ORIGINAL ARTICLE

UDC: 616-071.3:611.718
DOI: https://doi.org/10.2298/VSP180917055M

Gender-specific differences in the anthropometric characteristics of the distal femur and proximal tibia condyles

Polno specifične razlike u antropometrijskim karakteristikama donjeg okrajka butne kosti i gornjeg okrajka golenjače

Nadica Marinković*†, Ivan Aleksić*†, Jasenka Vasić Vilić‡, Nataša Janović§

Military Medical Academy, *Institute of Pathology and Forensic Medicine, ‡Institute of Radiology, Belgrade, Serbia; †University of Defence, Faculty of Medicine of the Military Medical Academy, Belgrade, Serbia; §University of Belgrade, Faculty of Medicine, Department of Anatomy, Laboratory for Anthropology, Belgrade, Serbia

Abstract

Background/Aim. In the course of identification, skeletal remains are used to determine the gender, age, and height of the body. The pelvic bone, skull, and femur were commonly used to determine gender; however, modern radiology techniques have enabled the use of other bones of the skeletal system (all long bones, scapula, clavicle, metacarpal and metatarsal bones, vertebras, ribs, etc.). The aim of this study was to determine whether certain anthropometric characteristics of the distal femur and proximal tibia are indicative of gender differences. **Methods.** The respective research has been carried out between 2011 and 2014 at the Institute of Pathology and Forensic Medicine and Institute of Radiology of the Military Medical Academy in Belgrade on 203 subjects (152 men and 50 women), between 11 and 63 years of age (35.50 ± 12.98). Diagnostic magnetic resonance imaging (MRI) imaging of the living persons' knees was used. Measures taken included the longest mediolateral diameter of the distal femur condyle, the mediolateral diameter of the proximal tibia condyle and the diameter of the proximal tibia intercondylar eminence. Descriptive statistics and the Student's *t*-test were used for statistical analyses of data. **Results.** The mediolateral diameter of the distal femur in men was from 7.70 cm to 9.70 cm (8.80 ± 0.39 cm), and in women from 6.60 cm to 8.50 cm (7.62 ± 0.39 cm). The mediolateral diameter of the proximal tibia in men was from 7.20 cm to 9.30 cm (8.09 ± 0.38 cm), and in women from 5.90 cm to 8.00 cm (7.04 ± 0.36 cm). The mediolateral diameter of the proximal tibia intercondylar eminence in men was from 1.00 cm to 2.30 cm (1.44 ± 0.21 cm), and in women from 0.90 cm to 2.00 cm (1.33 ± 0.21 cm). The measures obtained showed a gender-specific statistically significant difference. **Conclusion.** The mediolateral diameters of the distal femur condyle, proximal tibia condyle and proximal tibia intercondylar eminence are indicative of gender-specific differences and may be used in the procedure of determining gender based on skeletal remains.

Key words:
anthropometry; femur; sex factors; tibia.

Apstrakt

Uvod/Cilj. U toku postupka identifikacije osoba, skeletni ostaci se koriste za utvrđivanje pola, životnog doba i visine tela. Za utvrđivanje pola do sada su najčešće korišćene karlična kost, lobanja i butna kost, ali su savremene radiološke tehnike omogućile da se koriste i druge kosti skeletnog sistema (sve duge kosti, lopatica, ključna kost, metakarpalne, metatarzalne kosti, kičmeni pršljenovi, rebra i dr.). Cilj ovog rada je bio da se utvrdi da li su određene antropometrijske karakteristike donjeg okrajka butne kosti i gornjeg okrajka golenjače specifične za pol. **Metode.** Retrospektivno istraživanje sprovedeno je od 2011. do 2014. godine u Institutu za patologiju i sudsku medicinu i Institutu za radiologiju Vojnomedicinske akademije u Beogradu na 203 ispitanika (152 muškarca i 50 žena), životnog doba od 11 do 63 godina (35,50 ± 12,98). Korišćeni su snimci kolena živih osoba, urađeni u dijagnostičke svrhe magnetnom rezonancom (MRI). Mereni su najduži mediolateralni promer u predelu kondila donjeg okrajka butne kosti, mediolateralni promer u predelu kondila gornjeg okrajka golenjače i promer interkondilarne eminencije gornjeg okrajka golenjače. Za statističku analizu podataka korišćene su metode deskriptivne statistike i Studentov *t*-test. **Rezultati.** Pokazano je da mediolateralni promer donjeg okrajka butne kosti muškaraca iznosi od 7,70 cm do 9,70 cm (8,80 ± 0,39 cm), a žena od 6,60 cm do 8,50 cm (7,62 ± 0,39 cm). Mediolateralni promer gornjeg okrajka golenjače muškaraca je u rasponu od 7,20 cm do 9,30 cm (8,09 ± 0,38 cm), a žena od 5,90 cm do 8,00 cm (7,04 ± 0,36 cm). Mediolateralni promer interkondilarne

Correspondence to: Nadica Marinković, Military Medical Academy, Institute of Pathology and Forensic Medicine, Crnotravska 17, 11 000 Belgrade, Serbia. E-mail: nadicamarinkovic@yahoo.com

eminencije gornjeg okrajka golenjače muškaraca je bio od 1,00 cm do 2,30 cm (1,44 ± 0,21 cm), a žena od 0,90 cm do 2,00 cm (1,33 ± 0,21 cm). Ustanovljenim merama je pokazana statistički značajna razlika specifična za pol. **Zaključak.** Mediolateralni promeri u predelu kondila donjeg okrajka butne kosti, gornjeg okrajka golenjače i interkondilarne eminencije gornjeg okrajka golenjače pokazuju polnu specifičnost i mogu se koristiti u postupku utvrđivanja pola na osnovu skeletnih ostataka.

Ključne reči:
antropometrija; femur; pol, faktor; tibija.

Introduction

Forensic medicine is an interdisciplinary science that uses forensic anthropometry in its scope of work. Forensic anthropometry is a forensic anthropology discipline dealing with the identification and analysis of human skeletal remains with the help of different metric techniques [1, 2]. The skeletal remains are often the only material that can be used to determine the identity of a person, and thus they are used to determine the gender, age, and height of the body [3]. Pelvic bones [4, 5] and skulls [6], but also the long bones [7, 8], scapula, clavicle [9], metacarpal [10] and metatarsal bones, vertebras and ribs [1] are most frequently used to determine gender. Each identification procedure based on skeletal remains starts with a detailed description of individual bones, their anthropometric characteristics, the existence of signs of diseases, recent or old fractures and injuries [1]. The development of radiology and forensic anthropology brought about the use of various techniques for the analyses of anthropometric characteristics of the bones, allowing the visualization and precise measuring of certain bone elements on the bodies during the autopsy, on skeletal remains after exhumation, but also living persons. Radiologic knee examinations of living persons may be used to analyze the anthropometric characteristics of the distal femur and proximal tibia [11]. So far, several anthropometric characteristics of the distal femur and proximal tibia have been found that are gender-specific [12].

The aim of this research was to determine whether the following anthropometric characteristics – the mediolateral diameter of the distal femur condyle, the mediolateral diameter of the proximal tibia condyle and the diameter of the proximal tibia intercondylar eminence can be indicative of gender differences.

Methods

This retrospective study was carried out at the Institute of Pathology and Forensic Medicine and the Institute of Radiology of the Military Medical Academy in Belgrade using the archived materials covering the period from November 2011 until September 2014. The research included 203 subjects (152 men and 50 women), from 11 to 63 years of age. The average age of the subjects was 35.50 ± 12.98 years. Images in electronic form, made during the magnetic resonance imaging (MRI) examination of patients' knees were used for this research. Radiologic examinations of patients using MRI were done as part of the clinical examinations and diagnostic procedures of various painful knee conditions, including fractures and tumorous changes. Diagnostic MRI examinations were done using the GE SIGNA HDX-3T device, while the analyses included the distal femur and proximal tibia. During the anteroposterior examination, the diameters were measured in accordance with the standards of anteroposterior measuring: the mediolateral diameter of the distal femur condyle, the mediolateral diameter of the proximal tibia condyle and the diameter of the proximal tibia intercondylar eminence (Figure 1).

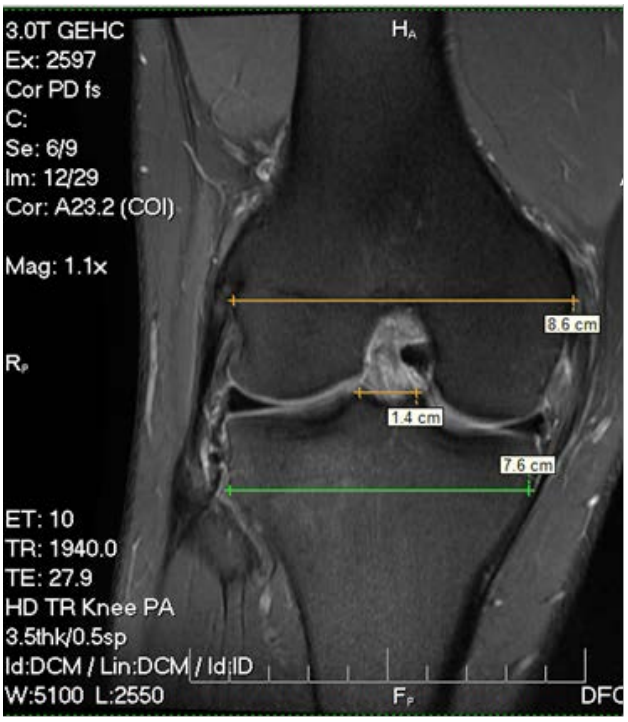

Fig. 1 – Magnetic resonance imaging examination of the knee: the longest mediolateral diameter of the distal femur condyle (orange), the longest mediolateral diameter of the proximal tibia condyle (green) and the longest diameter of the proximal tibia intercondylar eminence (orange).

Statistical analysis of the data obtained from this research was done using the statistical software IBM SPSS Statistics Version 23 by applying standard statistical methods of descriptive statistics (mean value ± standard deviation). The results were statistically analyzed using the parametric test (Student's *t*-test). The statistical significance level was $p < 0.05$.

Results

Statistical analyses of the data showed that the mediolateral diameter of the distal femur in men ranged from 7.70 cm to 9.70 cm (8.80 ± 0.39 cm), and in women from 6.60 cm

to 8.50 cm (7.62 ± 0.39 cm) (Figure 2). The mediolateral diameter of the proximal tibia in men ranged from 7.20 cm to 9.30 cm (8.09 ± 0.38 cm), and in women from 5.90 cm to 8.00 cm (7.04 ± 0.36 cm) (Figure 3). The mediolateral diameter of the proximal tibia intercondylar eminence in men ranged from 1.00 cm to 2.30 cm (1.44 ± 0.21 cm), and in women from 0.90 cm to 2.00 cm (1.33 ± 0.21 cm) (Figure 4).

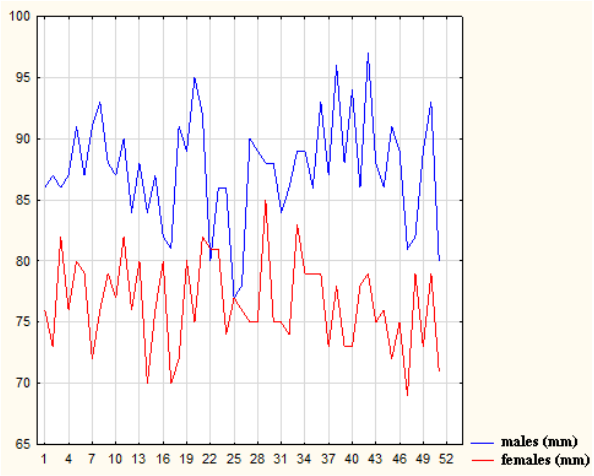

Fig. 2 – Mediolateral diameter of the distal femur condyle.

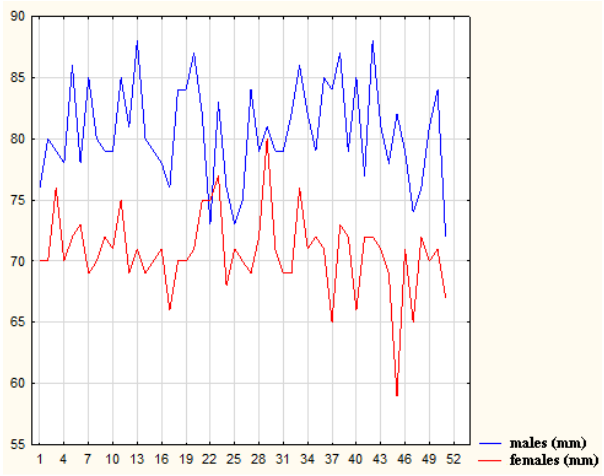

Fig. 3 – Mediolateral diameter of the proximal tibia condyle.

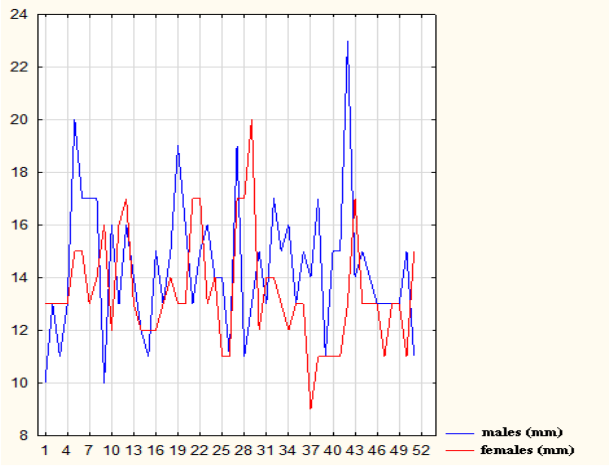

Fig. 4 – The proximal tibia intercondylar eminence diameter.

The statistical analyses using the parametric test – Student's *t*-test showed a statistically significant difference in all of the analyzed parameters, in particular the mediolateral diameter of the distal femur between men and women ($p < 0.0001$), the mediolateral diameter of the proximal tibia between men and women ($p < 0.0001$) and the mediolateral diameter of the proximal tibia intercondylar eminence between men and women ($p = 0.024$).

Discussion

The research showed a statistically significant differences in the mediolateral diameter of the distal femur, the mediolateral diameter of the proximal tibia and the mediolateral diameter of the proximal tibia intercondylar eminence between men and women in the analyzed sample. The diameters in the area of medial and lateral condyles of the distal femur in the population of India are smaller compared to our analyzed sample and measure up to 71.5 ± 2.5 mm in men and 65.1 ± 3.1 mm in women. The knee images made using computed tomography (CT) were used for the analyses of these diameters and it has been established that there are statistically significant differences in diameters in the area of medial and lateral condyles of the distal femur, as well as in diameters in the area of medial and lateral condyles of the proximal tibia between men and women [13]. The research of the femur diameter in the population of Yemen, done by using MRI images of femurs, used to measure the diameter of the medial and lateral condyles, intercondylar height and width, has shown a statistically significant difference in all measured diameters between men and women ($p < 0.001$) [14]. By virtue of measurements using a digital osteometer, gender-specific differences in the diameter of femurs were found in the population of Bulgaria, and the diameters that have proven to be the most gender-specific are the maximal length and bicondylar length of the femur [3]. By using a

CT during the autopsy, gender-specific differences were found in the relationship between the volume of the femur, tibia and fibula and their length in the population of Japan [15]. Additionally, by using the CT, differences between mediolateral and anteroposterior diameters of distal femur were found in various populations of the same race (Malaysia, India, China) with the lowest values for both genders in the population of India [13, 16]. By using the CT and MRI, a statistically significant difference in the mediolateral diameter of the distal femur was noticed in women from the population of China and in Caucasian women, but not in the anteroposterior diameter. The measured values of the mediolateral and anteroposterior diameter of the proximal tibia are smaller in women from the population of China compared to the Caucasian women, but larger in men from the population of China compared to Caucasian men. However, this has no statistical significance [17]. Using the CT on the population of Turkey, it has been found that, from 13 measured femur parameters, the greatest gender-specific difference is found in bicondylar length, neck length and mediolateral subtrochanteric width [18]. By using the combination of standard osteometric measuring and digital radiography to determine the bicondylar angle, it has been found that a gender-specific, statistically significant difference in bicondylar diameter exists in the population of Bengal [11]. By using 3D images of femurs of cadavers or patients undergoing surgery in the population of Korea, by measuring a total of 28 parameters, gender-specific differences were found in the majority of parameters, while population-specific differences were found for 14 parameters [19]. Using the standard osteometric measuring of the tibia on the cadavers from the population of the Mediterranean (Greece, Spain, Italy), gender-specific differences have been found that have statistically greater significance for the population of Greece in terms of tibia length and distal epiphyseal width, for the population of Spain in terms of tibia length and proximal epiphyseal width and for the population of Italy in terms of distal and proximal epiphyseal width [20].

Conclusion

The mediolateral diameter of the distal femur condyle, the mediolateral diameter of the proximal tibia condyle and the diameter of the proximal tibia intercondylar eminence are indicative of gender-specific differences in the population of Serbia and may be used in the procedure of determining gender based on skeletal remains. Since differences and specific characteristics have been found among different populations, it is clear that the research of population-specific anthropometric characteristics has to continue.

REFERENCES

1. *Krishan K.* Anthropometry in forensic medicine and forensic science-Forensic Anthropometry. Internet J Forensic Sci 2007; 2(1): 6.
2. *Galloway A, Simmons TL.* Education in Forensic Anthropology: appraisal and outlook. J Forensic Sci 1997; 42(5): 796–801.
3. *Timonov P, Fasova A, Badiani K, Radoinova D, Alexandrov A.* Sex determination from the femur in a Bulgarian modern population. Anil Aggraw Intern J Forensic Med Toxicol 2015; 16(2): 09728074. Available from: http://anilaggrawal.com/ij/vol_016_no_002/papers/paper001.html. [accessed: 2020 June 4].
4. *Rissech C, Garcia M, Malgosa.* Sex and age diagnosis by ischium morphometric analysis. Forensic Sci Int 2003; 135(3): 188–96.
5. *Patriquin ML, Steyn M, Loth SR.* Metric analysis of sex differences in South African black and white pelves. Forensic Sci Int 2005; 147(2–3): 119–27.
6. *Adams BJ, Byrd JE.* Interobserver variation of selected postcranial skeletal measurements. J Forensic Sci 2002; 47(6): 1193–202.
7. *Bhaskar BR, Doshi MA.* Sex determination from adult human humerus by discriminant function analysis. IJRMS 2017; 5(9): 3891–7.
8. *Cho HJ, Kwak DS, Kim IB.* Morphometric Evaluation of Korean Femurs by Geometric Computation: Comparisons of the Sex and the Population. Biomed Res Int 2015; 2015: 730538.
9. *Frutos LR.* Determination of sex from the clavicle and scapula in a Guatemalan contemporary rural indigenous population. Am J Forensic Med Pathol 2002; 23(3): 284–8.
10. *Falsetti AB.* Sex assessment from metacarpals of human hand. J Forensic Sci 1995; 40(5): 774–6.
11. *Biswas A, Bhattacharya S.* A morphometric and radiological study of the distal end of femur in West Bengal population. IJAE 2017; 122(1): 39–48.
12. *Kazuhiro S.* Sexual determination of long bones in recent Japanese. Anthropol Sci 2004; 112(1): 75–81.
13. *Shah DS, Ghyar R, Ravi B, Hegde CH, Shetty V.* Morphological measurements of knee joints in Indian population: comparison to current knee prostheses. Open J Rheumatol Autoim Dis 2014; 4(2): 75.
14. *Murshed KA, Cicekcibasi EA, Karabacakoğlu A, Sekar M, Zivlan T.* Distal femur morphometry: a gender and bilateral comparative study using magnetic resonance imaging. Surg Radiol Anat 2005; 27(2): 108–12.
15. *Hishmat AM, Michiue T, Sooava N, Orlani S, Ishikawa IA, Fawzu IA,* et al. Virtual CT morphometry of lower limb long bones for estimation of the sex stature using postmortem Japanese adult data in forensic identification. Int J Legal Med 2015; 129(5): 1173–82.
16. *Hussain F, Abdul Kadir MR, Zulkifly AH, Sa'at A, Aziz AA, Hossain G,* et al. Anthropometric measurements of the human distal femur: A study of the adult Malay population. Biomed Res Int 2013; 2013: 175056.
17. *Yue B, Varadarajan K, Ai S, Tang T, Rubash H, Li G.* Differences of knee anthropometry between Chinese and white men and women. J Arthroplasty 2011; 26(1): 124–30.
18. *Guhan O, Harrison K, Kris A.* A new computer-tomography-based method of sex estimation: Development of Turkish population-specific standards. Forensic Sci Int 2015; 255: 2–8.
19. *Cho HJ, Kwak DS, Kim IB.* Morphometric evaluation of Korean femurs by geometric computation: comparisons of the sex and the population. Biomed Res Int 2015; 2015: 730538.
20. *Kranioti EF, Apostol MA.* Sexual dimorphism of the tibia contemporary Greeks, Italians and Spanish: forensic implications. Int J Legal Med 2015; 129(2): 357–63.

Received on September 17, 2018
Revised on April 24, 2020
Accepted on June 2, 2020
Online First June, 2020