholds rather than fundamentally opposing biological mechanisms. Tanaka et al. (2023) demonstrated that optimal MRI thresholds for trochlear dysplasia vary according to whether bony or cartilaginous landmarks are used and may also differ by sex (17). This variability may partly explain the universal facet-asymmetry abnormality and limited discrimination of LTI in the current cohort.

Strengths

The principal strengths are the clinically focused and relatively homogeneous population of young male football players, balanced case and control groups, and simultaneous MRI assessment of several interrelated components of patellofemoral morphology. The study additionally evaluated cartilage injury across the complete Modified Outerbridge spectrum rather than simply dichotomizing cartilage as normal or abnormal. Age, BMI, knee dominance, and side of involvement were comparable between groups, thereby reducing confounding by these measured characteristics. The work also addresses an important evidence gap between general studies of patellofemoral morphology and athlete-specific research on cartilage damage.

Limitations

Several methodological issues temper interpretation. First, the case–control, single-center design establishes association but cannot establish temporality; severe cartilage abnormalities could coexist with, rather than result from, the observed morphology. Second, because case status was defined by the presence of patellofemoral anatomical variation, subsequent comparison of the same or closely related morphometric variables may introduce incorporation or classification bias and exaggerate between-group separation. Third, no multivariable regression was reported; consequently, the independent contributions of TT–TG distance, patellar height, trochlear depth, and other correlated morphological parameters cannot be distinguished. Fourth, multiple MRI parameters (five continuous and four categorical) were compared between groups without formal correction for multiplicity; the analysis should therefore be regarded as exploratory, and the possibility that some associations reflect chance findings cannot be excluded. The substantial difference in cartilage severity could also partly reflect referral or spectrum bias because all participants had knee pain and had already undergone MRI.

Measurement and generalizability limitations are equally relevant. Inter- and intra-reader reliability for the present morphometric measurements was not reported, while universal abnormal facet-asymmetry classification raises concern regarding threshold calibration. Although 70 participants exceeded the prespecified sample-size requirement based on the Insall–Salvati effect, the study may remain underpowered for smaller effects such as LTI or for interaction analyses. Generalization to female players, adolescents, older athletes, asymptomatic footballers, recreational populations, and populations with different anthropometric or anatomical distributions should therefore be cautious. Finally, cumulative training exposure, playing position, career duration, previous minor injuries, lower-limb alignment, muscle strength, and workload were not incorporated into adjusted analyses and remain plausible confounders or effect modifiers.

Future directions

Prospective multicenter studies should determine whether baseline trochlear depth, TT–TG distance, patellar height, and composite morphology profiles predict incident or progressive cartilage deterioration in football players. Such studies should use standardized MRI acquisition and knee positioning, blinded duplicate measurements with formal reliability testing, and arthroscopic validation when clinically available. Larger cohorts would permit multivariable and interaction modeling incorporating cumulative football exposure, sex, age, prior injury, alignment, and workload. Continuous morphometric variables should preferably be analyzed alongside clinically validated, population-specific thresholds rather than relying exclusively on categorical definitions. Ultimately, longitudinal studies linking anatomy to quantitative cartilage MRI, symptoms, functional performance, time loss from football, and return-to-play outcomes are required before these anatomical markers can justify preventive or corrective interventions.

Conclusion

This study demonstrates that symptomatic anatomical variations of the knee in young football players are associated with distinct structural characteristics on MRI, highlighting the potential role of anatomical morphology in the development of patellofemoral-related pathology and cartilage abnormalities. Although these variations may not represent isolated disease entities, their presence in symptomatic athletes may contribute to altered joint biomechanics, increased mechanical stress, and susceptibility to cartilage injury. Recognition of these anatomical factors may improve clinical assessment, facilitate individualized injury prevention strategies, and support more targeted rehabilitation approaches in athletic populations. MRI evaluation provides valuable information for identifying structural risk patterns that may not be apparent through clinical examination alone. Future longitudinal studies with larger multicenter cohorts are warranted to clarify causal relationships, determine prognostic significance, and establish evidence-based screening and management protocols for athletes at increased risk of knee pathology.

Abbreviations

BMI Body mass index

FIFA Fédération Internationale de Football Association

ICRS International Cartilage Regeneration and Joint Preservation Society

IQR Interquartile range

LTI Lateral trochlear inclination

MRI Magnetic resonance imaging

OA Osteoarthritis

SD Standard deviation

SPSS Statistical Package for the Social Sciences

TT–TG Tibial tubercle–trochlear groove

Declarations

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Authors Contributions

Soudabeh Alinezhad: Conceptualization, methodology, and imaging assessment; Zoubin Souri: Validation and data interpretation; Saeid Sadeghi Joni: Data acquisition and imaging assessment; Mohammad Amouzadeh-Lichahi: Formal analysis and manuscript review; Samman Mohammadi: Data analysis and original draft preparation; Sina Kamrani Moghadam: Supervision and critical revision. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate

The study was approved by the Ethics Committee of Guilan University of Medical Sciences (approval no. IR.GUMS.REC.1404.253). All participants provided written informed consent before enrollment. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

Clinical trial number

Not applicable

Consent for Publication

Not applicable.

Competing Interests

The authors declare that they have no competing interests.

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References

1. Smith RDJ, Hanrahan M, Gerber A, Tanaka MJ. Patellofemoral Disorders in Soccer Players. Sports Med Arthrosc Rev. 2024;32(3):146–55.
2. Roth TS, Osbahr DC. Knee Injuries in Elite Level Soccer Players. American journal of orthopedics (Belle Mead. NJ). 2018;47(10).
3. Sanchis-Alfonso V, McConnell J, Monllau JC, Fulkerson JP. Diagnosis and treatment of anterior knee pain. J ISAKOS. 2016;1(3):161–73.
4. Wilk KE, Arrigo CA. Principles of patellofemoral rehabilitation. Knee Arthroscopy and Knee Preservation Surgery. Springer; 2024. pp. 1–17.
5. Welsch GH, Regier M, Frosch K-H, Pachowsky ML, Henes FO, Adam G, et al. Whole-Organ Magnetic Resonance Imaging Score (WORMS) of the knee in professional soccer players. Cartilage. 2026;17(3):267–77.
6. Öztürk C, Güngör Ö. Relationship between patellofemoral joint morphology and chondromalacia patella. Acta Radiol. 2024;65(1):62–7.
7. Jamalipour Soufi G, Hekmatnia A, Hekmatnia F, Zarei AP, Bahrami M, Rasti S, et al. Association between patellofemoral osteoarthritis with demographic features and anatomical variants of the knee in non-traumatic patients. Int J Physiol Pathophysiol Pharmacol. 2023;15(6):142–9.
8. Katano H, Ozeki N, Mizuno M, Endo K, Okanouchi N, Fujita J, et al. Morphological analysis of three-dimensional MR images of patellofemoral joints in asymptomatic subjects. Sci Rep. 2023;13(1):16750.
9. Xará-Leite F, Vinha A, Valente C, Andrade R, Espregueira-Mendes J. Magnetic resonance imaging is able to detect patellofemoral focal cartilage injuries: a systematic review with meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2023;31(6):2469–81.
10. Association WM. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human participants. JAMA. 2025;333(1):71–4.
11. Duran S, Gunaydin E. Investigation of the relationship between trochlear morphology and medial patellar cartilage defect using magnetic resonance imaging. Acta Orthop Belg. 2021;87:352–8.

12. Namiri NK, Càliva F, Martinez AM, Pedoia V, Lansdown DA. A more posterior tibial tubercle (decreased sagittal tibial tubercle–trochlear groove distance) is significantly associated with patellofemoral joint degenerative cartilage change: a deep learning analysis. Arthroscopy. 2023;39(6):1493–501. e2.
13. Kim JN, Park HJ, Choi YG, Kim MS. Patellar height measured on radiographs and MR imaging and its relationship with chondromalacia patella. J Clin Ultrasound. 2026;54(2):391–8.
14. Xará-Leite F, Vinha A, Valente C, Andrade R, Espregueira-Mendes J. Magnetic resonance imaging is able to detect patellofemoral focal cartilage injuries: A systematic review with meta-analysis. Knee Surg Sports Traumatol Arthrosc. 2023;31(6):2469–81.
15. Kon E, Papakostas E, Andriolo L, Serner A, Massey A, Verdonk P, et al. ICRS-FIFA-Aspetar consensus on the management of knee cartilage injuries in football players: part 1–appropriateness of surgery in different clinical scenarios using the RAND/UCLA appropriateness method. Br J Sports Med. 2025;59(13):902–11.
16. Banach A, Hata N, Crawford R, Piontek T. Supratrochlear rim is correlated with isolated patellar chondromalacia on magnetic resonance imaging of the knee. Arthrosc Sports Med Rehabilitation. 2024;6(2):100855.
17. Tanaka MJ, Sodhi A, Wadhavkar I, Kane K, Velasquez Hammerle MV, Mangudi Varadarajan K, et al. Redefining trochlear dysplasia: normal thresholds vary by measurement technique, landmarks, and sex. Am J Sports Med. 2023;51(5):1202–10.

Figures

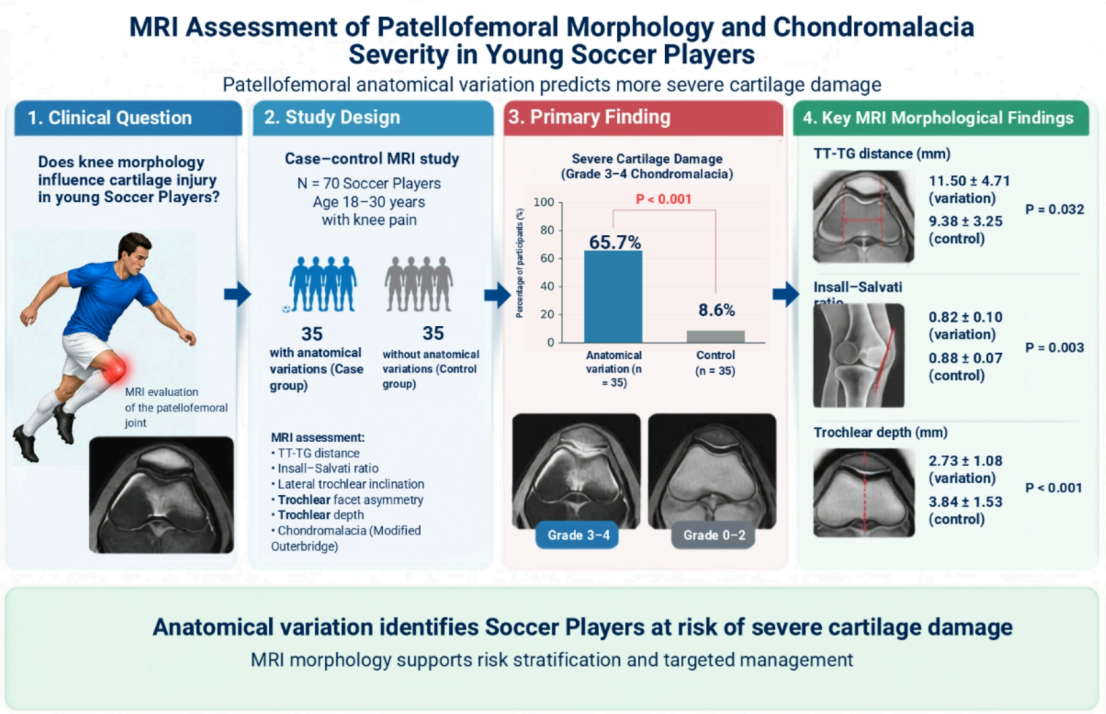


Figure 1

Graphical abstract represents a summary of the study findings