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Havuzdere (Yalova) Orta Çağ Popülasyonunda Patella Kemiğinden Metrik Analizle Cinsiyet Tahmini

Sex Estimation Using Metric Analysis of the Patella Bone in the Medieval Population of Havuzdere (Yalova)

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Öz- Bu çalışma, insan iskelet kalıntılarında cinsiyeti tahmin etmek için patella kemiği ölçümlerinin kullanılmasının güvenilirliğini araştırmaktadır. Havuzdere (Yalova-Türkiye) Orta Çağ popülasyonunda toplam 123 erişkin birey (49 kadın ve 74 erkek) incelenmiştir. Patella kemiğinden; maksimum yükseklik, maksimum genişlik ve maksimum kalınlık olmak üzere üç temel ölçüm alınmıştır ve toplam 346 ölçüm elde edilmiştir. Veriler SPSS 23 paket programında t-testi, Wilks Lambda testi, F-testi ve Diskriminant Fonksiyon Analizi gibi istatistiksel testler kullanılarak analiz edilmiştir.

Yapılan analizler patella ölçümlerinin cinsiyet belirlemede güvenilir doğruluk sağladığını ortaya koymuştur. Maksimum patella yüksekliği %85,6 (%82,2 kadın ve %87,9 erkek) ile en yüksek doğruluk oranına sahipken, bunu %81,4 ile maksimum patella genişliği (%78,3 kadın ve %83,6 erkek) ölçüsü izlemiştir. En düşük doğruluk %77,9 ile maksimum patella kalınlığı ölçüsünde (%83,7 kadın ve %74,0 erkek) bulunmuştur. Cinsiyet tahmin doğruluğu kadınlarda 1 ölçümde, erkeklerde ise 2 ölçümde daha yüksektir. Tüm ölçümler birlikte değerlendirildiğinde cinsiyeti doğru ayırt etme oranı artmıştır.

Bu bulgular, patella kemiğinin metrik ölçümlerinin antropolojik, biyoarkeolojik ve adli bağlamlarda cinsiyet tahmini için güvenilir bir yöntem olduğunu vurgulamaktadır. Çalışma, iskelet kalıntılarından cinsiyet belirlemenin gerekli olduğu durumlarda patella ölçümlerinin kullanılmasının önemini vurgulayarak hem akademik araştırmalara hem de adli soruşturmalardaki pratik uygulamalara katkıda bulunmaktadır.

Anahtar Kelimeler– *Cinsiyet Tahmini, Diskriminant Fonksiyon Analizi, Havuzdere (Yalova), Orta Çağ, Patella.*

Abstract – This study investigates the reliability of using patella bone measurements for estimating sex in human skeletal remains. A total of 123 adult individuals (49 females and 74 males) from the Havuzdere (Yalova-Türkiye) population, dating back to the Middle Ages, were examined. Three key measurements were taken from the patella bone: maximum height, width, and thickness, resulting in 346 measurements. The data were analyzed using statistical tests in SPSS 23, including the t-test, Wilks' Lambda test, F-test, and Discriminant Function Analysis.

The analysis demonstrated that patella measurements provide reliable accuracy for determining sex. Maximum patella height had the highest accuracy rate at 85.6% (82.2% females and 87.9% males), followed by maximum patella width at 81.4% (78.3% females and 83.6% males). The lowest accuracy was found in maximum patella thickness at 77.9% (83.7% females and 74.0% males). Sex estimation accuracy was higher for females in one measurement and for males in two measurements. When all measurements were evaluated together, the accuracy of correctly distinguishing sex increased.

These findings highlight that metric measurements of the patella bone are a reliable method for sex estimation in anthropological, bioarchaeological, and forensic contexts. The study underscores the value of using patella measurements in cases where sex determination from skeletal remains is necessary, contributing to both academic research and practical applications in forensic investigations.

Keywords– *Sex Estimation, Discriminant Function Analysis, Havuzdere (Yalova), the Middle Ages, Patella.*

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EXTENDED ABSTRACT

Sex estimation from skeletal remains is a fundamental goal in the disciplines of anthropology, bioarchaeology, forensic medicine, and archaeology for investigating population demographics or identifying unknown individuals. One method that has been shown to be particularly effective for estimating sex is the use of metric measurements from bones that exhibit sexual dimorphism. While much of the existing research has focused on commonly studied bones such as the pelvis or skull, the present study explores the potential of using measurements taken from the patella—a less commonly analyzed bone in sex estimation—for this purpose. The study focuses on a sample of 123 adult individuals, 49 females and 74 males, from the medieval population of Havuzdere in Yalova, Türkiye. Thought to date back as far as the Middle Ages, these individuals provide an important historical perspective on human variation and serve as a valuable comparative framework within which the patterns of sexual dimorphism can be contextualized across time. The three key measurements taken from the patella bone were maximum height, width, and thickness. These three measurements were selected as they are indicative of sexual dimorphism, with males generally exhibiting larger skeletal dimensions due to differences in body size, muscle mass, and biomechanical stress. The statistical analysis of the data was conducted using the SPSS 23 software package, employing several statistical tests including the t-test, Wilks' Lambda test, F-test, and Discriminant Function Analysis (DFA). The t-test was used to determine whether there were statistically significant differences between the male and female patella measurements, while the Wilks' Lambda test was applied to assess the discriminant power of the measurements in separating the two sexes. The F-test helped compare variances between the groups, and DFA was employed to create a predictive model for sex classification based on ~~the~~

patella dimensions. The results of the analysis indicated that the patella measurements provide a high degree of accuracy in sex estimation, with the maximum patella height measurement achieving an accuracy rate of 85.6%, correctly distinguishing between males and females in 82.2% of female cases and 87.9% of male cases. The second most accurate measurement was the maximum patella width, which had an accuracy rate of 81.4%, with 78.3% accuracy for females and 83.6% for males. These findings highlight the sexual dimorphism present in patella dimensions, with males typically exhibiting larger patellae in terms of both height and width compared to females. The least accurate measurement was maximum patella thickness, which still provided an accuracy rate of 77.9%, with 83.7% accuracy for females and 74.0% for males. The fact that maximum thickness had a higher accuracy rate for females compared to males may suggest that this measurement is less variable in females or that it reflects subtler differences in bone morphology between the sexes. Overall, the accuracy of sex estimation was higher for males in two measurements (height and width) and higher for females in one measurement (thickness), suggesting that different aspects of patella morphology may be more useful for sex estimation in one sex versus the other. When all three measurements were considered together, the overall accuracy of sex estimation improved, indicating that a multidimensional approach to patella measurements can enhance the reliability of sex classification. These findings have important implications for a range of fields. In forensic medicine, where the accurate identification of unknown individuals is critical, the ability to estimate sex reliably from the patella bone can be significant, especially in cases where more commonly used bones like the pelvis or skull are missing, damaged, or unavailable. In bioarchaeology, the findings contribute to a growing body of knowledge on sexual dimorphism in historical populations and provide a new method for estimating sex from skeletal remains in archaeological contexts. The Havuzdere population represents a significant historical population from the Middle Ages, and the ability to accurately estimate sex in this population enhances our understanding of its demographic composition, health, and lifestyle. Additionally, the study's findings are significant for anthropological research, as they contribute to our understanding of skeletal variation and sexual dimorphism across different bones and populations. The use of metric measurements from the patella bone in sex estimation also opens up new avenues for future research, particularly in populations where the patella is well preserved, but other bones are more fragmentary. Moreover, this research emphasizes the importance of using less commonly studied bones in sex estimation studies, highlighting that bones like the patella, which may not be as well-studied as the pelvis or skull, can still provide highly reliable data for estimating sex. The present study demonstrates that metric measurements taken from the patella bone—particularly maximum height and width—can be used reliably for sex estimation, with accuracy rates comparable to those of more traditionally used bones. These findings offer new tools and methodologies for forensic investigators, bioarchaeologists, and anthropologists seeking to estimate sex from skeletal remains, especially in cases where the preservation of other bones may have been compromised.

INTRODUCTION

A biological profile refers to the biological characteristics of an individual that can be estimated from skeletal remains. These include estimates of sex, age at death, height, ancestry, and disease status.[1]

If significant parts of the skeleton are preserved, identification of biological sex is relatively easy. The two parts of the skeleton that allow sex to be easily determined are the pelvis and skull. Sex discrimination in the human skeleton gives the most accurate results after the person reaches adulthood. However, human sexual dimorphism has complex behavioural, physiological, and anatomical dimensions. Anatomical differences are more pronounced in some soft tissue areas but are much more limited in the skeleton. After all, there are skeletal differences between male and female individuals, and these differences are important to osteologists.[2, 3]

In research on skeletal material, the cranium or pelvis may not always be suitable for sex estimation. Skeletons found in archaeological excavations often appear fragmented or incomplete. In addition, cases where more than one burial is discovered can create difficulties. In such situations, it is of great importance to carry out sex estimation, perhaps the most important stage in the identification of the individual, with available resources. A vital method for determining sex from the skeleton is the application of statistical analysis to osteological material after metric evaluation. DFA is one of these mathematical approaches. Sex estimation with the help of DFA is an advantageous method since it can be applied to each bone in the skeleton, and when possible, multiple data can be evaluated together.[4, 5, 6]

1. Material and Methods

1.1. Material

The skeletal remains analyzed in this study were unearthed during the 2013 archaeological excavation of a 15th-century necropolis located in Havuzdere, a village in the Altınova district of Yalova province, Türkiye (Fig 1). These remains, well-preserved, were processed and curated ~~in~~ at the Anthropology Laboratory of Ankara University, Faculty of Languages, History, and Geography. Morphological analyses of the cranium and pelvis were primarily used to determine the sex of the skeletons. Methods such as tooth wear, epiphyseal closure, and age-related changes in the symphysis pubis were used to determine age.[7, 8, 9]

[1] Craig Stanford, John S. Allen, Susan C. Antón, "Bioarchaeology and Forensic Anthropology" in *Biologial Anthropology: The Natural History of Humankind*, S. 533 (2013): 528-560, Third edition.

[2] Stanford, Allen and Antón, "Bioarchaeology and Forensic Anthropology" 537

[3] Tim D. White, Michael T. Black, and Pieter A. Folkens, *Human Osteology* (USA: Academic Press, Third Edition, 2012), 410.

[4] Erksin Güleç, Mehmet Sağır, İsmail Özer, "İnsan İskeletlerinde Foramen Magnumdan Cinsiyet Tayini.", *Ankara Üniversitesi Dil ve Tarih Coğrafya Fakültesi Dergisi*, 43, S.2 (2003): 1-9.

[5] İsmail Özer, "Eski Anadolu ve Japon İskeletlerinde Diskriminant Fonksiyon Analiziyle Cinsiyet Tayini", *OLBA*, 22, S.2-3 (2014): 1-14.

[6] Öznur Gülhan, "Pelvis'ten Radyolojik Yöntemler ile Cinsiyet Tayini: Türkiye Örneklemi", *Antropoloji*, 36, (2018): 53-69.

[7] Douglas H. Ubelaker, *Human Skeletal Remains*, (Smithsonian Institution. Chicago: Aldine Publishering Company, 1978)

[8] WEA (Workshop of European Anthropologists), "Recommendation for Age and Sex Diagnoses of Skeleton", *Journal of Human Evolution*, 9, (1980): 517-549.

[9] İsmail Özer, "*Dilkaya (Van) Populasyonunun Diskriminant Fonksiyon Analizi ve Anadolu Toplulukları Arasındaki Yeri*," Yayımlanmamış Doktora Tezi, (Ankara Üniversitesi, 1999).

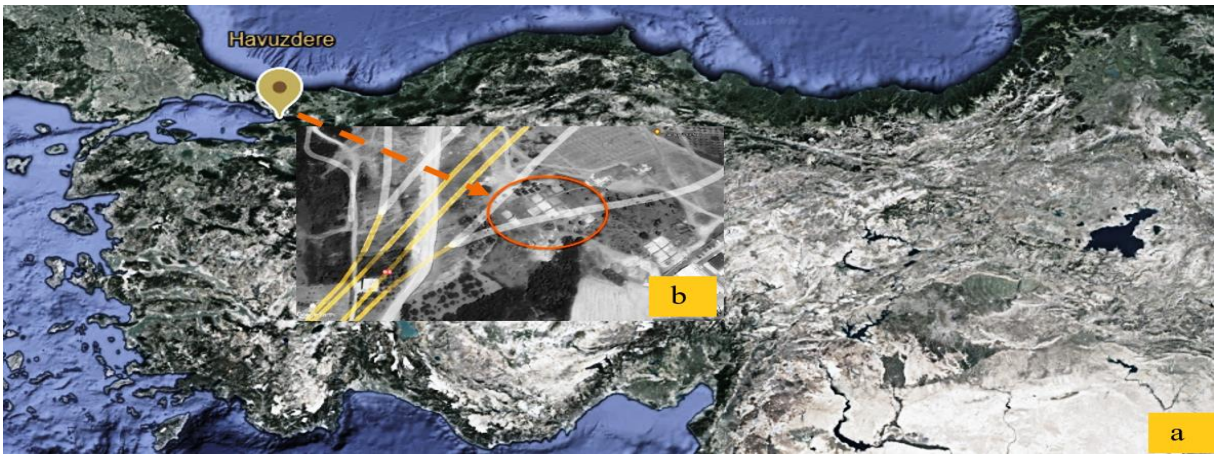

Fig 1. a) Location of Havuzdere (Google Earth / 09.02.2024) b) Satellite Image of Havuzdere, August 2013 (Google Earth / 03.06.2024)

Only adult individuals, aged 18 and above, with complete epiphyseal closure and whose sex was reliably determined through morphological criteria, were included in the study. Skeletal remains that exhibited significant postmortem damage, pathological alterations (such as osteoarthritis or enthesopathies), or traumatic injuries were excluded to ensure data integrity and analytical accuracy (Table 1).

Table 1: Sex and age distribution of Havuzdere adult individuals whose patella measurements were taken

Age Groups	Sex Distribution		
	Female	Male	Female + Male
18-29,9 (Young Adult)	8	8	16
30-44,9 (Middle Adult)	30	57	87
45+ (Old Adult)	11	9	20
Total	**49**	**74**	**123**

1.2. Method

Measurements of the left patella were taken based on the methods described by Martin[10], Dayal and Bidmos[11] using an osteometric board and a spreading caliper (Table 2, Fig 2).

1.3. Statistical Analysis

The statistical evaluation of the collected data was performed using SPSS version 23. To assess group differences and the discriminative ability of variables, a combination of statistical tools including the t-test, Wilks' Lambda test, F-test, and DFA was employed. The t-test assessed mean differences between sexes, while the Wilks' Lambda test assessed the discriminatory power of each variable. The F-test compared group variances, and DFA was used to generate predictive models for sex classification based on the patella measurements. [12, 13]

[10] Martin, Rudolf, "Lehrbuch der Anthropologie in Systematischer Darstellung mit Besonderer Berücksichtigung der anthropologischen Methoden für Studierende," *Ärtze und Forschungsreisende*. (1928): Vol 2: Kraniologie, Osteologie. Jena, Germany: Gustav Fischer.

[11] Manisha Ramanlal Dayal and Mubarak Ariyo Bidmos, "Discriminating Sex in South African Blacks Using Patella Dimensions", *Journal of Forensic Sciences*, 50(6), (2005): 1294–1297.

[12] Şeref Kalaycı, *SPSS Uygulamalı Çok Değişkenli İstatistik Teknikleri* (Ankara: Asil Yayın Dağıtım, 2014)

[13] Özer, "Eski Anadolu ve Japon İskeletlerinde,"

Table 2: Measurements used on the patella bone

Code	Measurement	Definition	Resources
MPW	Maximum Patella Width	It is the largest distance between the medial and lateral edges. The measuring instrument is a spreading caliper or osteometry board.	[14]
MPH	Maximum Patella Height	It is the largest distance between the base and the apex. The measuring instrument is a spreading caliper or osteometry board.	[15]
MPT	Maximum Patella Thickness	It is the largest distance between anterior and posterior. The measuring tool is a spreading caliper.	[16]

Fig 2: Patella bone of an individual coded B5 M65 (Female / 20-25 years old) in the Havuzdere population (1. MPW: Maximum Patella Width, 2. MPH: Maximum Patella Height, 3. MPT: Maximum Patella Thickness)

2. Results

Metric values of the patella and statistical analyses using these values are given in Table 3. Accordingly, it was observed that all measurements taken from the patella were higher in males than in females. In the t-test analysis, all measurements were found to be significant at $p<0.001$ level.

According to the Wilks' Lambda test, maximum patella height and maximum patella thickness measurements were found to be the most significant measurements between the sexes. In the F- test, another test of variance analysis, the measurements that showed the most significant difference in the Wilks' lambda test were found to be the ones that best reflected sex differences (Table 3).

Table 3. Mean, standard deviation, and statistical values of the patella bone of Havuzdere individuals.

Variables	Female (N=49)			Male (N=74)			Analyzes (Female+Male=123)		
	N	Mean (mm)	SD	N	Mean (mm)	SD	t-Test*	Wilks' Lambda Test	F Test
Patella									
MPW	46	40,196	3,339	67	45,030	3,098	7,895*	0,623	62,220
MPH	45	38,933	2,551	66	43,902	2,450	10,316*	0,487	108,533
MPT	49	19,204	1,266	73	21,288	1,431	8,250*	0,614	64,785

*p<0,001
SD: Standard deviation
MPW: Maximum Patella Width, MPH: Maximum Patella Height, MPT: Maximum Patella Thickness

[14] Martin, "Lehrbuch der Anthropologie,"
[15] Martin, "Lehrbuch der Anthropologie,"
[16] Dayal and Bidmos, "Discriminating Sex,"

The discriminant analysis results of the metric data obtained from the patella bone in the Havuzdere population are given in Table 4. For each function, the discriminant function coefficient, constant, sectioning point, distinction point, and percentage of correct sex separation are given in the table. Accordingly, the maximum patella height measure of sex is 85.6%; the maximum patella width measurement was able to distinguish 81.4% accurately. The lowest discrimination rate is the maximum thickness measure at 77.9%.

Table 4. Discriminant function analysis of the patella bone of Havuzdere individuals

Variables	Coefficient	Constant	Sectioning Point	Distinction Point	Accuracy (%)		
Patella					**Female**	**Male**	**Female + Male**
MPW	0,313	-13,466	-0,141	43,062	78.3	83.6	81.4
MPH	0,401	-16,815	-0,189	41,888	82.2	87.9	85.6
MPT	0,731	-14,955	-0,15	20,451	83.7	74.0	77.9
AV					88.4	83.9	85.7

AV: All Variables (only % accuracy rates used)

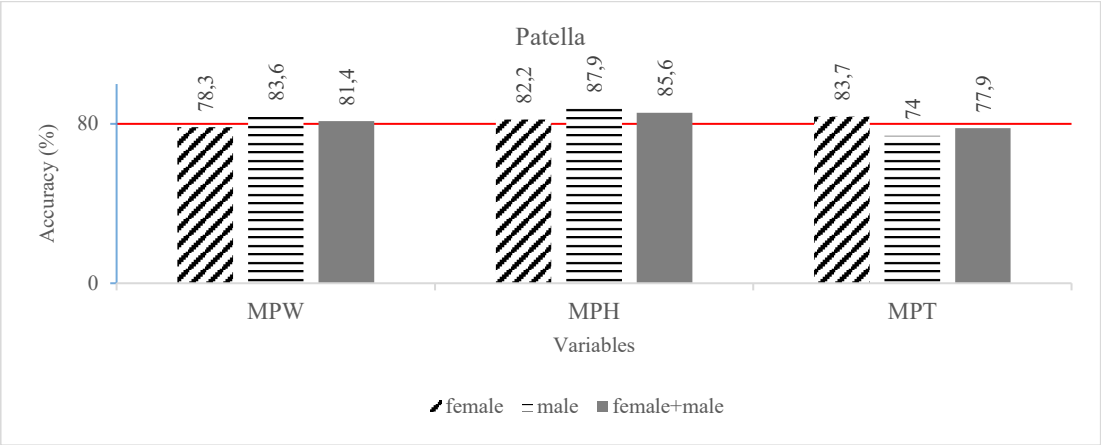

Fig 3. Accuracy rates with discriminant function analysis of patella bone of Havuzdere individuals

There was one measurement with an accuracy rate below 80% for both sexes. It correctly distinguished the maximum thickness measurement in female individuals with a rate of 83.7%. The lowest discrimination rate is the maximum patella width measure at 78.3%. The maximum patella height measurement accurately distinguished 87.9% of male individuals. The lowest discrimination rate is the maximum thickness measure at 74.0% (Table 4, Fig 3).

3. Discussion

The findings of this study provide valuable insights into the utility of patellar measurements for sex estimation and contribute to the growing body of research on postcranial skeletal dimorphism. While the measurements of the patella demonstrated significant sexual dimorphism, it is crucial to interpret these results within the framework of methodological limitations and contextual factors.

In this section, studies which used univariate discriminant analysis (UDA) examined. The total number of variables used in the studies is provided in the tables. In the discussion section, the number and percentage values of the variables reported in other studies consistent with the present research are provided. Similarities and differences were revealed by comparing this study with previous studies (Table 5). In the Havuzdere population, patella height measurements were more determinative of sex than width and thickness measurements. Measurements in males were classified more accurately than those in females.

In his study, Kemkes-Grottenthaler[17] used skeletons dating back to the Early Middle Ages. Seven measurements were taken from the patella bones of 52 people (26 females, 26 males) whose sex was determined by morphological methods. Three measurements are compatible with the current study. The highest rate was the maximum patellar height measurement at 80.8% (80.8% females, 80.0% males). Maximum patella width (73.1% females, 80.8% males) and thickness measurements (80.8% females, 73.1% males) remained below 80% with a rate of 76.9%. Phoophalee et al.[18] took six measurements from the patella of 191 individuals from Northern Thailand (54 females, 137 males) whose sex was known, and three measurements were consistent with the current study. The highest rate was the maximum height measurement at 84.8%. The maximum width measurement was 81.2%. The maximum thickness remained below 80% at 74.7%. In a study, Michiue et al.[19] took four measurements from the patella of 220 Japanese individuals (110 females, 110 males) of known sex, and two measurements (maximum height and thickness measurements) are compatible with the current study. The maximum height measurement was 80.9% (80.3% females, 84.5% males) and the maximum thickness measurement was 74.1% (76.8% females, 71.9% males), below the 80% accuracy percentage. In a study, Indra et al.[20] used the patella and talus bones of 234 Swiss individuals (117 females, 117 males) whose sex was known. Three measurements were taken from the patella, and all three are compatible with the current study. Maximum height is 82.48% (75.21% females, 89.74% males), and maximum width is 81.20% (82.05% females, 80.34% males). The maximum thickness remained below 80% with a rate of 62.82% (29.06% females, 96.58% males). In a study, Bidmos et al.[21] took six measurements from the patella of 260 South African individuals (130 females, 130 males) whose sex was known. Three measurements are compatible with the current study. The highest rate was the maximum height measurement of 81.5% (83.8% females, 79.2% males). Maximum width and thickness measurements remained below the 80% accuracy percentage with rates of 78.5% (80.0% females, 76.9% males) and 74.6% (76.2% females, 73.1% males), respectively. As in these studies, we see that the highest rate of patella measurements in the Havuzdere population is the height measurement. In addition, the accuracy percentages of thickness measurement in the Havuzdere population and the Kemkes-Grottenthaler[22] study are close to one another. Although the general accuracy percentages in the study of the Havuzdere population and Phoophalee et al.[23] are very close, no further comments can be made since the accuracy percentages for males and females are not given separately.

In their study, Akhlaghi et al.[24] took three measurements from the patella of 113 Iranian individuals (56 females, 57 males) whose sex was known, and all three measurements (maximum width, height, and thickness measurements) were consistent with the current study. The highest accuracy rate was the maximum width measurement at 91.2%. The maximum height measurement was 89.4%. The maximum thickness remained below 80% at 74.3%. In a different study, Yasar Teke[25] took three measurements from the patella of 220 Turkish individuals (110 females, 110 males) of known sex, and all three measurements (maximum width, height, and thickness measurements) are compatible with the current study. The highest accuracy rate was the maximum width measurement of 86.5% (89.0% females, 84.0%

[17] Ariane Kemkes-Grottenthaler, "Sex Determination by Discriminant Analysis: An Evaluation of the Reliability of Patella Measurements", *Forensic Science International*, 147(2-3), (2005).

[18] Paolo Phoophaleea et al., "Sex Determination by Patella Measurements in Thais," *The 1st ASEAN Plus Three Graduate Research Congress (AGRC2012)*, (2012): 472-477.

[19] Michiue et al., "Virtual Computed Tomography Morphometry of the Patella for Estimation of Sex Using Postmortem Japanese Adult Data in Forensic Identification", *Forensic Science International*, 285, (2018): 206.e1–206.e6.

[20] Indra et al., "Testing the Validity of Population-Specific Sex Estimation Equations: An Evaluation Based on Talus and Patella Measurements", *Science & Justice*, 61(5), (2021): 555–563.

[21] Bidmos et al., "Machine Learning and Discriminant Function Analysis in the Formulation of Generic Models for Sex Prediction Using Patella Measurements", *International Journal of Legal Medicine*, 137(2), (2023): 471–485.

[22] Kemkes-Grottenthaler, "Sex Determination,"

[23] Phoophalee et al., "Sex Determination,"

[24] Akhlaghi et al., "Identification of Sex,"

[25] Yasar Teke et al., "Determining Gender by,"

males), the height measure has a rate of 84.5% (86.0% females, 83.0% males). The thickness measurement remained below the 80% accuracy percentage with a rate of 79.0% (77.0% females, 81.0% males). In a study, Rahmani et al.[26] took three measurements from the patella of 161 Iranian individuals (82 females, 79 males) whose sex was known. All three measurements (maximum width, height, and thickness) are compatible with the current study. The highest accuracy rate was the maximum width measurement at 85.1% (87.7% females, 82.3% males) and was the only measurement above the 80% accuracy rate. The height measurement remained below the 80% accuracy percentage with a rate of 75.2% (74.4% females, 75.9% males) and thickness with a rate of 65.8% (70.7% females, 60.8% males). In their study, Srinak and Sukvitchai[27] took six measurements from the patella of 130 individuals (65 females, 65 males) from Central Thailand, whose sex was determined by DNA analysis. Three measurements (maximum height, width, and thickness) are consistent with the current study. The maximum width measurement is 84% (86% females, 82% males), the maximum height measurement 82% (82% females, 86% males), and the maximum thickness measurement 80% (80% females, 80% males). In these studies, the width measurement was the highest ratio in patella measurements.

Table 5. Sex estimation studies performed with metric measurements from the patella bone

Author	Population	Material	Sample (N)	NV*	UDA (↑/↓)**
[28]	Southern Italy	Dry Bone/ 1970	40 female / 40 male	7	↑%78.75 ↓%62.50
[29]	Germany	Dry Bone / Early Medieval Ages (4.-8. century AD)	26 female / 26 male	7	↑%80.8 ↓%71.2
[30]	Iran	Current Cadavers / 2007-2008	56 female / 57 male	3	↑%91.2 ↓%74.3
[31]	Northern Thailand	Dry Bone / Current	54 female / 137 male	6	↑%85.3 ↓%72.8
[32]	Japan	Forensic Autopsy Measurements / 2010-2014 / CT	110 female / 110 male	4	↑%87.7 ↓%74.1
[33]	Türkiye	Living Individuals / 2015 / MR	110 female / 110 male	3	↑%86.5 ↓%79.0
[34]	Iran	Living Individuals / 2019-2020 / MR	82 female / 79 male	3	↑%85.1 ↓%65.8

[26] Rahmani et al., "Anthropometric Characteristics,"

[27] Srinak and Sukvitchai, "Sex Estimation ,"

[28] Introna Jr et al., "Sex Determination by Discriminant Analysis of Patella Measurements", *Forensic Science International*, 95(1), (1998): 39–45.

[29] Kemkes-Grottenthaler, "Sex Determination,"

[30] Akhlaghi et al., "Identification of Sex in Iranian Population Using Patella Dimensions", *Journal of Forensic and Legal Medicine*, 17 (3), (2010): 150–155.

[31] Phoophalee et al., "Sex Determination,"

[32] Michiue et al., "Virtual Computed Tomography,"

[33] Yasar Teke et al., "Determining Gender by Taking Measurements from Magnetic Resonance Images of the Patella", *Journal of Forensic and Legal Medicine*, 58, (2018): 87–92.

[34] Rahmani et al., "Anthropometric Characteristics of Patella for sex Estimation Using Magnetic Resonance Images", Forensic Imaging, 23, (2020): 1-5.

[35]	Switzerland	Dry Bone / 1930-1960	117 female / 117 male	3	↑%82.48 ↓%62.82
[36]	South Africa	Dry Bone / Dart Collection	130 female / 130 male	6	↑%81.5 ↓%74.6
[37]	Central Thailand	Dry Bone / 2003-2020	65 female / 65 male	6	↑%88 ↓%77
The present study	Havuzdere (Yalova) / Türkiye	Dry Bone / Medieval Ages	49 female / 74 male	3	↑%85.6 ↓%77.9

*NV: Number of Variables
**UDA (↑/↓): Univariate Discriminant Analysis (Highest '↑' and lowest '↓' accuracy rate)

The study in which Introna Jr. et al.[38] took seven measurements from the patella of 80 Italian individuals (40 females, 40 males) of known sex is the only study in which the thickness measurement was the highest among the measurements taken. Three of the measurements are consistent with the current study. The maximum thickness measurement was 78.75% accurate, the height 72.50%, and the width was 71.25% accurate. All values were below 80% accuracy.

An examination of the aforementioned studies indicates that the maximum patella height and maximum patella width measurements yield relatively higher accuracy rates in sex estimation. The anatomical relationship of the patella bone to the femur and tibia bones affects the morphological features of the patella. In particular, the patella's shape, size, and structural features are associated with its connection to the femur and tibia bones and are significant in the sex estimation process.

Introna Jr. et al.[39] compared their study results with those of different populations. They emphasized that sexual dimorphism models differ between populations and that the resulting formulas may not have the same level of accuracy when applied to groups other than the Italian population. Likewise, Srinak and Sukvitchai[40] showed in their study that the findings obtained from Central Thai individuals cannot be used with the discriminant equation developed for the Northern Thai population. This situation highlighted the need for region-specific analysis, including in different regions within the same population. When the two studies conducted in Türkiye are compared, it is evident that both the overall accuracy ranking and the accuracy rates for male and female individuals are different.[41] These examples provide strong evidence for the need for population-specific standards.

Although the patellar measurements used in this study yielded high accuracy rates for sex estimation, there are inherent limitations associated with methods based solely on skeletal morphology. In the absence of death records or genetic data, a certain margin of error is inevitable. For example, the classification accuracy based on maximum patella height was 85.6%, while maximum width yielded an accuracy of 81.4%. While these figures indicate a strong potential for discriminating between sexes, they also demonstrate that complete accuracy cannot be achieved. Therefore, the results of osteometric analyses should be interpreted with caution, particularly in archaeological or forensic contexts where additional verification is not possible. Future research incorporating larger sample sizes and

[35] Indra et al., "Testing the Validity,"
[36] Bidmos et al., "Machine Learning and Discriminant,"
[37] Srinak and Sukvitchai, "Sex Estimation from Patella Using Discriminant Analysis in Central Thai Population", *Canadian Society of Forensic Science Journal*, (2023): 1-17.
[38] Introna Jr. et al., "Sex Determination by Discriminant,"
[39] Introna Jr. et al., "Sex Determination by Discriminant,"
[40] Srinak and Sukvitchai, "Sex Estimation ,"
[41] Yasar Teke et al., "Determining Gender by,"

multidisciplinary approaches, including genetic testing where feasible, may further improve the reliability of sex estimation from skeletal remains.

CONCLUSIONS

The patella bone was used in this study, which was conducted on a total of 123 adult individuals (49 females, 74 males) from the Havuzdere (Yalova) population dating back to the Middle Ages. When the average values of male and female measurements were compared, it was observed that the male average values were higher than those of the females. Upon application of t-test analysis significant results were obtained at the $p<0.001$ level for all measurements taken from the patella. In sex predictions made using DFA, although males were not dominant, they more often reflected sexual dimorphism. According to the study's findings, the maximum patella height measurement correctly predicted sex in 85.6% (82.2% females, 87.9% males) of cases; the maximum patella width measurement was able to accurately distinguish sex in 81.4% of cases (78.3% females, 83.6% males). The lowest discrimination rate was for the maximum thickness measurement, at 77.9% (83.7% females, 74% males). Height and width measurements of the patella are more reliable than thickness measurements. When all variables were evaluated together, the percentage of correct sex discrimination increased (88.4% females, 83.9% males, 85.7% female + male). It is possible to reliably discriminate sex using the patella bone with the help of DFA.

The findings of this research demonstrate that metric analysis of the patella bone offers a valid and efficient method for estimating sex from skeletal remains. Particularly in scenarios where more commonly used elements such as the pelvis or skull are unavailable, the patella serves as a practical alternative. These results contribute to forensic anthropology, archaeological interpretation, and bioarchaeological investigations by providing a dependable method of sex determination based on a durable and often preserved skeletal element.

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