Original article

Distal femoral morphology: The difference between genders

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Abstract

We measured 11 linear morphometric parameters in 100 human femurs of which 52 were male and 48 female, to ascertain the difference between male and female femora. The epicondylar width (EBW) mean was 82.65±3.96 mm in male and 72.47±3.49 mm in female samples ($p<0.001$). Intercondylar notch width (ICW) mean in males was 19.32±4.10 mm, and in the females 18.04±3.40 mm ($p<0.01$). Intercondylar notch height (ICH) mean in males was 29.05±4.57 mm and in the females 26.85±4.10 mm ($p<0.05$). Maximal Medial Condylar Width (MCWmax) was 35.86±2.89 mm in males and 31.50±2.86 mm in females ($p<0.001$). Medial condylar width (MCW) was 26.73±2.77 mm in males and 23.81±3.01 mm in females ($p<0.001$). Maximal Lateral Condylar (LCWmax) width was 36,05±2.68 mm in males and 31.70±2.03 mm in females ($p<0.001$). Lateral Condylar Width (LCW) was 28.11±2.71mm in males and 24.45±2.61 mm in females ($p<0.001$). Medial Condylar Height (MCH) in males was 38.40±3.91 mm and in females 33.02±4.01 mm ($p<0.001$). Lateral Condylar Height (LCH) was 39.25±3.54 mm in males and 32.83±3.54 mm in females ($p<0.001$). Medial Condylar Depth (MCD) was 61.88±4.04 mm in males and 54.45±3.59 mm in females ($p<0.001$). Lateral Condylar Depth (LCD) was 64.67±4.48 mm in males and 56.68±3.62 mm in females ($p<0.001$). The obtained findings can be used for gender specific total knee protheses, understanding anterior cruciate ligament (ACL) rupture epidemiology and in identifying the gender of skeletal remains.

Keywords: Femur, Condyles, Arthroplasty, Endoprothetics, Anterior Cruciate Ligament

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Introduction

Morphometric parameters of distal femoral anatomy are crucial in knee protheses design, especially in individual protheses design [1]. Knee osteoarthritis is the main etiological factor for endoprothetic surgery of the knee and as such also presents with differences between healthy and diseased knees [2, 3]. Also, studies have shown that certain morphometric parameters of the distal femoral anatomy can be a risk factor for Anterior Cruciate Ligament (ACL) ruptures [4, 5, 6, 7], although such studies have not been confirmed [8, 9, 10]. Many studies describe the difference between male and female femoral anatomy [1, 11, 12, 13, 14, 15, 16]. Most of them are based on radiographic assessment, although such methods have been described as inaccurate due to magnification adjustments [4]. Inconclusive findings from other studies compelled us to conduct research on dry femora specimens using standard anthropometric measurements. The current study used 100 femora, whose distal femoral morphometric parameters were measured by sliding calipers in order to assess the difference between male and female subjects.

Materials and methods

The study sample consisted of 100 adult human femora from the Department of Anatomy, Medical School, University of Sarajevo. Of the 100 femora, 52 were male and 48 were female. The gender of the femurs was determined by parameters suggested in multiple studies. Those consisted of 1.) Femoral head diameter 2.) Epicondylar Breadth Width 3.) Midshaft Femoral Diameter 4.) Midshaft Femoral Circumference. Femurs with visible pathological alterations were excluded from the study. All measurements were obtained using non-digital sliding calipers whose units were expressed in centimetres. Measurements were done according to Martin [17]. The measurements obtained were: 1.) Epicondylar Breadth Width (EBW), defined as the largest distance between lateral and medial femoral epicondyles; 2.) Intercondylar notch width (ICW), defined as the largest distance between the medial side of lateral femoral condyle and the lateral side of the medial femoral condyle; 3.) Intercondylar notch height (ICH) defined as the largest distance between the deepest and the most superficial part of the intercondylar notch; 4.) Maximal Medial Condylar Width (MCWmax), defined as the largest distance between the lateral side of the medial femoral condyle and the medial femoral epicondyle; 5.) Medial condylar width (MCW) defined as the largest distance of the medial and lateral edge of the articular surface on the medial femoral condyle; 6.) Maximal Lateral Condylar Width (LCWmax) defined as the largest distance between the medial side of the lateral femoral condyle and the lateral epicondyle; 7.) Lateral Condylar Width (LCW) largest distance between the medial and lateral edge of the articular surface of the lateral femoral condyle; 8.) Medial Condylar Height (MCH), defined as the distance between uppermost and lowermost part of the posterior part of the medial femoral condyle; 9) Lateral Condylar Height (LCH), defined as the distance between uppermost and lowermost edge of the posterior part of the lateral femoral condyle; 10.) Medial Condylar Depth (MCD), defined as the distance between the most posterior and the most anterior parts of the medial femoral condyle and 11.) Lateral Condylar Depth (LCD), defined as the distance between the most posterior and the most anterior parts of the lateral femoral condyle. A one trained person has measured the femurs, taking each measure three times from which the mean was taken as the definite value. All values are expressed in milimeters and rounded to two decimals. The data were recorded on a standardized paper sheet after which we made a database and finished data analysis in Microsoft Excel. We have taken values of $p < 0.05$ was taken as statistically significant.

Results

EBW mean was 82.65±3.96 mm in male and 72.47±3.49 mm in female samples ($p<0.001$). The maximum value was 92 mm and the minimum 76 mm in males and maximum 86 mm, minimum 62 mm for females (Table 1). ICW width mean in males was 19.32±4.10 mm, in the females 18.04±3.40 mm ($p< 0.01$). Maximum and minimum values in males of ICW were 32 mm and 10 mm respectively and in the females 25 mm and 10 mm (Table 1). ICH mean in males was 29.05±4.57 mm and in the females 26.85±4.10 mm ($p<0.5$) (Table 1). Maximum and minimum values in males were 40 mm and 15 mm respectively and in females 35 mm and 16 mm. MCWmax was 35.86±2.89 mm in males and 31.50±2.86 mm in females ($p<0.001$) (Table 1). Maximum and minimum values for males were 43 mm and 30 mm and 40 mm and 25 mm for females. MCW was 26.73±2.77 mm in males and 23.81±3.01 mm in females ($p<0.001$) (Table 1). Maximum and minimum values in males were 33 mm and 21 mm respectively , in females they were 34 mm and 20 mm. LCWmax was 36,05±2.68 mm in males and 31.70±2.03 mm in females ($p<0.001$) (Table 1). Maximum and minimum values for males were 42 mm and 30 mm and in females 36 mm and 28 mm. LCW was 28.11±2.71mm in males and 24.45±2.61 mm in females ($p<0.001$) (Table 1). Maximum and minimum values for males were 36 mm and 22 mm and in females 32 mm and 20 mm. MCH in males was 38.40±3.91 mm and in females 33.02±4.01 mm ($p<0.001$) (Table 1). Maximum and minimum values in males were 49 mm and 29 mm and for females 43 mm and 28 mm. LCH was 39.25±3.54 mm in males and 32.83±3.54 mm in females ($p<0.001$) (Table 1). Maximum and minimum values for males were 46 mm and 35 mm and for the females they were 42 mm and 26 mm. MCD was 61.88±4.04 mm in males and 54.45±3.59 mm in females ($p<0.001$) (Table 1). Maximum and minimum values for males were 73 mm and

Table 1. Gender difference in distal femoral morphology

Variables	Males (n=52)	Females (n=48)	p
Epicondylar width (mm)	82. 65 ± 3. 96	72. 47 ± 3. 49	< 0. 001
Intercondylar notch width (mm)	19. 32 ± 4. 10	18. 04 ± 3. 40	< 0. 01
Intercondylar notch height (mm)	29. 05 ± 4. 57	26. 85 ± 4. 10	< 0. 5
Maximal Medial Condylar Width (mm)	35. 86 ± 2. 89	31. 50 ± 2. 86	< 0. 001
Medial condylar width (mm)	26. 73 ± 2. 77	23. 81 ± 3. 01	< 0. 001
Maximal Lateral Condylar Width (mm)	36. 05 ± 2. 68	31. 70 ± 2. 03	< 0. 001
Lateral Condylar Width (mm)	28. 11 ± 2. 71	24.45 ± 2. 61	< 0. 001
Medial Condylar Height (mm)	38. 40 ± 3. 91	33. 02 ± 4. 01	< 0. 001
Lateral Condylar Height (mm)	39. 25 ± 3. 54	32. 83 ± 3. 54	< 0. 001
Medial Condylar Depth (mm)	61. 88 ± 4. 04	54. 45 ± 3. 59	< 0. 001
Lateral Condylar Depth (mm)	64. 67 ± 4. 48	56. 68 ± 3. 62	< 0. 001

51 mm and for females 61 mm and 49 mm. LCD was 64.67±4.48 mm in males and 56.68±3.62 mm in females ($p<0.001$) (Table 1). Maximum and minimum values for males were 73 mm and 54 mm and for females 64 mm and 50 mm.

Discussion

This study was conducted using dry femora applying classical methods, because such approach has few advantages over radiological methods [4, 17]. Generally, using radiological methods means having a larger sample since it usually involves living subjects. Also, radiological methods have been described as inaccurate, since modifying for magnification did not produce measures as accurate as those done on dry femora, although CT and MRI are described as not having such magnification artefacts in comparison to radiographs [4, 14]. The current study has its own disadvantages in regards to the small sample size and imprecise age of femora. The EBW difference between male and female samples was found to be very highly significant ($p< 0.001$). The results from this study correlate equally with similar studies [1, 16]. Male EBW was larger than female EBW in all of the studies and the mean values were different in studies between western and Asian samples [12, 16]. Cheng et al. have found that the Chinese population has a smaller mean EBW in both males and females in reference to western counterparts although the difference between male and female femora has remained the same [12]. The results from Urabe et al. in the Japanese population confirm the EBW mean difference between races [18]. According to Terzidis et al. no difference has been found between side to side correlation [11]. The EBW is an important morphometric parameter seeing that it is one of the two main linear values in designing knee protheses, since it correlates well with other distal femoral parameters [19]. This study confirms the possible need for individual protheses for males and females based on given results. ICW has been different in male in relation to females and was defined as very significant ($p<0.01$). ICH difference was significant ($p<0.05$) between male and female samples. This study confirms the results from other similar studies involving the intercondylar notch parameters difference between genders, who also found that the intercondylar notch was narrower in females than in males [4, 5, 6, 7]. It was found that the ICH was larger in males than in females, which is counter-argumentative that the intercondylar notch is deeper in females than in males. In contrast to the individual values (ICH, ICW and ICV) indices from the said values were not necessarily different in males and in the females. Intercondylar notch parameters are possibly correlated to ACL injuries and the fact that females sustain non- contact ACL injuries more often than males. The possible mechanism has been described by Palmer [20]. Intercondylar notch parameters are also attributed to the commoner occurrence of osteoarthritis [21]. This might be due to the fact that narrower intercondylar notches contain laxer anterior cruciate ligaments which results in more prominent anterior tibial translation and damaging of cartilage. More often non-contact injuries in females have been contributed to a number of factors including menstrual periods, muscle stiffness, height, weight and femoral parameters [8]. Some studies have shown that a narrower intercondylar notch is indeed a risk factor for ACL injuries, while others disagree [4, 5, 6, 9]. This might be due to the fact that the data gathering methods differ, since it was shown that some (i.e. radiography) imaging methods are not reliable in measuring intercondylar parameters in comparison to dry femora [4]. Practically, measuring intercondylar notch parameters in athletes is not a good risk predictor, which does not mean that true intercondylar notch parameters do not correlate as well having in mind that this study showed that the intercondylar notch parameters indeed differ between males and females [9]. MCWmax, MCW, LCWmax and LCW all differed between male and female femora ($p<0.001$) which is understandable since they all positively correlate with EBW, respectively [19]. Such results are equal to those obtained by other authors. As such they are important in knee endoprotheses design nominally but the EBW or medio-lateral width measurement is rather measured because of simplicity and the aforementioned positive correlation [19]. MCH and LCH are different between male and female counterparts ($p<0.001$). MCD and LCD in males and females are significantly different. The results are in accordance with other similar studies, where the difference between male and female samples was apparent [1, 11, 12, 16]. The difference was ascertained between side to side measurements with MCD values being greater than LCD, both in males in females. It seems that the Bosnian population, based on this study, has lower mean values of both MCD and LCD in males and females in relation to other studies on Caucasian femora [12]. Chinese femora have the overall lowest mean of MCD and LCD [12]. Distal femoral depth parameters (MCD, LCD) are also called anteroposterior parameters, particularly in knee protheses design [12, 19]. The parameters are one of the two major linear parameters in knee protheses design, respectively and as such are crucial in knee prothesis design [19]. This study confirms the difference between male and female counterparts and reinforces the possible need for sex specific knee protheses.

Conclusion

The difference in linear morphometric parameters of the distal femur between male and female femora was determined in all of the cases. The difference in intercondylar notch parameters was less obvious in regard to the other morphometric parameters. Anteroposterior parameters mean in the Bosnian population could be smaller than that of other Caucasian samples. This study confirms the gender differences and the possible justification for gender specific knee protheses and ACL injury occurrence in female athletes. Furthermore, the importance of obtained findings is in their promising use in identifying the gender of skeletal remains.

Declaration of interest

The authors declare no conflicts of interest.

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