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Evaluation of Tibial Parameters Calculated from Computed Tomography Images According to Age and Gender

Bilgisayarlı Tomografi Görüntüleri Üzerinden Hesaplanan Tibia Parametrelerinin Yaş ve Cinsiyete Göre Değerlendirmesi

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Abstract: Objective: Bones from human remains are preserved in nature for long periods of time due to their compact structure, making them useful for identification. Although some bones are known to exhibit dimorphism, the tibia and femur are highly resistant to erosion and can be used to assess age and sex. The aim of this study was to assess age and sex using tibial parameters calculated from computed tomography (CT) scans. Methods: This study was performed by retrospectively analysing CT angiography images of the lower extremities of 114 individuals between 2015 and 2022. The individuals were divided into age groups 30-40 (age group 1), 41-50 (age group 2), 51-60 (age group 3). Images were transferred in DICOM format to the Radiant DICOM Viewer program and tibia measurements were performed. Results: The Kruskal-Wallis H test was used to compare the age groups, and the length between the left condylus medialis and lateralis parameter was compared between the 1st and 2nd age groups, and the distance between the right condylus medialis-malleolus medialis parameter was compared between the 1st and 3rd age groups. There was a statistically significant relationship between the 1st and other age groups for the left condylus medialis-malleolus medialis distance parameter between the 1st and 3rd age groups, and between the 1st and other age groups for the right condylus lateralis-malleolus lateralis distance parameter. The one-way ANOVA test showed a significant relationship between the 1st and 3rd age groups in the left condylus medialis-malleolus medialis distance parameter. It was concluded that there was a statistically significant difference between the sexes in all parameters except the length between the left condylus medialis and lateralis (MCLC-RL, LL) ($p<0.05$). Conclusion: As a result of our study, it was found that the parameters we obtained from the erosion resistant tibia are important markers in determining age and sex.In this context, we believe that the study will contribute to forensic science.
Keywords: Tibia, Age and sex estimation, Morphometry.

Öz: Amaç: İnsan kalıntılarından kemikler kompakt yapılarından dolayı doğada uzun süre korunur ve bu durum kimliklendirmede kullanışlı olmalarını sağlar. Dimorfizm gösterdiği bilinen kemikler olsa da tibia ve femur erozyona karşı ciddi derecede dirençli olmaları dolayısı ile yaş ve cinsiyet değerlendirmelerinde kullanılabilir. Bu çalışmanın amacı bilgisayarlı tomografi (BT) görüntüleri üzerinden hesaplanan tibia parametrelerinden yaş ve cinsiyetin değerlendirmesidir. Gereç ve Yöntem: Bu çalışma 2015-2022 yılları arasında 114 bireye ait alt ekstremite BT anjio görüntülerinin retrospektif olarak incelenmesi ile gerçekleştirildi. Bireyler 30-40 (1. yaş grubu), 41-50 (2. yaş grubu), 51-60 (3. yaş grubu) yaş gruplarına ayrıldı. Görüntüler DICOM formatında Radiant DICOM Viwer programına aktarıldı ve tibia üzerinden ölçümler gerçekleştirildi. Bulgular: Kruskal Wallis H testi ile yaş grupları karşılaştırıldı ve sol condylus medialis ile lateralis arası uzunluk parametresinde 1. ile 2. yaş grubu arasında sağ condylus medialis-malleolus medialis arası uzaklık parametresinde 1. yaş grubu ile diğer yaş grupları arasında, sol condylus medialis-malleolus medialis arası uzaklık parametresinde 1. ile 3. yaş grubu arasında, sağ condylus lateralis-malleolus lateralis arası uzaklık parametresinde 1. yaş grubu ile diğer yaş grupları arasında

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istatistiksel olarak anlamlı ilişki olduğu bulundu. One Way Anova testi ile sol condylus medialis-malleolus medialis arası uzaklık parametresinde 1. ve 3. grupları arasında anlamlı ilişki bulundu. Sol condylus medialis ile lateralis arası uzunluk (CML-RL, LL) hariç tüm parametrelerde cinsiyetler arasında istatistiksel olarak anlamlı fark olduğu sonucuna ulaşıldı ($p<0.05$). Sonuç: Çalışmamız sonucunda erozyona karşı dirençli olan tibia'dan belirlediğimiz parametrelerin yaş ve cinsiyeti belirlemede önemli belirteçler olduğu belirlendi. Bu bağlamda çalışmanın adli bilimlere katkı sağlayacağını düşünmekteyiz.
Anahtar Kelimeler: Tibia, Yaş ve cinsiyet tahmini, Morfometri.

Introduction

Identity is defined as the physical characteristics of an animate or inanimate person, such as height, weight, ethnicity, age and gender, that distinguish one person from another. Collecting and describing information about the characteristics of identity is called identification. Identification of the deceased through remains is a fundamental part of forensic anthropology. In the event of natural disasters, terrorist attacks or mass killings, there is an urgent need to identify people (Phombut et al., 2021; Secgin et al., 2022; Erkartal et al., 2023; Vij, 2011). Sex estimation is considered the most important biological characteristic for identification in forensic medicine (Schmidt et al., 2013). There is an urgent need for preliminary identification in special circumstances such as natural disasters, wars and when economic conditions are inadequate. DNA methods developed in forensic medicine are not sufficient to meet the rapid needs in these circumstances (Secgin et al., 2022). Using various radiological methods on human remains, ambiguous identities can be determined, and in some cases it may even be necessary to extrapolate from only one bone or bone fragment (Erkartal et al., 2023). In the literature, skull and pelvic bones, also known as dimorphic bones, are generally preferred for sex and age estimation (Secgin et al., 2021, 2022; Toy et al., 2022). However, long bones, particularly the tibia and femur, are highly resistant to erosion and may be useful for sex estimation if they remain intact (Phombut et al., 2021). It is also worth noting that although bilateral organ asymmetries are well and clearly described in the literature, bilateral differences in the extremities, especially in the tibia, have not found a place in the literature (Gülhan, 2020a; Shrestha & Malla, 2019).

Computed tomography (CT) is a radiological imaging technique that allows coronal, axial and sagittal cross-sectional imaging of specific areas of the body (Aydoğdu et al., 2017). It is compact and can handle soft tissues in depth in three dimensions (Zak et al., 2021).

The aim of this study is to evaluate the age and sex of tibia parameters determined from computed tomography (CT) images. We believe that the results will increase the usability of the tibia for age and sex estimation and contribute to the fields of forensic medicine, anatomy and radiology.

Material and Methods

This study was performed on lower extremity CT angiography images (without fracture, implant or other pathology in the tibia) recorded in the PACS (Picture Archiving and Communication System) archive system of individuals enrolled at Karabuk University Teaching and Research Hospital with various health problems between 2015 and 2022. The images were divided into age groups 30-40, 41-50, 51-60, and CT images of 114 individuals were randomly selected and assigned to the groups. All images were transferred to the Radiant DICOM Viewer program in DICOM format and measurements of the parameters determined from the right and left sides were performed:

- The length from the right medial condyle to the lateral condyle (MCLC-RL),
- Length from left medial condyle to lateral (MCLC-LL),
- Tibia body width from the centre of the right tibia (TB-RW),
- Tibia of body width from the centre of the left tibia (TB-LW),
- Distance from the right medial condyle to the medial malleolus (MCMM-RL),
- Distance from the left medial condyle to the medial malleolus (MCMM-LL),
- Distance from the right lateral condyle to the lateral malleolus (LCLM-RL),
- Left lateral condyle to lateral malleolus (LCLM-LL),
- Right medial malleolus-tibial tuberosity-lateral malleolus angle (MMTTLM-RA),
- Left medial malleolus-tibial tuberosity-lateral malleolus angle (MMTTLM-LA) (Figure1).

Bone measurements are based on the outer surface of the bone, i.e. the cortex. For the tibial midbody width measurement, the total length of the tibia was measured and the width of the tibia at the midline was measured. To test the reliability and precision of the metric measurements used in the study, the measurements were repeated three times by the same radiologist.

Statistical Analysis

The Anderson-Darling test was used to test whether the data were normally distributed. Mean, standard deviation, median, minimum and maximum values were included in the descriptive data of normally distributed parameters and median, minimum and maximum values were included in the non-normally distributed parameters. For pairwise comparisons,

the two-sample T-test was used for normally distributed parameters and the Mann-Whitney U-test for non-normally distributed parameters. For the relationship between parameters, the Pearson correlation test was used for normally distributed data and the Spearman rho correlation test for non-normally distributed data. One-way ANOVA test was used for group analysis. G-Power test was used for power analysis. The n was determined to be 56 with a reliability of G-power $p<0.05$.

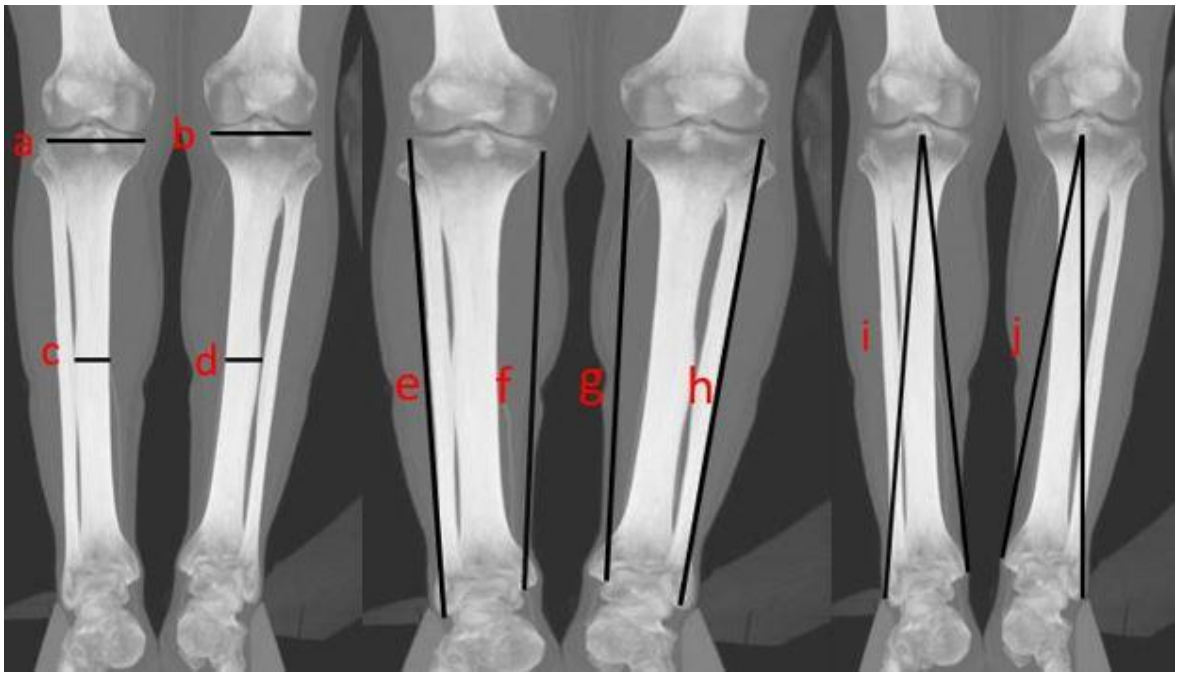

Figure 1. Demonstration of Measurement Parameters

[a: Length from the right medial condyle to the lateral condyle (MCLC-RL), b: Length from the left medial condyle to the lateral condyle (MCLC-LL), c: Tibial body width from the right tibial midline (TB-RW), d: Tibial body width from the left tibial midline (TB-LW), e: Distance from the right lateral condyle to the lateral malleolus (LCLM-RL), f: Distance from the right medial condyle to the medial malleolus (MCMM-RL), g: Distance from the left medial condyle to the medial malleolus (MCMM-LL), h: Distance from the left lateral condyle to the lateral malleolus (LCLM-LL), i: Right medial malleolus-tibial tuberosity-lateral malleolus angle (MMTTLM-RA), j: Left medial malleolus-tibial tuberosity-lateral malleolus angle (MMTTLM-LA)].

Results

CT angiography images of 50 female and 64 male aged 30-40, 41-50, 51-60 years were used in our study. LCLM-LL and MMTTLM-LA parameters were found to fit the normal distribution, while all other parameters did not fit the normal distribution. The descriptive statistics of the parameters that fit the normal distribution in our study are shown in Table 1.

Table 1: Descriptive Statistics of Data Fitting the Normal Distribution

Parameters	Gender	Mean	Standard deviation
LCLM-LL (cm)	Male	38.16	2.650
	Female	34.26	1.73
MMTTLM-LA°	Male	9.7	0.74
	Female	9.5	0.60

Descriptive statistics of the parameters that did not fit the normal distribution are shown in Table 2.

The parameters obtained were evaluated in relation to gender and it was found that there was a statistically significant difference between genders in all parameters except MCLC-LL ($p<0.05$) (Table 3).

No significant correlation was found between LCLM-LL and MMTTLM-LA parameters ($r=0.011$, $p=0.904$). Significant correlations were found for all parameters except for 3 parameters that did not fit the normal distribution. In addition, a very high significant correlation was found between 5 parameters (Table 4).

Table 2: Descriptive Statistics of Data Not Fitting Normal Distribution

Parameters (cm)	Gender	Median	Minimum	Maximum
MCLC-RL	Male	7.55	4.45	8.96
	Female	6.60	5.90	8.29
MCLC-LL	Male	7.50	5.90	8.26
	Female	6.50	5.70	7.97
TB-RW	Male	2.65	2.0	3.4
	Female	2.325	1.8	2.95
TB-LW	Male	2.70	1.97	3.45
	Female	2.33	1.76	2.92
MCMM-RL	Male	35.90	30.60	43.15
	Female	32.71	21.54	37.40
MCMM-LL	Male	36.00	26.40	42.70
	Female	32.60	29.52	35.90
LCLM-RL	Male	38.29	32.32	44.76
	Female	34.25	30.92	39.72
MMTTLM-RA°	Male	9.67	8.20	18.46
	Female	9.46	8.36	10.63

Table 3: Comparative Analysis of Parameters in Terms of Genders

Parameters	Test Used	p
Yaş	Mann Whitney-U	**0.00**
MCLC-RL	Mann Whitney-U	**0.00**
MCLC-LL	Mann Whitney-U	0.87
TB-RW	Mann Whitney-U	**0.00**
TB-LW	Mann Whitney-U	**0.00**
MCMM-RL	Mann Whitney-U	**0.00**
MCMM-LL	Mann Whitney-U	**0.00**
LCLM-RL	Mann Whitney-U	**0.00**
LCLM-LL	Two Simple T	**0.00**
MMTTML-RA	Mann Whitney-U	**0.02**
MMTTML-LA	Two Simple T	**0.03**

Parameters were compared according to age groups and a significant relationship was found between the 1st and 2nd age groups for the MCLC-LL parameter, between the 1st and 2nd, 1st and 3rd age groups for the MCMM-RL parameter, between the 1st and 3rd age groups for the MCMM-LL parameter and between the 1st and 2nd, 1st and 3rd age groups for the LCLM-LL parameter ($p<0.05$). One-way ANOVA test was applied to those with normal distribution and a significant relationship was found between the 1st and 3rd groups in the LCLM-LL parameter ($p<0.05$).

Table 4: Results of Spearman Rho Correlation Test for Correlation Between Parameters That Do Not Fit Normal Distribution

Parameters	MCLC-RL	MCLC-LL	TB-RW	TB-LW	MCMM-RL	MCMM-LL	LCLM-RL
MCLC-LL	.914[e] **.000**						
TB-RW	.484[c] **.000**	.474[c] **.000**					
TB-LW	.496[c] **.000**	.438[c] **.000**	.858[e] **.000**				
MCMM-RL	.737[d] **.000**	.683[d] **.000**	.564[c] **.000**	.561[c] **.000**			
MCMM-LL	.663[d] **.000**	.630[d] **.000**	.538[c] **.000**	.510[c] **.000**	.942[e] **.000**		
LCLM-RL	.751[d] **.000**	.701[d] **.000**	.596[c] **.000**	.595[c] **.000**	.980[e] **.000**	.935[e] **.000**	
MMTTML-RA	.160[a] **.000**	.200[b] **.000**	-.043[a] **.000**	-.066[a] **.000**	-.000[a] 1.000	.046[a] .630	-.010[a] .917

a: Very weak relationship, b: Weak relationship, c: Medium relationship, d: High relationship, e: Very high relationship

Discussion

In this study evaluating age- and sex-related changes in tibia bone, statistically significant differences were found for sex and age ($p<0.05$).

Osteometric measurements using radiological imaging techniques provide a reliable database for morphometric studies (Gülhan, 2020b). Sherk et al. (Sherk et al., 2012) reported that the tibia is exposed to different physical factors in daily life and that there is a statistically significant difference between the sexes in volumetric measurements and that the tibia is significantly longer, heavier and has a higher bone density in men than in women. In our study, all parameters except MCLC-LL showed significant gender differences.

The study by Gülhan et al. (Gülhan, 2020a) used similar parameters to our study, but Gülhan focused mainly on tibial asymmetry. We analysed the tibia in relation to gender and age using the same parameters. Gülhan et al. reconstructed CT angiography images using virtual 3D modelling, no statistically significant difference was observed between the right and left tibia values for all four measurements taken from male and female samples ($p>0.05$), but the difference between the right and left side in the CML parameter taken from the proximal epiphysis of the tibia was higher in men than in women, while the highest difference in women occurred in the maximum CMMM parameter. In our study, we analysed CT angiography images of 114 individuals aged 30-60 years, and only the MCLC-LL parameter did not differ by sex ($p = 0.87$).

Tümer et al. (Tümer et al., 2019) examined the tibia, fibula, calcaneus and talus bones in terms of shape variation and found no significant difference between the left and right sides in terms of variation according to gender. According to Quintens L. et al. (Quintens et al., 2019), the greatest variation in the anatomy of the tibia is in the length of the bone. In the study by Shrestha et al. (Shrestha & Malla, 2019) MCLC-RL, CML-LL parameters were measured in 150 individuals and bilateral asymmetry was found in 44% of them and it was found that this asymmetry was more pronounced in males than in females. In our study, we found that there was a significant difference between the sexes in the same parameter.

In studies where the CML parameter was measured by CT, it was found that the average values were in the range of 7.2-7.5 cm in men and 6.5-6.7 cm in women (Babacan & Kafa, 2020; Bilkay et al., 2016; Naidoo et al., 2015; Phombut et al., 2021; Sume, 2019). In our study, MCLC-RL was 7.55 cm in males and 6.60 cm in females, and MCLC-LL was 7.50 cm in males and 6.50 cm in females. In our study, in agreement with the literature, the CML parameter is higher in males than in females.

Toy S. and Secgin Y. (Toy & Secgin, 2022) examined 33 dry tibia bones by photo-analysis method and found the CT mean width to be 2.382±0.312 cm. In our study, the median

value of TB-RW parameter was 2.65 cm in males and 2.325 cm in females, and the median value of TB-LW parameter was 2.70 cm in males and 2.33 cm in females.

Başoğlu (Başoğlu, 2010) evaluated the MCMM-RL and LL parameters of 37 females and 51 males and found 48 cm for males and 47 cm for females. In our study, the length of the tibia corresponds to the distance between the condylus medialis and the malleolus medialis, and we found the MCMM-RL parameter to be 35.90 cm in males and 32.71 cm in females, and the MCMM-LL parameter to be 36.00 cm in males and 32.60 cm in females. The differences in measurement results may be due to methodological differences.

Ageing affects many tissues and structures in the body and has the greatest effect on bone tissue. Ageing in bone results in conditions such as loss of bone mass, structural deformation, increase in yellow bone marrow, decrease in mineral content, and slowing of healing and repair (Akdeniz et al., 2019). In our study, we found significant associations between age groups.

Conclusion

As a result of our study, it was concluded that the tibia, which has a compact structure, is an important alternative for sex and age estimation in forensic science. In this respect, we believe that it will make a great contribution to forensic science.

Ethics Approval: This study was conducted with the 2021/635 numbered decision of Karabük University Non-Interventional Clinic Research Ethics Committee.

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