Original Article

Chondromalacia Patella among Military Recruits with Anterior Knee Pain: Prevalence and Association with Patellofemoral Malalignment

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Abstract

Background: The aim of this study was to investigate the frequency of chondromalacia patella (CMP) and to evaluate its relation with trochlear morphometric and patellofemoral alignment measurements as well as with edema in superolateral region of Hoffa's fat pad (SHFP) in military recruits with anterior knee pain (AKP). **Materials and Methods:** Knee magnetic resonance imaging examinations of 288 military recruits with AKP were retrospectively evaluated. Patellar cartilage lesions were graded using modified Noyes system. Quantitative measurements of trochlear morphology (sulcus angle, trochlear sulcus depth, and lateral trochlear inclination [LTI]) and patellofemoral alignment (patellar translation [PT], lateral patellofemoral angle (LPA), Insall-Salvati index, and tibial tuberosity-trochlear groove distance) were made. The SHFP region was assessed for the presence of edema. Mean values of measurements in knees with and without CMP and in knees with early and advanced stage CMP were compared. **Results:** We found CMP in 169 (58.7%) patients. Patients with CMP demonstrated a significantly greater sulcus angle (P = 0.012), smaller LTI (P = 0.004), greater PT (P = 0.01), smaller LPA (P = 0.036), greater Insall-Salvati ratio (P = 0.034), and higher incidence of SHFP edema (P = 0.001) compared to those without CMP. While none of the measurements were associated with the severity of cartilage damage, the incidence of SHFP edema was significantly correlated with the severity of CMP (P = 0.001). **Conclusion:** CMP is a common disorder among military recruits with AKP. Patellofemoral malalignment is an important contributory factor in the development of CMP, and the presence of edema in SHFP may be a strong indicator of underlying severe CMP in this population.

Keywords: *Chondromalacia patella, magnetic resonance imaging, patellofemoral joint, trochlear morphology*

Introduction

One of the most common complaints among people applying to health units for knee-related disorders is anterior knee pain (AKP).[1] There is a considerable diversity in the factors leading to the formation of AKP. Soft-tissue impingement, structural anomalies, chondromalacia patella (CMP), the reduced envelopment function of the patellofemoral system, and pelvifemoral dysfunction are regarded as the main causes of AKP in young and active patients.[2] Imaging is essential for enclosing tissue damage and/or structural alterations in patients with AKP. Magnetic resonance imaging (MRI) allows a comprehensive evaluation of patellofemoral joint and is the method of choice in not only detecting cartilage and soft-tissue lesions but also evaluating trochlear and patellar morphology.[3,4]

Being associated with a progressive cartilage loss and disability, CMP has a particular importance among other causes of AKP.[5] Although it has been suggested that a wide variety of factors including trauma, anatomical predisposition, patellofemoral malalignment, and overuse contributes to the formation of CMP, the actual cause of CMP has not been clarified.[6] In several recent studies, the relation between CMP and knee morphometric and alignment measurements in young adults has been evaluated.[5,7-11] CMP has also been associated with the formation of edema in the superolateral region of the Hoffa's fat pad (SHFP).[8] In addition to being associated with CMP, the relation of SHFP with knee morphometric and alignment

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measurements has been explored.[12] Overuse is regarded as another contributory factor having an important place among other causes of CMP. It is shown that the frequency of chondromalacia increases in those who are engaged in professions or sports that are overloading the knee joint.

Military recruits characteristically represent a healthy, young population who are subjected to a regular and demanding training program that requires high physical performance. AKP has been reported to be a common occurrence during recruitment training.[13-15] However, in none of the previous studies, the prevalence of CMP among military recruits with AKP has been evaluated. Our aim in this study was to investigate the frequency of CMP in military recruits with AKP and to evaluate the relation between CMP and trochlear morphometric and patellofemoral alignment measurements. Besides, we aimed to explore the frequency of SHFP in this community and to evaluate its relation with CMP.

Materials and Methods

Patient population

With institutional review board approval, the clinical and radiological records of military recruits who admitted to the Department of Orthopedics with the complaint of AKP were screened. The ones who were suffering from an AKP which was worsening during certain activities such as descending stairs, climbing, or jumping for longer than 1 month and who underwent a knee MRI examination between January 1, 2017 and April 1, 2018, were included in the study. Patients with a history of direct trauma to the knee, a history or presence of inflammatory knee disease, prior surgery, and patients with findings of internal derangement were excluded from the study. In consequence, the study group consisted of 288 knees of 288 patients. The age of the population ranged between 20 and 27 (mean 21 ± 1,86 years).

In Turkey, all male citizens at the age of 20 are obliged to serve in the armed forces unless they attend a college or a university. College and university graduates should fulfill their military obligation before the age of 29. Nevertheless, the vast majority of male citizens perform their military duties at the beginning of their twenties. All military recruits should have passed the physical examination before enrollment to ensure that they are able to perform a physically intensive and demanding recruit training program. Hence, these soldiers characteristically represent a highly active, healthy, young, male population.

Magnetic resonance imaging protocol

MRI examinations were performed using a 1.5T scanner (Gyroscan Intera, Philips Medical Systems, Nederland B.V.) with a dedicated knee coil. During scanning, the patients were given supine position with their knees at full extension. The imaging protocol constituted the following five routine sequences: coronal fast spin-echo T1 weighted (repetition time [TR]/echo time [TE]: 550/17 ms, echo train length [ETL]: 3, matrix: 320 × 224, field of view [cm]: 14 cm × 14 cm, and slice thickness: 3 mm); sagittal fat-suppressed proton density weighted (TR/TE: 2584/23 ms, ETL: 8, matrix: 384 × 224, FOV: 14 cm × 14 cm, and slice thickness: 3,5 mm); coronal fat-suppressed proton density-weighted (TR/TE: 2850/22 ms, ETL: 6, matrix: 320 × 224, FOV: 14 cm × 14 cm, and slice thickness: 3 mm); axial fat-suppressed proton density weighted (TR/TE: 3250/30 ms, ETL: 8, matrix: 448 × 224, FOV: 12 cm × 12 cm, and slice thickness: 3 mm); and sagittal fast spin-echo T2 weighted (TR/TE: 5050/70 ms, ETL: 16, matrix: 384 × 256, FOV: 14 cm × 14 cm, and slice thickness: 3 mm).

Image analysis and measurements

Patellar cartilage evaluation

Patellar cartilage lesions were graded according to the modified Noyes system: grade 0, normal cartilage; Grade 1, increased T2 signal in an intact cartilage; Grade 2A, cartilage loss less than half of the entire thickness; Grade 2B, cartilage loss more than half of the entire thickness; Grade 3, cartilage loss comprising the entire thickness[16] [Figure 1]. Grades 1 and 2A lesions were termed as early stage, and Grade 2B and 3 lesions were termed as advanced stage cartilage lesions.

Trochlear morphometric measurements

Sulcus angle (SA), trochlear sulcus depth (SD), and lateral trochlear inclination (LTI) were measured to evaluate trochlear morphometry. The measurements were performed at the bone surfaces. The point 3 cm above the level of the tibiofemoral joint space was the point to measure SA and SD. SA is the angle formed between two lines paralleling

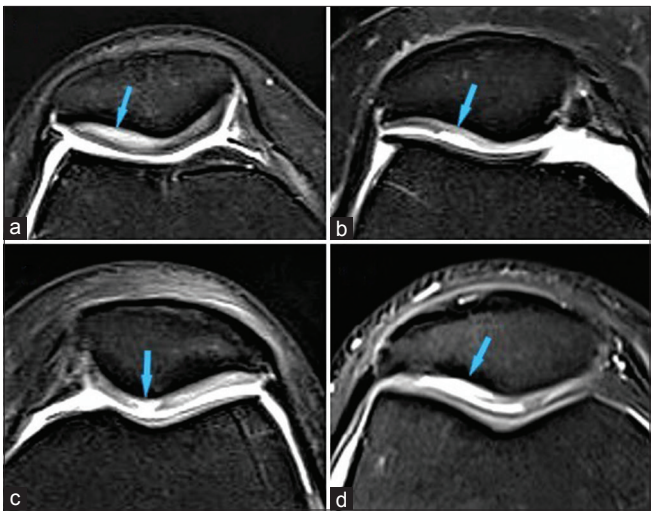

Figure 1: Axial proton density weighted, fat-suppressed magnetic resonance images showing patellar cartilage lesions according to modified Noyes system. (a) Grade 1, (b) Grade 2, (c) Grade 3, and (d) Grade 4, cartilage changes are seen

the medial and lateral facets of trochlea [Figure 2a], and the angles smaller than 144° are considered as normal.[17] SD is measured as the distance from the point where the SD is maximum to the line passing from the front edges of the femoral condyles [Figure 2b]. Normal SD is accepted as ≥3 mm.[18] LTI was measured in the most superior section depicting trochlear cartilage. LTI is the angle that the facet of the lateral trochlea makes with the line passing through the posterior edges of the femoral condyle [Figure 2c]. An LTI >11° is considered as normal.[19]

Patellofemoral alignment measurements

Patellar translation (PT) was measured on the axial section which depicted the most medial border of the patella. It is the distance between two parallel lines passing through the most medial margin of the patella and the most anterior margin of the medial condyle. These two lines should be perpendicular to the line connecting posterior edges of femoral condyles. A normal PT is <2 mm[20] [Figure 3a]. Lateral patellofemoral angle (LPA) is the angle between the line bordering the lateral patellar facet and the line passing through the anterior edges of both femoral condyles. A LPA ≥8° is considered as normal[21] [Figure 3b].

The patellar position was evaluated using Insall-Salvati ratio which is measured on the sagittal plane. The measurement was performed on the sagittal section where the maximum length of the patella was visualized, as the patellar tendon length divided by the patellar length. Ratio values between 0.9 and 1.3 were recorded as normal[22] [Figure 3c].

To determine the lateralization of tibial tuberosity, we measured the distance between the point where the trochlear depth is greatest, and the patellar tendon-tibial tuberosity attachment site (TT-TG distance), using the method described in previous studies[23,24] [Figure 4].

Evaluation of superolateral region of the Hoffa's fat pad

The SHFP region was assessed for the presence of a high T2-signal indicative of the presence of edema [Figure 3]. In equivocal cases, signal intensity measurement in the region of interest which was at least 20% higher than the signal of neighboring normal fat pad was taken as positive[12] [Figure 5].

Intra- and interobserver reliability assessment

All quantitative and semi-quantitative measurements were performed by a radiologist who was experienced in musculoskeletal imaging. To test the intraobserver reliability, the same radiologist repeated all measurements 1 month after the first assessment. To test the interobserver reliability, another radiologist blindedly performed quantitative and semi-quantitative measurements of randomly selected 80 knees among 288 knees.

Statistical analysis

Mean values of morphologic measurements in knees with and without CMP, and in knees with early and advanced stage CMP, were compared. The normality of distribution of continuous variables was tested by Shapiro–Wilk test.

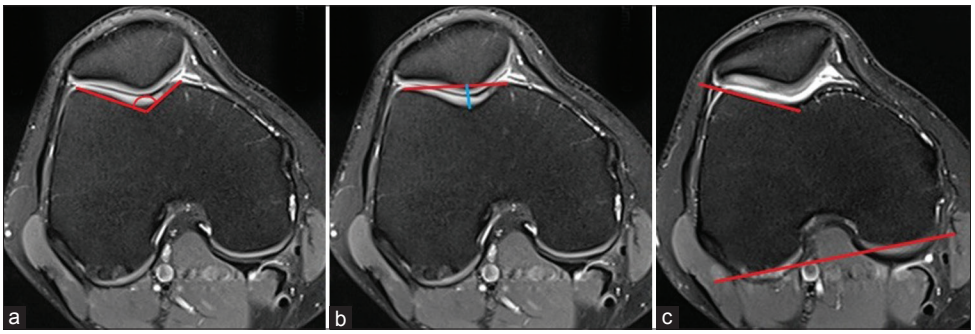

Figure 2: Axial proton density weighted, fat-suppressed magnetic resonance imaging sections demonstrating the methods of determining trochlear measurements. (a) Trochlear sulcus angle. (b) Trochlear depth. (c) Lateral trochlear inclination

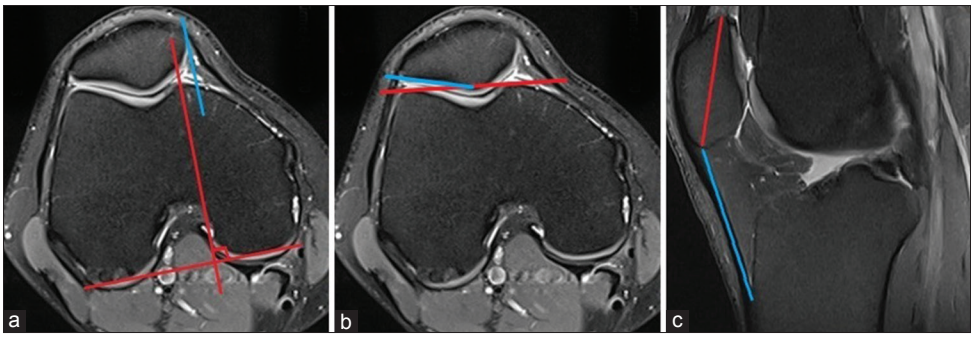

Figure 3: Axial (a and b), and sagittal (c) proton density weighted, fat-suppressed magnetic resonance imaging sections demonstrating the methods of determining patellofemoral alignment measurements. (a) Patellar translation. (b) Lateral patellofemoral angle. (c) Insall-Salvati ratio

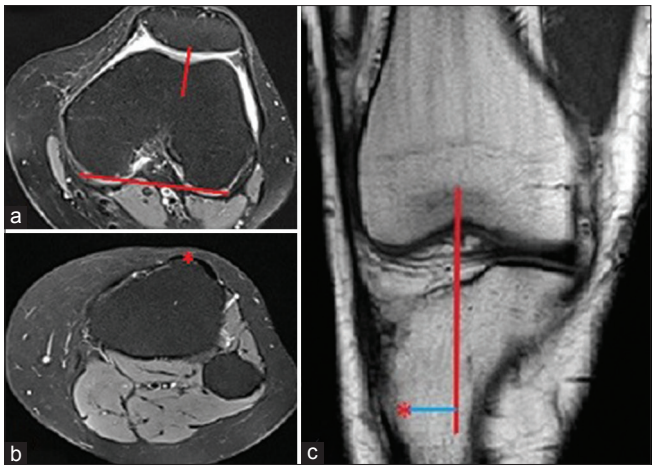

Figure 4: Axial magnetic resonance imaging images at 3 cm above the tibiofemoral joint cleft (a) and through tibial tuberosity (b), and a coronal magnetic resonance imaging section (c) demonstrating the tibial tuberosity to trochlear groove distance measurement method

Student's *t*-test was used to compare two independent groups for normal data, and Mann–Whitney *U*-test was used for nonnormal data. Chi-square test was applied to investigate the relation between the presence of CMP and SHFP edema. SPSS for Windows version 24.0 (SPSS Inc., Armonk, NY, USA) was used for all statistical analyses.

Results

On MRI, 169/288 patients (58.7%) had CMP. Table 1 shows the results of comparison between patients with and without CMP. Patients with CMP demonstrated a significantly greater SA (P = 0.012), a significantly smaller LTI (P = 0.004), a significantly greater PT (P = 0.01), a significantly smaller LPA (P = 0.036), and a significantly greater Insall-Salvati ratio (P = 0.034). Of the study group, 128 (44.4%) had edema in SHFP. The incidence of SHFP edema was significantly higher in patients with CMP compared to those without CMP (P = 0.001). Although there was a trend toward higher TT-TG distance in patients with CMP, this relation did not reach statistical significance (P = 0.052).

Of 169 patients with CMP, 146 (86.3%) were in early stage, whereas 23 (13.7%) were in advanced stage. Table 2 summarizes the results of patients with early and advanced stage CMP. Trochlear morphometric and patellar alignment measurements did not show significant differences between the two groups. However, the incidence of SHFP edema was significantly higher in patients with advanced stage CMP compared to those with early-stage CMP (P = 0.001).

Intra and interobserver intraclass correlation coefficients for all quantitative and semi-quantitative measurements were 0.91 and 0.86, respectively.

Discussion

We investigated the prevalence of CMP and its associations with trochlear morphometric and patellar alignment measurements as well as with the presence of SHFP edema in military recruits presenting with AKP. Knee MRI study of 288 patients revealed CMP in 169 (58.7%) patients. Of the knees with CMP, 146 (86.3%) were in early stage whereas 23 (13.7%) were in the advanced stage. We determined that patients with CMP demonstrated significantly greater SA, PT, and Insall-Salvati ratio while they showed significantly smaller LTI and LPA. However, we found that no measurement method correlated significantly with CMP severity. On the other hand, the frequency of SHFP edema was significantly higher in patients with CMP compared to those without chondral lesion and in patients with advanced chondral lesions compared to the ones with early-stage chondral alterations. Our results show that a patellofemoral morphometry and soft-tissue inflammation-related CMP is present in over than half of the military recruits presenting with AKP. In addition, our results suggest SHFP edema as a strong indicator of underlying severe CMP in this population.

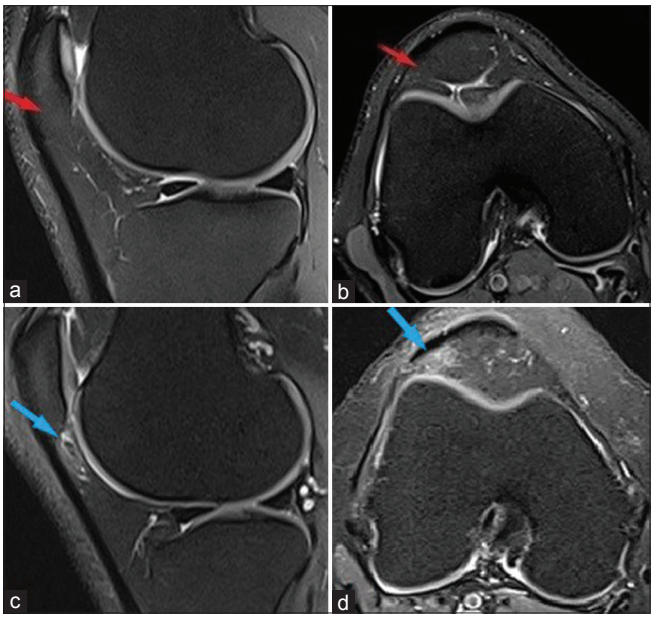

Figure 5: Sagittal (a and c) and axial (b and d) magnetic resonance images showing superolateral Hoffa's fat pad. a and b show normal fat signal (red arrows) in this area. In another patient's knee, there is increased signal (blue arrows) consistent with edema (c and d)

AKP has been reported as a frequent complaint among recruits undergoing military training.[13-15] According to the previous studies, incidence rates for AKP in military recruits vary from 9.7 to 571.4/1000 person-years.[25] However, the annual prevalence value reported for the AKP in the general population is 22.7%.[25] To the best of our knowledge, the CMP frequency in military recruits with AKP has never been investigated to date. The prevalence of CMP we detected in our study is higher than those previously reported in studies carried out in the general population.[9,10,26] Zhang *et al*. found the frequency of CMP among students from gymnastic department with AKP as 11.6%–20.1%.[26] According to another study

Table 1: Mean±standard deviation values of morphologic measurements in knees with and without chondromalacia patella

	Patients with CMP (*n*=169)	Patients without CMP (*n*=119)	*P*
Trochlear sulcus angle (°)	141.14±15.9	139.34±11.09	0.094
Trochlear sulcus depth (mm)	4.57±2.14	5.27±1.98	0.012*
Lateral trochlear inclination (°)	19.68±5.63	21.51±4.87	0.004*
Patellar translation (mm)	1.89±3.67	0.67±2.02	0.001*
Lateral patellofemoral angle (°)	3.93±8.13	5.71±6.17	0.036*
Insall-Salvati ratio	1.24±0.24	1.19±0.2	0.034*
TT-TG distance (mm)	14.09±5.87	12.68±4.96	0.052
SHFP edema, *n* (%)	102 (60.4)	26 (21.8)	0.001*

*Statistical significance. CMP=Chondromalacia patella, TT-TG=Tibial tuberosity-trochlear groove, SHFP=Superolateral Hoffa's fat pad

Table 2: Mean±standard deviation values of morphologic measurements in knees with early and advanced chondromalacia patella

	Patients with early CMP (Grades 1 and 2A) (*n*=146)	Patients with advanced CMP (Grades 2B and 3) (*n*=23)	*P*
Trochlear sulcus angle (°)	140.99±16.26	142.04±13.72	0.813
Trochlear sulcus depth (mm)	4.54±2.08	4.74±2.49	0.668
Lateral trochlear inclination (°)	19.58±5.78	20.28±4.69	0.583
Patellar translation (mm)	1.96±3.77	1.48±3	0.733
Lateral patellofemoral angle (°)	3.82±8.08	4.7±8.6	0.954
Insall-Salvati ratio	1.25±0.24	1.2±0.26	0.190
TT-TG distance (mm)	14.05±5.9	14.28±5.85	0.781
SHFP edema, *n* (%)	81 (55.5)	21 (91.3)	0.001*

*Statistical significance. CMP=Chondromalacia patella, TT-TG=Tibial tuberosity-trochlear groove, SHFP=Superolateral Hoffa's fat pad

conducted by Lu *et al*., the total prevalence of chondral lesions in general population is 38%.[10] The higher CMP prevalence we recorded among military recruits with AKP (58.7%) can be attributed to the overloading of the knee joint and the wear of the patellar cartilage as a result of the intensive training program that the soldiers are exposed to.

There are many publications in the literature evaluating the relation between CMP and trochlear morphology and patellar alignment. SA, which is supposed to reflect the entire femoral trochlear morphology, is a widely preferred measure to evaluate the trochlear anatomy. On the other hand, LTI is a measurement that evaluates only the lateral trochlear morphology.[5] The reported results about the relation between CMP and these two methods are inconsistent. Certain previous studies[5,7,8] have reported a significant relation between SA and cartilage damage, whereas others[11,27] found no association between them. Ali *et al*.[28] reported that a structural abnormality in the lateral trochlea increases the risk of developing cartilage damage in young adults and that there is a significant relationship between LTI and patellar cartilage injury. Another study revealed no significant association between LTI and CMP.[7] Given the results we have obtained in our study, the relation between CMP and SA was not significant, but CMP showed a significant association with LTI. The quadriceps contraction that accompanies the knee flexion has a strong effect that pushes the patella in lateral direction. The main obstacle preventing the lateral over displacement of the patella is the barrier effect of the lateral trochlear condyle. In the case of a flattened lateral facet, the possibility of lateral displacement of patella increases during knee flexion. Therefore, the amount of contact between the patella and the lateral condyle increases causing patellar cartilage wear.[5] The results obtained in the current study indicate that the disability of the lateral trochlea in adequately fulfilling its barrier function is more determinative than an abnormality of the entire trochlear geometry in the formation of cartilage damage in the military population.

Thakkar *et al*. reported a significant correlation between increased TT-TG distance measurement and cartilage damage in the lateral facet, and they suggested that TT-TG distance is much more useful for correlating with patellar cartilage chondrosis than other MRI parameters.[11] However, the data we have obtained in our study did not support this suggestion. The difference between the mean TT-TG distance values of the knees with and without CMP was not statistically significant, according to our results. The differences in age, gender, and physical activity among the populations selected in the two studies may be the reason of the discrepancy between the results of the two studies. The population of the study carried out by Thakkar *et al*. was selected from the general population in an older age group as compared to the population in our study and comprised both males and females. In our young,

active, male population, factors other than lateralization of tibial tuberosity may have predominated in cartilage damage formation. However, to verify this presumption, there is a need for extensive research with large series showing different character traits. In our study, other patellar alignment measurements include PT, LPA, and Insall-Salvati ratio all correlated with CMP in consistency with the previous studies.[8,10]

Recently, a relation between patellofemoral malalignment and edema in SHFP has been described. Significant correlations between SHFP edema and PT, LPA, and Insall-Salvati ratio have been reported.[12,29] In addition, Sebro and Weintraub showed a significant correlation between the presence of SHFP edema and patellar cartilage damage.[8] Patellar malalignment may result in inadequate engagement of the patella with the trochlea during knee flexion leading to an increased pressure on lateral facet and surrounding soft tissues and may contribute to fat pad impingement and patellar cartilage damage. In accordance with the previous data, we found that there is a significant association between SHFP edema and CMP. Furthermore, we found that SHFP is the only parameter among other measurements to correlate with the severity of cartilage damage. We found the prevalence of SHFP edema to be 44.4% in patients with AKP, 55.5% in patients with early-stage CMP, and 91.3% in patients with advanced stage CMP. These findings indicate that the presence of SHFP edema strongly suggests the presence of underlying severe patellar cartilage damage in patients under military training. This may be interpreted as military training-specific activities enhance the patellar disengagement effect of patellofemoral malalignment and potentialize the formation of SHFP edema and CMP more prominently compared to daily activities or active sports do.

The main limitation of this study is that only military personnel were included in the study and that the findings in the army and in the general population were not compared. Another limitation of this study is the lack of comparative evaluation of knee MRI findings of soldiers with and without knee pain. There is a need for comparative studies involving different populations to confirm the results of this study and the interpretations made based on its results.

Conclusion

The results of this study demonstrate that CMP is a common disorder among military recruits with AKP and that the presence of CMP correlates with the measurement methods that define the structural features of the lateral trochlea and patellofemoral alignment. Patellofemoral malalignment is an important contributory factor in the development of CMP, and the presence of edema in SHFP may be a strong indicator of underlying severe CMP in patients under military training.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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