International Journal of
Medical Toxicology & Forensic Medicine
November 2017, Volume 7, Number 4

Research Paper: Gender Identification With Knee Bicondylar Width and Vertical Diameter of the Femur Head Based on Radiography Assessment

Behjat Ghorbanzadeh[1], Siamak Soltani[1*], Kamran Aghakhani[1], Sahar Rismantab Sani[2], Shayesteh Ashrafi Esfahani[1]

1. Department of Forensic Legal Medicine, Rasoul-e-Akram Hospital, Iran University of Medical Sciences, Tehran, Iran.
2. Department of Clinical Sciences, School of Medicine, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Use your device to scan and read the article online

Citation: Ghorbanzadeh B, Soltani S, Aghakhani K, Rismantab Sani S, Ashrafi Esfahani Sh. Gender Identification With Knee Bicondylar Width and Vertical Diameter of the Femur Head Based on Radiography Assessment. International Journal of Medical Toxicology & Forensic Medicine. 2017; 7(4):209-214. http://dx.doi.org/10.22037/ijmtfm.v7i4(Autumn).17358

doi: http://dx.doi.org/10.22037/ijmtfm.v7i4(Autumn).17358

Article info:
Received: 30 Apr. 2017
Accepted: 11 Aug. 2017

Keywords:
Anthropology, Gender, Femur

ABSTRACT

Background: Some skeletal criteria especially for bones of lower limbs are considerably different between men and women that may help in identifying the gender. We studied two lower limbs parameters, i.e. bicondylar width and vertical diameter of the femoral head based on radiographic assessment in gender identification.

Methods: Bicondylar width and vertical diameter of the femoral head of 280 radiographs taken from people aged 30 to 75 years were measured. Additionally, gender and age subgroups were recorded and added to the measured anthropometric parameters in the checklist of the study.

Results: The mean width of both left and right bicondylar bones as well as vertical diameter of both left and right femoral heads were significantly different between men and women. Considering two parameters of bicondylar width and vertical diameter of femoral head, the measurements could differentiate gender, with 96.7% sensitivity, 72.2% specificity, and 96.0% accuracy.

Conclusion: By measuring bicondylar width and vertical diameter of the femur head, it is possible to determine gender with a high discriminative capability.

1. Introduction

The identification is an essential component of cadaver examination [1]. In case of soft tissue destruction, the identification and diagnosis can be based solely on examination of residual bone and also assessment of its anatomical and pathological abnormalities [2]. In personal identification studies, gender identification is one of the most important steps. One of the known problems in forensic medicine is gender identification based on skeleton or its

*** Corresponding Author:**
Siamak Soltani, MD
Address: *Department of Forensic Legal Medicine, Rasoul-e-Akram Hospital, Iran University of Medical Sciences, Tehran, Iran.*
Tel: *+98 (21) 64352353*
E-mail: *research.rasoul2@gmail.com*

remnants that needs various specialties such as anatomy, radiology, archeology, and even dentistry [3].

So far, various bones have been used to determine the gender. While putrefaction and mass disasters make identification and gender determination of cadavers impossible in legal medicine centers, bone remnants still are useful in gender identification [4]. Because of disaster-prone condition of Iran, forensic medicine usually challenges with the fragmented skeletal components and the determination of both gender and anthropometric parameters can effectively help in identifying human identity [5]. However, some skeletal criteria especially for the bones of lower limbs are considerably different between men and women that may help in identifying the gender [6]. On the other hand, anthropometric parameters are frequently specific for each geographical place and ethnic group and thus preparing specific guideline and chart to determine human identity in each region seems necessary [7, 8]. This study aimed to value two lower limbs parameters, i.e. bicondylar width and vertical diameter of the femoral head based on radiographic assessment in gender identification.

2. Materials and Methods

In this cross-sectional study, bicondylar width and vertical diameter of the femoral head of 280 radiographs from subjects, aged 30 to 75 years, were studied. The study was conducted at Rasoul-e-Akram Hospital between 2014 and 2015. All subjects were resident in Tehran that were selected by convenience sampling methods and categorized at four age subgroups; 30 to 39 years, 40 to 49 years, 50 to 59 years, and 60 to 69 years. Considering the carcinogenic effects and risks of radiation with X-rays and due to ethical issue, the graphs of patients who underwent X-rays for other diagnostic indications, were used.

The exclusion criteria comprised gender uncertainty, age less than 18 years, poor quality of X-ray images (frequently because of rotation), the presence of fracture or prosthesis in assessed bone, and the presence of each pathological evidence in the bone. Regarding vertical diameter of the femoral head measurement, in total, 140 images were obtained that 70 were specified to men and 70 were specified to women. Also, 140 images were also obtained from 70 men and 70 women (35 in the left-sided and 35 in the right-sided). The measurements of 5 cm, and 92 cm in routine object film and focal-film, respectively, were used for taking films from the anteroposterior view.

All measurements were conducted by DiVision Lite Marco Imaging software, as they have been brought into an original size by the software. The required information about the bicondylar width and vertical diameter of the femoral head were assessed by Ruler Syngo software. Measurements and the results were presented in mm. The vertical diameter of femoral head was measured as the straight distance between the highest to the lowest point of the femoral head at the right angle to the long axis of the femur neck (Figure 1) and was measured as the maximum distance across the condyles in the transverse plane (Figure 2). Additionally, gender and age subgroups were recorded and added to the measured anthropometric parameters in the study checklist.

Mean and standard deviation values for quantitative variables were calculated and categorical variables were summarized and represented by absolute frequencies and percentages. The normality of the study data was checked by Kolmogorov-Smirnoff test. The categorical variables were compared using the Chi-square or Fisher exact test, when more than 20% of cells were observed with the expected count of less than 5. The quantitative variables were also compared with Mann-Whitney U or t test.

Evaluation of the different measured lower limb parameters for gender identification was performed using ROC curve. In this regard, by calculating area under the ROC curve (AUC), the value of bicondylar width and vertical diameter of the femur head, to discriminate male from female genders, was examined; then the best cutoff point for these parameters were specified; resulted in the optimized sensitivity and specificity. Higher AUC indicates stronger discriminative power of the femur dimensions in sex determining. In this analysis, true positive was defined as the variable classified the radiograph to be of a male and the individual was actually a male; true negative was defined as the variable classified the radiograph to be of a female and the individual was actually a female; false positive was defined as the variable classified the radiograph to be of a male and the individual was actually a female; and false negative was defined as the variable classified the radiograph to be of a female and the individual was actually a male. In addition, the sensitivity was defined as the ratio of true positive to the sum of true positive and false negative. Also, the specificity was calculated as the ratio of true negative to true negative and false positive. For statistical analyses, SPSS 22.0 (SPSS Inc., Chicago, IL) was used. P values of 0.05 or less were considered statistically significant.

3. Results

In assessment, the mean(SD) age of the cases was 43.61(12.50) years (range: 30–72 years) with no dif-

ference in mean(SD) age between men and women [42.24 (12.36) years versus 44.98(12.58) years, P=0.19]. Half of the cases (51.4%) were in the age range of 30 to 39 years, while only 2.8% were between 70 and 79 years. The mean(SD) width of right bicondylar bone was 86.45(6.99) mm (range: 78–99 mm) in men and 78.12(6.45) mm (range: 65.8–91 mm) in women with a significant difference (P<0.001) (Table 1). Similarly, the mean width of left bicondylar bone was 86.45(6.50) mm (range: 78.1–99 mm) in men and 77.94(4.54) mm (range: 72.3–89 mm) in women with a significant difference (P<0.001) (Table 1). The area under the ROC analysis could show that the measurement of both right (AUC=0.802, 95%CI: 0.700–0.905, P<0.001) and left (AUC=0.871, 95%CI: 0.792–0.951, P<0.001) could effectively discriminate genders (Figures 3 and 4). In this regard, the cutoff value of 81.3 mm for right yielded a sensitivity of 68.6% and a specificity of 68.6% to discriminate male from female genders. Also, the cutoff point of 81.5 mm for left obtained a sensitivity of 74.3% and a specificity of 74.3% to discriminate two genders. Regardless of the side of the bone, the best cutoff value to differentiate male from female genders was 78.5 mm yielding a sensitivity of 72.9% and a specificity of 72.9%.

In assessment of vertical diameter of the femur head, the mean(SD) age of the cases was 47.38(11.86) years (range: 30–73 years) with no difference in mean(SD) age between men and women [45.60(12.37) years versus 49.14(11.15) years, P=0.19]. About one-third of the cases (35.0%) were in the age range of 30-39 years, while only 2.9% were 70 to 79 years old. The mean(SD) vertical diameter of the right femoral head was 51.02(3.46) mm (range: 43–58.5 mm) in men and 44.63(2.33) mm (ranged from 41.6 to 53.4 mm) in women with a significant difference (P<0.001). Similarly, the mean vertical diameter of the left femoral head was 51.21(4.14) mm (range: 43.3–59.4 mm) in men and 44.67(3.40) mm (range: 35.5–52.7 mm) in women with a significant difference (P<0.001). The area under the ROC analysis could show that the measurement of both vertical diameter of right femoral head (AUC=0.917, 95%CI: 0.872-0.961, P<0.001) and left femoral head (AUC=0.914, 95%CI: 0.869–0.960, P<0.001) could effectively discriminate genders (Figures 5 and 6). In this regard, the cutoff value of 43.6 mm for vertical diameter of right femoral head yielded a sensitivity of 91.3% and a specificity of 75.7%. Also, the cutoff point of 46.7 mm for vertical diameter of left femoral head obtained a sensitivity of 91.3% and a specificity of 70.0%.

Table 1. Measurement of the vertical diameter and bicondylar width of femur head (mm)

Parameter	Side	Gender	Mean	SD	Min	Max	P
Vertical diameter of femoral head	Right	Male	51.02	3.46	43	58.5	<0.001
		Female	44.63	2.33	41.6	53.4	
	Left	Male	51.21	4.14	59.40	43.30	<0.001
		Female	46.67	3.40	35.50	52.70	
Bicondylar width of femur	Right	Male	86.45	6.99	78	99	<0.001
		Female	78.12	6.45	65.80	91	
	Left	Male	86.45	6.50	78.10	99	<0.001
		Female	77.94	4.54	72.30	89	

International Journal of
Medical Toxicology & Forensic Medicine

Table 2. Measurements of sensitivity and specificity, accuracy using both methods in sex determination

Index	Cut-Off Point (mm)	Sensitivity (%)	Specificity (%)	Accurac (%)	P
Vertical diameter of femoral head	46.4	91.3	71	96	<0.001
Bicondylar width of femur	78.5	72.9	72.9	96	<0.001

International Journal of
Medical Toxicology & Forensic Medicine

Figure 1. Measurement of bicondylar width of femur

Figure 2. Measurement of vertical diameter of the femur head

Regardless of the side of the bone, the best cutoff value for vertical diameter of femoral head to differentiate male from female genders was 46.4 mm yielding a sensitivity of 91.3% and a specificity of 71.0% (Table 2). In total, by considering two parameters of bicondylar width and vertical diameter of femur head, gender differentiation is possible with 96.7% sensitivity, 72.2% specificity, and 96.0% accuracy.

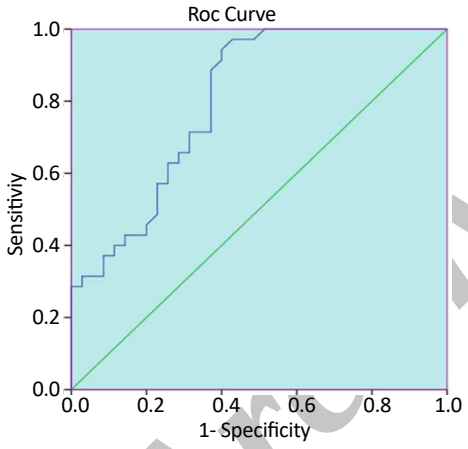

Figure 3. Area under the ROC analysis to determine value of right of femur to discriminate gender

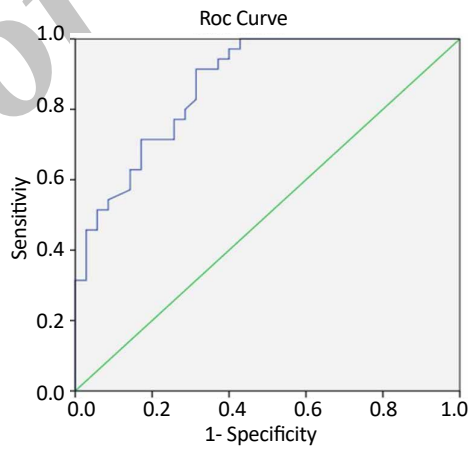

Figure 4. Area under the ROC analysis to determine value of left to discriminate gender

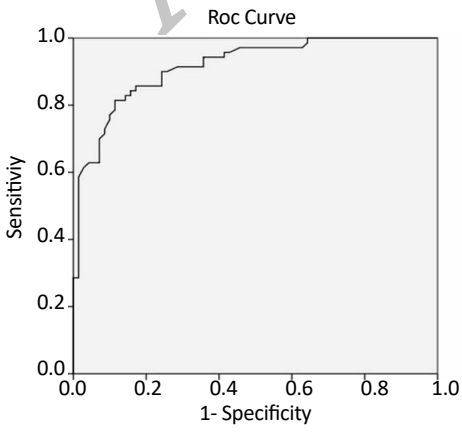

Figure 5. Area under the ROC analysis to determine value of right vertical diameter of right femoral head to discriminate gender

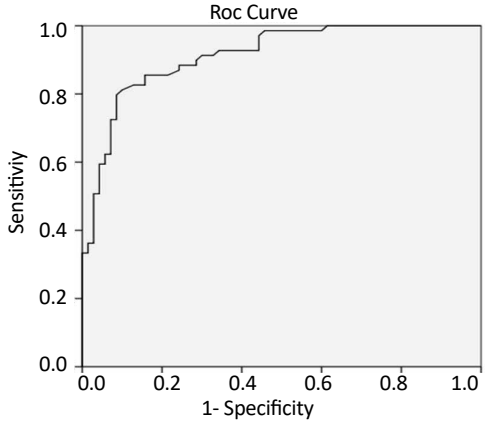

Figure 6. Area under the ROC analysis to determine value of left vertical diameter of right femoral head to discriminate gender

4. Discussion

Based on our study results, both bicondylar width and vertical diameter of femur head as the main parameters of lower extremities can be effectively used for gender determination. However, by considering two parameters simultaneously, determining gender can be more accurate. Because of the potential effects of geographical and ethnic characteristics on the anthropometric parameters of lower extremities, determining the reliable indices of extremities to estimate gender in each population is very important in forensic medicine, especially on cadavers and remained limbs. In this regard, we showed that the measurement of both indices with the yielded cutoff values can discriminate gender with acceptable sensitivity and specificity.

The assessment of these parameters is not only helpful to discriminate gender, but also for the design of joint and internal fixation materials in the limbs. Studies have demonstrated that there are differences between osteometric parameters of the femur among genders; for example, femoral intercondylar notch width and vertical diameter of the femur head [9-11]. However, the most frequently measured anatomic parameter of the distal femur is the bicondylar width of the femur. However, studies have a great variation on the definition of measuring points, in the measurement techniques and the type of sample that resulted in different measurement parameters on gender discrimination [12-14].

We measured the vertical diameter of the femur head for gender identification because we believe that this parameter is more reliable than other parameters for discriminating genders. In this study, the highest to the lowest point of the femoral head was measured at right angle to the long axis of the femoral neck that is in accordance with the standard definition [15].

Our measurements on vertical diameter of the femoral head are comparable with the previous surveys on different populations. Purkait et al. study [16] on Indian population indicated maximum vertical and horizontal diameter as the best discriminators (each attained 92.1% accuracy). In Clavero et al. study [17] on Spanish people, the prediction equation obtained using 9 variables of the femur and hip bone using a sample of CT images correctly classified 99.1 % of individuals.

Findings of Clavero study indicated that determining femoral head diameters can be highly effective for sex prediction. In Mitra et al. study in Iran [18], the mean values of the right and left maximum femoral head diameters and the minimum width of the femoral neck were significantly higher in men than in women. The accuracy of sex prediction with the right and left maximum femoral head diameters was 78%. Then, they concluded that with availability of only the proximal part of the femur, the sex can be identified with a relatively high accuracy via taking a radiograph. In a study on Malawian people [19], a significant difference was found in the mean diameter of femoral heads between genders which was reported greater in males.

In a study on South African whites and blacks [20], the identification point and demarking point (Identification and demarking points have been taken from the diameters of the head of the femur) were found in both white and black South Africans. The mean head diameter of the male femur was significantly greater than the mean head diameter of the female femur in both population groups.

To determine the sex differentiation ability of the femur, different measurements have been performed by anatomists who finally found that the head diameter and width of the lower end discriminate better than any other part of the bone [6-10]. Moreover, it was found that dimension of femoral head differs regarding race, heredity, climate, and other geographical factors. Therefore, every population has their own metric standards [21-25].

We also found that the maximum distance across the condyles in the transverse plane has powerful ability for identifying gender. The similar results have been obtained in other related studies. According to Vrooijink et al. [26], significant differences exist between male and female subjects regarding medial condyle width and lateral condyle width. Another study by Terzidis et al. [27] revealed that sex identity can be determined with the difference in (men had a significantly greater width than women); Also, Jacob et al. obtained similar results; their study confirmed that it is a good indicator of sexual dimorphism. On the whole, the parameters of femur bicondylar width and vertical diameter of femur head, separately or together can discriminate gender in our population; however, because of the multiethnic nature of our population, further studies considering different ethnic groups seems necessary.

5. Conclusion

By measurement of femur and vertical diameter of the femoral head, it is possible to determine gender with a high accuracy.

Acknowledgments

The authors appreciate their technical support of Rasoul-e-Akram Hospital Clinical Research Development Center and Iran University of Medical Sciences.

Conflict of Interest

The authors declared no conflicts of interest regarding the publication of this paper.

References

[1] Burns KR. Forensic Anthropology Training Manual. New Jersey: Prentice Hall Publishing; 2007.

[2] Ciaffi R, Gibelli D, Cattaneo C. Forensic radiology and personal identification of unidentified bodies: A review. La Radiologia Medica. 2011; 116(6):960-8. doi: 10.1007/s11547-011-0677-6

[3] Buikstra JE, King JL, Nystrom KC. Forensic Anthropology and Bioarchaeology in the American Anthropologist Rare but Exquisite Gems. American Anthropologist. 2003; 105(1):38–52. doi: 10.1525/aa.2003.105.1.38

[4] Pickering RR, Bachman DC. 2009. The use of forensic anthropology. New York: CRC Press-Taylor and Francis Group.

[5] Ulijaszek SJ, Masci-Taylor CJN. Anthropometry: The individual and the population—Cambridge studies in biological anthropology. Cambridge, UK: Cambridge University Press; 1994.

[6] Ahmed AA. A study of correlations within the dimensions of lower limb parts for personal identification in a Sudanese population. The Scientific World Journal. 2014; 2014:1–6. doi: 10.1155/2014/541408

[7] Holobinko A. Forensic human identification in the United States and Canada: A review of the law, admissible techniques, and the legal implications of their application in forensic cases. Forensic Science International. 2012; 222(1-3):394. doi: 10.1016/j.forsciint.2012.06.001

[8] Krogman WM, Iscan YM. The human skeleton in forensic medicine. 2nd ed. Springfield, Illinois, USA: Charles C. Thomas Pub Ltd; 1986.

[9] Charlton WPH, John TAS, Ciccotti MG, Harrison N, Schweitzer M. Differences in femoral notch anatomy between men and women. The American Journal of Sports Medicine. 2002; 30(3):329–33. doi: 10.1177/03635465020300030501

[10] Harner CD, Paulos LE, Greenwald AE, Rosenberg TD, Cooley VC. Detailed analysis of patients with bilateral anterior cruciate ligament injuries. American Journal of Sports Medicine. 1994; 22(1):37–43. doi: 10.1177/036354659402200107

[11] Shelbourne KD, Facibene WA, Hunt JJ. Radiographic and intraoperative intercondylar notch width measurements in men and women with unilateral and bilateral anterior cruciate ligament tears. Knee Surgery, Sports Traumatology, Arthroscopy. 1997; 5(4):229–33. doi: 10.1007/s001670050055

[12] Dargel J, Michael JWP, Feiser J, Ivo R, Koebke J. Human knee joint anatomy revisited: morphometry in the light of sex-specific total knee arthroplasty. Journal of Arthroplasty. 2011; 26(3):346–53. doi: 10.1016/j.arth.2009.12.019

[13] Farrally MR, Moore WJ. Anatomical differences in the femur and tibia between Negroids and Caucasoids and their effects upon locomotion. American Journal of Physical Anthropology. 1975; 43(1):63–9. doi: 10.1002/ajpa.1330430110

[14] Porter AMW. Analyses of measurements taken from adult femurs of a British population. International Journal of Osteoarchaeology. 1995; 5(4):305–23. doi: 10.1002/oa.1390050402

[15] Chauhan R, Paul S, Dhaon BK. Anatomical parameters of North Indian hip joints-Cadaveric study. Journal of the Anatomical Society of India. 2002; 51(1):39-42.

[16] Purkait R. Sex determination from femoral head measurements: a new approach. Legal Medicine. 2003; 5:347–50. doi: 10.1016/s1344-6223(02)00169-4

[17] Clavero A, Salicrú M, Turbón D. Sex prediction from the femur and hip bone using a sample of CT images from a Spanish population. International Journal of Legal Medicine. 2014; 129(2):373–83. doi: 10.1007/s00414-014-1069-y

[18] Akhlaghi M, Bakhtavar Kh, Allahyar Parsa V, Razavi Nouri A, Mehdizadeh F, Vasheghani Farahani M, et al. Sexing based on measurements of the femoral head parameters on pelvic radiographs. Journal of Forensic and Legal Medicine. 2014; 23:70–5. doi: 10.1016/j.jflm.2014.01.004

[19] Igbigbi P, Msamati B. Sex determination from femoral head diameters in black Malawians. East African Medical Journal. African Journals Online (AJOL); 2009; 77(3):64-77. doi: 10.4314/eamj.v77i3.46611

[20] Asala SA. Sex determination from the head of the femur of South African whites and blacks. Forensic Science International. 2001; 117(1-2):15–22. doi: 10.1016/s0379-0738(00)00444-8

[21] Urvik CK, Tulsibhai CS, Pratik NT, Jayesh KR, Vidya KS, Dilip VG et al. Sex determination from vertical diameter of femoral head in Gujarati population. International Journal of Advanced Research. 2014; 2(6):859-863.

[22] Asala SA, Mbajiorgu FE, Papandro BA. A Comparative study of femoral head diameters and sex differentiation in Nigerians. Cells Tissues Organs. 1998; 162(4):232–7. doi: 10.1159/000046438

[23] Igbigbi P, Msamati B. Sex determination from femoral head diameters in black Malawians. East African Medical Journal. 2009; 77(3):147-51. doi: 10.4314/eamj.v77i3.46611

[24] Javadakar BS. A study of the measurement of the head of the femur with special reference to sex: A preliminary report. Journal of the Anatomical Society of India. 1961; 10:25-27.

[25] Leelavathy N, Rajangans S, Janakirams S, Thomas IM. Sexing of femora. Journal of the Anatomical Society of India. 2000; 49(1):17-20.

[26] Vrooijink SH, Wolters F, Van Eck CF, Fu FH. Measurements of knee morphometrics using MRI and arthroscopy: a comparative study between ACL-injured and non-injured subjects. Knee. Knee Surgery, Sports Traumatology, Arthroscopy. 2011; 19(Suppl 1):S12-6. doi: 10.1007/s00167-011-1502-4

[27] Terzidis I, Totlis T, Papathanasiou E, Sideridis A, Vlasis K, Natsis K. Gender and side-to-side differences of femoral condyles morphology: osteometric data from 360 Caucasian dried femori. Anatomy Research International. 2012; 2012:1-8. doi: 10.1155/2012/679658