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Research Article

Exposure to Live in Geographically Steep Terrain Decreases Patella Height and Increases the Incidence of Patella Baja

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Abstract

Objectives: This study aims to investigate the effect of the geographical conditions on patellar height.

Methods: Two different groups of the same society were created according to the geographical structures that people live in (fully rugged mountainous terrain Giresun and flat terrain Alanya). But the daily activities such as kneeling, praying, squatting or sitting with crossed legs were same culturally. The study included patients living and working in these areas, as their parents, throughout their lives. Knee MRI of patients who did not suffer anterior knee pain were retrospectively evaluated. The Insall-Salvati index (ISI) was calculated and the patella baja incidence rates were compared between regions using the Fisher's exact test.

Results: A total of 885 knee MRIs were evaluated. The mean ISI for all individuals was found significantly different with a mean of 0.946±0.141 in Giresun and 1.014±0.13 in Alanya (p<0.001). The incidence of patella baja for all individuals was 5% in Giresun and 2% in Alanya (p=0.01).

Conclusion: Our findings suggested that as the inclination of the region gets steeper; the patella height decreases and the patella baja incidence rate increases. Living in steep sloped geographical structures may be relevant in the etiology of patella baja.

Keywords: Mountainous geographic structure, patella baja, patella height

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Patella baja is a medical condition in which the knee cap is abnormally positioned lower than its normal location in the knee joint.[1] Insall-Salvati index (ISI) is used for calculating the patellar height. ISI reveals the ratio of the patellar tendon length to patellar length.[2,3] The decrease of this ratio is named as patella baja.[1–3] The changes in the height of patella are related to some diseases such as anterior knee pain, patellar dislocation and quadriceps tendon rupture.[4–6] In many reports, lifestyles (such as kneeling, praying, squatting and sitting with crossed legs) along with genetic and ethnic factors are emphasized for etiology of patella baja and patella alta.[5,7–10] The studies emphasizing the lifestyle mostly refer the patellar tendon lengthening due to hiperflexed knees.[5,7–10] The majority of those stud-

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ies have been completed in places like China,[5,10] India[7] and the Middle East[9] in relatively flat-lying or fully flat-lying geographical regions. However, when all these studies are examined closely, authors conclude that patella height is correlated more with cultural factors such as sitting position and eating meals while sitting on the ground rather than geographical structures.

Environmental exposure is a known factor at disease occurance.[11] The term 'exposure' usually refers to air pollution, water pollution, chemicals etc. But there are other instances too. For example, hot and cold temperature exposure is important on performance.[12] Expose to high-voltage lines for the purpose of evaluating childhood leukemia and electromagnetic radiation via geographically living near or far has previously revealed.[13] Exposure to live in different geographical areas may show different effect to musculoskeletal system.[14]

Studies investigating the effects of geographical conditions on the formation of patella baja, however, are not very common. Yet, we had observations to believe that an investigation on this effect is needed; in the mountainous rugged terrain region (Giresun) that we worked in, we noticed that patellas of people who lived in this area were more distally located according to our routine radiological examinations and our professional experience. Hence, we planned to document any association of geographical conditions with the formation or etiology of patella baja.

Within this objective, we aimed to investigate the following questions: 1) Do the geographical living conditions change the patellar height? 2) Do the geographical living conditions affect the incidence of patella baja? 3) Are the geographical living conditions effective in the etiology of patella baja?

Methods

A local ethics committee permission was obtained for this retrospective study. While there are studies defining a mountainous region as “a terrain with about 50 km horizontal and about 500 m vertical dimensions” with respect to different purposes,[15,16] we defined the mountainous region as a terrain in which the residents have to routinely walk through up or down a hill with a steepness of 15° or higher, while in the plain region, they don’t (or very rarely) have to do this during their daily activities.

Based on the above definition, the patients were divided into the following two groups:

Group 1: The patients who were referred to outpatient clinic of orthopedics and traumatology at Giresun University Training and Research Hospital. The city of Giresun and its sorroundings are a mountainous region.[17]

Group 2: The patients who were referred to the outpatient clinic of physical therapy and rehabilitation at Alanya University School of Medicine. The city of Alanya and its sorroundings are a plain region.[18]

Both groups were very similar in terms of culture, lifestyle, kneeling, praying, squatting, sitting with crossed legs and society. The only difference between the groups was geographical conditions; one region is a mountainous area (Giresun) while the other region is a plain region (Alanya).

Knee magnetic resonance images of all the patients were evaluated retrospectively.

Inclusion Criteria

Patients who had lived their whole lives in the same region and worked in fields, as their parents, with their knee MRI taken for some reason were investigated. For a more homogenous study, patients whose hometown is not one of the studied cities were not evaluated. The patients included in the study were older than 18 years old. In clinical examinations, McMurray test was used, while in radiological examinations, MRI was used for diagnosis of any meniscus tear. The patients with neutral alignment at lower extremity, and patients with full range of motion were included into the study. In the presence of the suspicion of varus/valgus deformity, the patients were evaluated by orthoroentgenography. At MRI examination, modified Outerbridge grading classification system[19] was used for examining the cartilage of the knees. Meniscus tears were examined by MRI as previously described.[20]

Exclusion Criteria

Patients who were not born, lived and worked in the studied regions were not evaluated to ensure that the study was geographically and culturally homogenous. Patients below the age of 18 years, with trauma anamnesis of the same lower extremity, with previous surgery of the same lower extremity, with knee contracture, with Osgood-Schlatter disease, with varus-valgus or recurvation deformities, with inflammatory diseases, with neuromuscular diseases; patients whose MRI were taken because of trauma, knee instability, patellofemoral pain; patients with clear ripples in patellar tendon at MRI sagital sections; patients with inappropriate sagittal MR images; and patients whose files were not available were excluded from this study.

Calculation of Insall-Salvati Index, and Determination of Patella Baja

Patients had their knee MR taken on a 1.5 Tesla MR device in Giresun (MAGNETOM Aera(®); Siemens Healthcare, Erlangen, Germany) and in Alanya (Intera; Philips Medical Systems, Best, The Netherlands). MRI images of the patients were evaluated using remote internet connection via PACS programs that were present in both hospitals. On sagittal T2 MRI sections, the patellar tendon length and patella bone length were measured and the ISI was calculated as described by Shabshin et al.[3] (Fig. 1a, b). For this method, the shortest length of the patellar tendon and the longest length of the patella are measured on sagittal sections. For the measurements, the sections passing through the most central point of the patellas were used. For example, if there were 9 sagittal sections, the fifth section was used; if there were 8 sagittal sections, the section with the shortest patellar tendon and the longest patellar bone was chosen from the fourth and fifth sections. If the ISI was less than 0.74 for all individuals, it was accepted as patella baja (Fig. 1a) while more than 1.50 was accepted as patella alta (Fig. 1b); for males, ratios less than 0.74 were accepted as patella baja and above 1.32 were accepted as patella alta, while for females, ratios less than 0.79 were accepted as patella baja and above 1.52 were accepted as patella alta (Table 1). Measurements were made by 2 orthopedists and 1 radiology expert. Firstly, the knee MRI of 10 patients were measured by 3 researchers together to standardize the measurement method. These first 10 patients were excluded from the study, while MRI measurements of patients included in the study were separately investigated by 3 observers at different times.

Table 1. Insall-Salvati ratio for patella baja on knee MRI (Shabshin et. al. 2004)

	Patella baja	Patella alta
In all individuals	<0.74	>1.50
In males	<0.74	>1.32
In females	<0.79	>1.52

Statistical Analysis

Each MRI was measured by 3 raters. Intraclass Correlation Coefficient (ICC) was used to measure inter-rater reliability. ICC estimates and their 95% confident intervals were calculated using SPSS statistical package version 15 (SPSS Inc, Chicago, IL) based on a mean-rating (k=3), absolute-agreement and two way mixed effects model. Values less than 0.5 were indicative of poor reliability, values between 0.5 and 0.75 indicated moderate reliability, values between 0.75 and 0.9 indicated good reliability, and values greater than 0.90 indicated excellent reliability.

The main interest of the study was to compare ISI index of a mountainous region with that of a plain region. Cohen's d effect size for two sample t test from previous studies was calculated and revealed a large effect size. Thus, only a small number of patients would be sufficient. The data collection was neither difficult nor expensive, thus the number of patients in the study was much larger than the required number for reaching a power of 0.80.

The rest of the statistical analyses were performed using R Statistical Software (www.rproject. org), a free software environment for statistical computing and graphics. Kolmogorov-Smirnov test, Boxplots, QQ and PP plots were used to assess the distributions of quantitative variables. Baseline characteristics of the groups were presented as mean, standard deviation (SD), minimum and maximum values for quantitative variables and as frequencies and percentages for categorical variables. Welch's two sample t-test was applied to compare means of a mountainous region (Giresun) and a plain region (Alanya) with respect to age and ISI. Fisher's exact test of homogeneity was applied to test whether the distribution of patellar height and gender were the same for Giresun and Alanya regions. The relative odds (odds ratios) and relative risk of having pa-

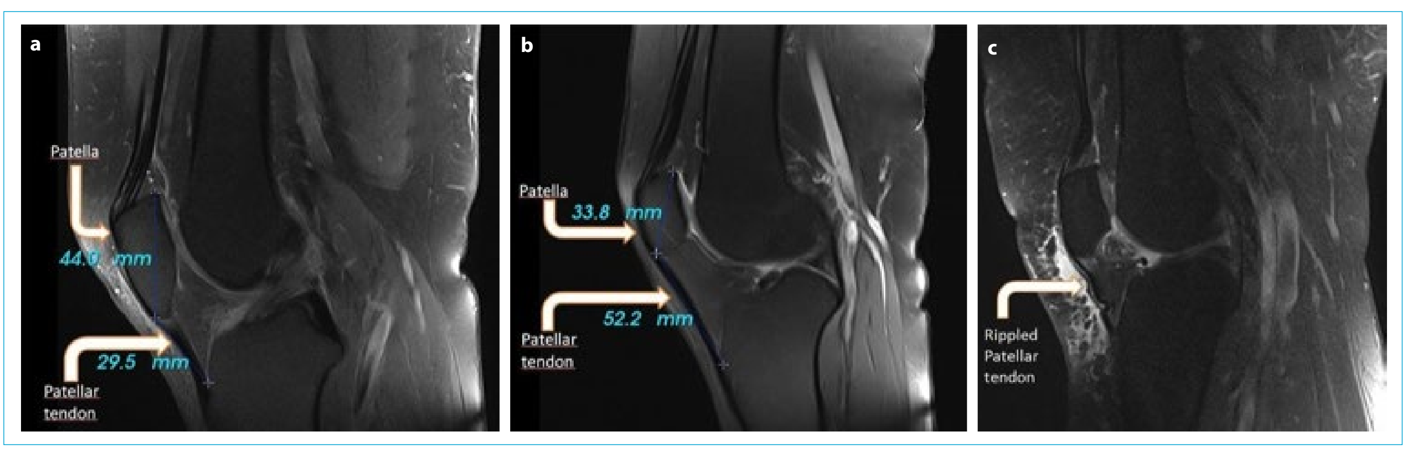

Figure 1. a,b shows the calculation of patellar tendon length and patellar bone length for Insall-Salvati ratio measurement on sagittal T2 weighted MRI section. **(a)** Sagittal image of a patella Baja case. The Insall-Salvati ratio is 0.67 **(b)** Sagittal image of a patella Alta case. The Insall-Salvati ratio is 1.54. **(c)** Sagittal image of a rippled patellar tendon.

Table 2. Descriptives and comparisons of quantitative characteristic variables of the regions

	Mountainous (Giresun) (n=400)		Plain (Alanya) (n=485)		Test-statistic	
Variables	**Mean (SD)**	**Range**	**Mean (SD)**	**Range**	**t (df)**	**p**
Age	46 (14.04)	18-80	46.45(13.26)	18-78	t(831.21)=0.44	0.6582
I-S Index	0.946 (0.141)	0.59-1.32	1.014 (0.13)	0.65-1.50	t(829)=7.3	<0.001*

*:p<0.05; t: Welch's t statistic; df: degrees of freedom.

tella baja in the mountainous region (Giresun) versus the plain region (Alanya) were given for each gender. Cochran Manthel Haenzsel test was used to test for conditional independence taking gender as a stratification variable. Breslow-Day test was used to test whether the odds of having patella baja in a mountainous region compared to plain region were equal for each gender. DescTools and stats packages in R program were used for Breslow-Day test and Cochran Manthel Haenzsel test, respectively. P<0.05 was considered statistically significant.

Results

It was of interest to test whether there was a significant difference between ISI of a mountainous region (Giresun) and a plain region (Alanya) in Turkey The post hoc power of the study for Cohen's d effect size of 6 was calculated as 0.99 for a type I error of 0.05, which indicated that the power of the study was high.

The mean age of the groups was statistically insignificant between groups (46±14.04 and 46.45±13.26 for Giresun and Alanya, respectively, p=0.6582) (Table 2).

ICC was 0.87 with 95% confidence interval 0.82-0.92. Based on the ICC results, it is concluded that the degree of reliability of the measurements is "good".

It was found that the mean ISI of people living in the mountainous region (Giresun) was significantly smaller than the mean ISI of people living in the plain region (Alanya) (0.946±0.141 versus 1.014±0.13, t (829)=7.3, p<0.001) (Table 2).

The people in the study groups were first categorized into different patella types using the general criteria for all individuals in Table 1. There was only 1 patella alta (Fig. 1b) combined with patella norma which reduced the patella type into two groups for more appropriate analyses. There was only one rippled patellar tendon (Fig. 1c) and that case was excluded.

For the first categorization, we had sufficient evidence to conclude that the distribution of patellar heights for all individuals was significantly different for the mountainous region (Giresun) and the plain region (Alanya), mountainous region (Giresun) having a high incidence of people with patella baja than that of plain region (Alanya) (5% versus 2%, p=0.01). Thus, the odds of patella baja were 2.97 fold higher in the mountaneous region compared to the plain region. The second criterion in Table 1 was used to categorize people into different patellar height types based on their genders. The number of patella baja cases based on the second classification (re-

Table 3. Descriptive statistics and associations of region and categorical variables

	Mountainous (Giresun)		Plain (Alanya)		Test-statistic	p
Variables	**N**	**Percent (%)**	**N**	**Percent (%)**		
Gender						
Female	209	52	315	65	Fisher's exact	0.003*
Male	191	48	170	35		
Patella height (All individuals)[1]						
Baja	19	5	8	2	Fisher's exact	0.01*
Norma&Alta	381	95	477	98		
Patella height (gender considered)[2]						
Baja	34	9	18	4	Fisher's exact	0.004*
Norma&Alta	366	91	467	96		

*p<0.05; [1]: general specification limits are used for the classification of patella types; [2]: gender specified limits were used for the classification of patella types.

Table 4. Contingency table between patella height types and the region stratified by gender.

Gender	Female			Male			Tests	
Region/Patella	Baja, n (%)	Norma, n (%)	Total	Baja, n (%)	Norma, n (%)	Total	χ^{2BD} (p)	χ^{2CMH} (p)
Giresun	24 (11)	185 (89)	209	10 (5)	181 (95)	191	1.478 (0.224)	9.598 (0.002)
Alanya	12 (4)	303 (96)	315	6 (4)	164 (96)	170		
Total	36	488	524	16	345	361		
OR		3.27			1.51			
RR		3.01			1.48			

BD: Breslow-Day; CMH: Cochran Manthel Haenzsel; OR: Odds ratio; RR: relative risk.

garding gender criterion) was higher in women than the patella baja cases in women based on all individuals criterion [(19 "based on all individuals" versus 34 "based on gender" for mountainous region (Giresun); 8 versus 18 for plain region (Alanya), respectively)]. For the second categorization, we also had sufficient evidence to conclude that the distribution of patella types was significantly different between people in mountainous region (Giresun) and those in plain region (Alanya), Giresun having a larger proportion of people with patella baja than Alanya (9% versus 4%, p=0.004). Thus, the odds of patella baja were 2.41 fold higher in the mountainous region compared to the plain region (Table 3).

It was also of interest to figure out whether the odds ratios for patella type differed with respect to gender.

The gender was thought as a confounding factor being effective on patella type; thus, the samples were stratified by gender. The analyses in Table 4 are based on the gender considered classification in Table 1. Among the females, the relative odds of having patella baja in mountainous region (Giresun) versus plain region (Alanya) were estimated to be 3.27 (RR=3.01). Among the males, the relative odds of having patella baja in mountainous region (Giresun) versus plain region (Alanya) were estimated to be 1.51 (RR=1.48). The difference between the odds ratios was not statistically significant (χ^2 BD (1)=1.478, p=0.224).

When gender was set as a condition, patella type and region were found to be associated as M-H test came out significant (χ^2 CMH (1)=9.598, p=0.002). In both subgroups of the population, the odds of having patella baja were greater in mountainous region (Giresun) than in plain region (Alanya). The gender was not found as a confounding factor; therefore, we concluded that gender based analysis revealed the association of patella type and region. Thus, people in mountainous region (Giresun) had a significantly higher incidence of patella baja than that of people in plain region (Alanya) when considering the overall comparisons.

Discussion

According to our literature review, this is the first report to investigate the geographical structure that people live in, in terms of patellar height and etiology of patella baja. This study was carried out in two geographically different regions of Turkey; a mountainous region (Giresun) and a plain region (Alanya). The study groups were similar in terms of lifestyle, genetic and ethnic factors, which are reported to be important for the etiology of patella baja.[5,7–10] We found that the mean ISI was statistically lower at mountainous region than that of the plain region (Table 2) (p<0.001). We also found the incidence of patella baja was higher at mountainous region (Giresun) comparing to the plain region (Alanya) in terms of all individuals and when gender was considered (p=0.01 and p=0.004, respectively). The geographical conditions in which people live may change the patellar height and may be effective in the development of the patella baja as compensation to environmental factors, because of the reduced energy consumption during walking with bent knees on slopes.[21,22]

Because of the association between patella baja and anterior knee pain,[5] we excluded the patients with anterior knee pain symptoms to avoid any biased result. Anomalies of patellar height are related to patellofemoral function disorders like chrondromalasia patella and subluxation-dislocation. Patella baja may develop due to a variety of reasons like quadriceps tendon rupture, neuromuscular diseases, achondroplasia and tibial tuberosity surgery. As is known, open wedge high tibial osteotomy surgery reduces the ISI.[23] In our study, none of these secondary formation causes were present in the evaluated cases. There is no correlation between patellar height and meniscus tear.[6] So we preferred the patients with any meniscus tear with the aim of standardizing the study group. It is well known that the ISI is not affected by age.[2,24] So we included the patients with a wide range of age. In the current study, the mean age was statistically insignificant (p=0.6582) (Table 2).

For radiological assessment of patellar height, many methods have been used.[25,26] In general, patellar height is calculated by lateral X-rays.[27,28] In recent years, however, an alternative method to calculate patellar height has also been used. This method refers MRI sagittal images to calculate patellar height.[3,5] To calculate ISI by MRI is similar to calculating by X-Rays.[29] The ISI is accurately measured at flexion of the knees[7,30] while MRI is measured in the extended knees.[3,29,31] This discrepancy is because of the measurement of the patellar tendon indirectly by the lateral X-Ray between the approximate tibial and patellar attachment. In contrast, at sagittal knee MRI sections, the edge of anatomic structures can easily be defined. From this point of view, we planned to measure the ISI with sagittal MRI investigations. During these measurements, care should be taken as to whether the patellar tendon is rippled or not. In our study, the presence of taut, uneven and rippled patellar tendons was investigated on MRI sections; and rippling of the patellar tendon was excluded from the study (Fig. 1c). A study investigating the ISI on previously-taken MRI observed no rippling of the patellar tendon.[29] In MRI, the edges of anatomic structures can easily be defined. Also, the measurement technique for ISI at sagittal MRI is a standard method[3] that allows to determine which section the measurements must be made. In our study, we conducted measurements on knee sagittal MRI images due to the convenience and accuracy.[3,5,29,31] Likewise, the probable cause of highly compatible ICC (0.80) in the current study may be related to the method's being a standard technique.

In the mountainous region (Giresun) of the present study, there are no plains. People, living in this mountainous region, must continuously walk up and down the steep slopes. Additionally, hazzlenut farming is an important source of income in the region. Hazzelnut trees grow on very steep slopes. In the plain region (Alanya) of the present study, on the other hand, people make farming mostly on plains. As seen in other eastern societies, kneeling, squatting and sitting with crossed legs are very common in the societies of this study as well. All the individuals included in the present study are very similar to other eastern societies in terms of culture, lifestyle and frequently hyperflexing the knee joints.

When studies related to patellar height are evaluated, it is seen that patellar height in African societies is similar to that of Western societies.[8] Studies of Eastern societies, such as the one by Leung et al.[10] in Southern China, have shown that patella height is higher compared to Western societies. Lu et al.[5] in an MRI study of Chinese society taking the ISI as 0.80 found only 11 patella baja after MRI investigation of a total of 1703 knees. In a study of Middle Eastern society, Althani et al.[9] found the patella baja proportion was 3.8%. Upadhyay et al.[7] identified the patella baja incidence as 3% in the Indian population with common habits of squatting and crossing of legs. Studies of Chinese, Indian and Middle Eastern societies observed low rates of patella baja and higher ISI values. When the geographical conditions of these study regions are investigated, the Indian and Chinese regions were observed to be partly mountainous and partly plain. The region where Arab societies lived was located on a complete plain. In Western societies, lifestyles are limited to sitting on chairs. The first group (mountainous region) of current study has a geographically very mountainous terrain while the second group (plain region) has a plain terrain. The ISI findings of some studies are briefly given with the geographical structures at table 5. The cultural lifestyle of people living in the current study regions have similarities to the cultural lifestyle of eastern societies.[5,7,9,10] In the present study, as residential areas get steeper, ISI decreases from 1.014±0.13 to 0.946±0.141 ($p<0.001$) (Table 2), and patella baja observation rates statistically increase from 2% to 5% for all individuals ($p=0.01$) (Table 3). We also found the same statistically important findings in terms of gender as well ($p=0.002$) (Table 4).

Table 5. Comparison of previous studies with the present study. The geographical conditions of the studies carried out were obtained from the corresponding authors through e-mail and Google Map. We asked if the region was plain, mountainous, partly mountainous or partly plain

	Region	**Geographical characteristics**	**Total number of patients**	**Number of patients with patella baja (%)**	**Number of patients with patella alta (%)**	**Mean Insall-Salvati index(±SD)**
Lu et al. (2016)	China	Partly mountainous, partly plain	1703	11 (0.6)	27.5	1.13±0.14
Upadhyay et al. (2013)	India	Partly mountainous, partly plain	400	12 (3)	2.8	1.14±0.18
Althani et al. (2016)	Middle East	Fully plain	764	29 (3.8)	38	1.2±0.17
Present Study	Turkey	Mountainous	400	19 (5)	0	0.946±0.14
Present Study	Turkey	Plain	485	8 (2)	0	1.014±0.13

SD: standard deviation.

In gait analysis on slope, it is well known that knee flexes while walking.[21] As patella settles distally, the energy expenditure of extensor mechanism (quadriceps) decreases while walking with flexed knees.[22] The probable causes of the lower ISI in the mountainous region may be related to this gait analysis characteristics. The patella may be located more distally in sloped areas, as a compensation to decrease the energy expenditure of extensor mechanism.

The relationship between patella baja and anterior knee pain is obvious. The current study does not suggest a direct clinical approach to treat patella baja but puts forth a possible etiology of patella baja. However, health managers attribute more importance to preventive medicine by exercise programs in mountainous areas to prevent or delay anterior knee pain of people living in these areas.

While we report important findings, our study has some limitations. Firstly, it is not a cohort study of knee pathologies and it is not a prospective study. Using fully healthy individuals' knee MRIs would yield better controlled results. Also we did not eliminate the possible racial differences between groups in deep. Although too complicated to be done, adding groups of mountainous and plain regions from a different and preferentially far country would also help draw more global conclusions. Finally, calculating ISI with other independent methods would also generate more robust results.

Conclusion

In conclusion, to the best of our knowledge, this is the first report investigating the association of patellar height and patella baja with the perspective of geographical conditions that people live in. When the height of patella of people living in geographically different conditions is compared, the patellar height decreases and the incidence of patella baja increases as the geographical conditions get more steeper. The development of patella baja due to the decrease of patellar height may be a compensation of musculoskeletal system to environmentally challenging factors due to live in a mountainous region. Likewise, our results suggest that the etiology of patella baja may not be related only to cultural, genetic and ethnic factors but additionally may be related to exposure to geographical conditions as well. These results may help to health ministry of governments to develop health policies such as providing the orthopedists in these regions with advanced/specific training (e.g. during knee replacement surgery, conducting quadriplasty to reduce the risk of patellar tendon rupture), and proposing routine isometric quadriceps exercises through the public health programs[32] within the scope of preventive medicine. Therefore, future cohort studies should be carried out to more clearly reveal the association of patellar height with the geographical conditions.

Disclosures

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Ethics Committee Approval: The Ethics Committee of Giresun University Clinical Research provided the ethics committee approval for this study (KAEK-16, 17/05/2017).

Peer-review: Externally peer-reviewed.

Conflict of Interest: None declared.

Authorship Contributions: Concept – C.Z.E., K.A.; Design – K.A., O.O.; Supervision – K.A., O.O.; Materials – K.A., O.O.; Data collection &/or processing – K.A., O.O., N.O.; Analysis and/or interpretation – E.A., K.A.; Literature search – K.A., N.O.; Writing – K.A., E.A.; Critical review – C.Z.E.

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