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Anatomical and morphometric evaluation of the third trochanter in dry femurs

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Abstract

Aim: The objective of the study is to fill the gaps in knowledge about the third trochanter (TT) by quantifying these anatomical measurements and examining the morphological characteristics associated with its presence.

Materials and Methods: The length, diameter, types, location, and distances to the greater and lesser trochanters of the third trochanter were determined. Measurements of the greater trochanter, lesser trochanter, and gluteal tubercle lengths and diameters of 144 femurs available in the Medical Faculty laboratory were taken using a digital caliper to calculate their relationships with the third trochanter (TT).

Results: In our study of 144 dry femurs, we identified the presence of TTs in 25.35% of cases, which equates to 36 femurs. Notably, we observed significant gender differences in the prevalence of TTs, with 27 males having TTs compared to 9 females, indicating a higher occurrence of TTs in males (p= 0.027). Average femur length and width were 41.23 mm and 27.05 mm, Greater trochanter had dimensions of 45.27 mm by 38.66 mm, and lesser trochanter measured 24.89 mm by 17.78 mm. In TT-identified femurs, the TT had an average length and diameter of 39.46 mm and 26.01 mm, respectively. The study also provided measurements for gluteal tuberosity and trochanter distances, helping in orthopedic and anatomical research.

Conclusion: In our study conducted on 144 dry femurs with sex determination using morphometric methods, it was found that the third trochanter (TT) was detected in 25.35% of the cases, showing significant sexual dimorphism in favor of males. These femurs exhibited specific morphological characteristics, including an increased superior sagittal diameter, elevated diaphysis platymetry index, and an enlarged greater trochanter. Additionally, the presence of the third trochanter may reflect adaptations to mechanical forces and evolutionary changes, making it a valuable trait for anatomical and genomic studies, as well as surgical procedures that require access to the femoral medullary cavity.

Introduction

The third trochanter (TT) is an accessory bony projection, which can take the form of a raised crista, tubercle, or tuberosity, located either on the gluteal tuberosity or at the upper extremity of the femur [1]. This anatomical feature, referred to as the TT, marks the termination point of the deep fibers of the distal half of the gluteus maximus muscle [2-5]. The application of excessive mechanical force to the deep fibers of the gluteus maximus muscle that attach to the gluteal tuberosity can alter the bone's structure.

This mechanical stress can influence the proximal diaphysis's morphology, ultimately leading to the development and prominence of the TT [6-9]. The significance of the TT in pertrochanteric fractures has recently been postulated to exhibit a correlation with the patterns of fracture lines observed in pertrochanteric fractures. It is posited that the presence of the TT may serve as a mechanism for augmenting skeletal mass, thereby reinforcing the proximal diaphysis in response to heightened ground reaction forces [10-11].

The presence of a relationship between the incidence of the TT and distinct femoral morphology suggested a shared developmental basis for this discrete trait with the size and/or shape components of femoral growth and development [12-14]. Several studies indicated that the TT holds substantial information content pertaining to the underlying hereditary factors within human populations [15]. The precise etiology behind the occurrence of ridges or eleva-

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tions in certain cases remained enigmatic.

This spectrum of ridges, trochanters, and tuberosities may have conceivably represented a microevolutionary trend [1,11]. The existence of osseous prominences, including crista, ridges, and tuberosities, exhibits a direct correlation with the activities of adjacent musculature. The TT assumes a pivotal role as a valuable anatomical landmark in biomechanical investigations and densitometry, while also serving as the preferred access point for medullary cavity procedures [7].

The study identified a prevalence of the third trochanter in 25.35% of dry femurs, highlighting notable gender differences and morphological characteristics that suggest the third trochanter is linked to altered gluteal muscle functionality.

Materials and Methods

The research was conducted within the Medical Faculty. Ethical approval for the study was granted by the Ethics Committee of Akdeniz University School of Medicine (13.09.23/739). All procedures adhered rigorously to the principles outlined in the Declaration of Helsinki.

The sample size for this study was determined based on a power analysis conducted using preliminary data from previous studies on the prevalence of the third trochanter. The study analyzed a total of 144 dry femurs of Turkish origin to assess the prevalence and characteristics of the third trochanter. For morphometric analysis, measurements were acquired using a 0.5-150 mm LCD Digital Vernier Dial Microcaliper (USA). To ensure intra-observer precision, three established precision estimates were computed according to the previous studies [16-19]. The technical error of measurement (TEM), the relative technical error of measurement (rTEM), and the Reliability Coefficient (R) were measured for both genders.

In this study, we conducted measurements of several key anatomical parameters pertaining to the TT within the femur, including its length, diameter, types, precise location, and distances in relation to both the greater trochanter and lesser trochanter. Additionally, measurements of the length and diameters of the greater trochanter and lesser trochanter and gluteal tuberosity were also performed. Subsequently, we applied statistical analyses to the gathered data, facilitating comparisons that accounted for gender and side-specific differences. We performed a statistical analysis and compare gender according to the existence of the TT and the correlation of TT with measurements of femur. We used tests such as chi-squared test for categorical data (gender vs. TT existence) and correlation analysis (Pearson correlation) for (TT) measurements vs. femur measurements]. The following parameters were measured on both sides of the dry femur (Figure 1):

1. The Length and Width of the Femur
2. The Length and Width of the Greater Trochanter
3. The Length and Width of the Lesser Trochanter
4. The Existence of Third Trochanter (TT)
5. The Length and Width of TT
6. Greater trochanter-TT (Distance)
7. Lesser trochanter-TT (Distance)
8. Gluteal Tuberosity

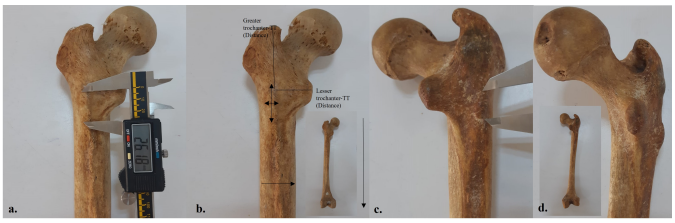

Figure 1. a. The length and width of the Third Trochanter [TT] were measured using a digital caliper [in millimeters] as depicted in the diagram b. The distances from the upper point of the TT to the Greater and Lesser Trochanters were measured. Additionally, the length and width of the Femur were calculated, along with the length and width of the Greater and Lesser Trochanters c. The presence of TT was detected in various types d. The presence of TT was detected in different locations.

Statistical analysis

Statistical analysis were conducted utilizing SPSS Statistics software version 25.0 [SPSS Inc. Chicago, IL, USA]. Comparative analysis of continuous clinical variables was carried out using the Independent t test. For categorical variables, the chi-squared test was used to compare gender according to the existence of the Third Trochanter And the correlation between the parameters were analysed with Pearson correlation analysis.. Statistical significance was established at a threshold of p-value < 0.001.

Results

For males, the Technical Error of Measurement (TEM) is 0.221 with a Relative TEM (rTEM) of 0.523% and a Reliability Coefficient (R) of 0.613. For females, the TEM is 0.394 with an rTEM of 1.040% and an R of 1.092. These values provide an estimate of the measurement error and repeatability for the "Length of Femur" data in each group (male and female).

The descriptive statistics of the parameters were presented in Table 1. The following results were derived: A total of 36 TTs (n=144) were observed, with 9 in females and 27 in males. The average TT length measured 24.48 mm, while the average TT width was 15.91 mm. Significant disparities in TT presence were identified between genders

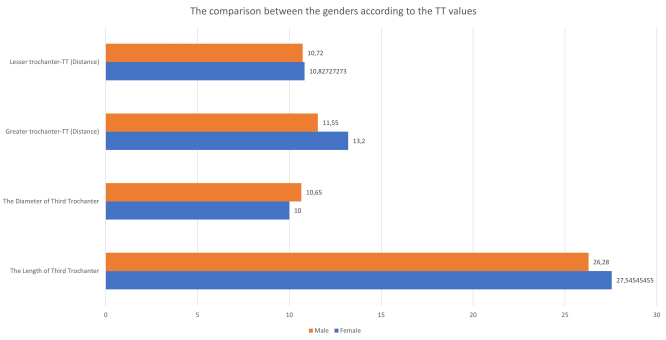

Figure 2. The comparison between the genders according to the TT values.

Table 1. Descriptive statistics of the parameters.

Parameters	Min	Max	Mean	Standard Deviation (SD)	Standard Error of Mean (SEM)
Diameter of Femur	19.8	32.1	27.05	2.458	0.2063
Length of Greater Trochanter	4.8	58.8	45.27	5.358	0.4496
Diameter of Greater Trochanter	25.6	46.2	38.66	3.796	0.3186
Length of Lesser Trochanter	18.3	37.5	24.89	3.759	0.3155
Diameter of Lesser Trochanter	11.4	25.7	17.78	2.436	0.2044
Length of Third Trochanter	14.6	37.6	26.94	6.164	1.345
Diameter of Third Trochanter	7.1	13.2	10.31	1.882	0.4107
Greater Trochanter-TT Distance	6.3	17.8	12.41	2.939	0.6414
Lesser Trochanter-TT Distance	7.9	15.7	10.78	1.825	0.3981
Gluteal Tuberosity	32.4	97.4	66.68	15.30	1.284

Table 2. Statistical analysis of parameters with multiple t-tests.

Parameters	t, df	p value (two-tailed)	SD	SEM	95% Confidence Interval	R squared (partial eta squared)
Diameter of Femur	t = 131.1 df = 141	0.00045	2.458	0.2063	26.64 - 27.46	0.9919
Length of Greater Trochanter	t = 100.7 df = 141	0.00018	5.358	0.4496	44.38 to 46.16	0.9863
Diameter of Greater Trochanter	t = 121.3 df = 141	0.00068	3.796	0.3186	38.03 - 39.29	0.9905
Length of Lesser Trochanter	t = 78.90 df = 141	0.00167	3.759	0.3155	24.27 - 25.51	0.9779
Diameter of Lesser Trochanter	t = 86.98 df = 141	0.00055	2.436	0.2044	17.38 - 18.18	0.9817
Length of Third Trochanter	t = 20.03 df = 20	0.00000	6.164	1.345	24.14 - 29.75	0.9525
Diameter of Third Trochanter	t = 25.10 df = 20	0.00000	1.882	0.4107	9.453 - 11.17	0.9692
Greater Trochanter-TT Distance	t = 19.35 df = 20	0.00021	2.939	0.6414	11.08 - 13.75	0.9493
Lesser Trochanter-TT Distance	t = 27.07 df = 20	0.00147	1.825	0.3981	9.946 - 11.61	0.9734
Gluteal Tuberosity	t = 51.94 df = 141	0.00193	15.30	1.284	64.14 - 69.22	0.9503

(p=0.027), with a notably higher prevalence among males than females (Figure 2).

These findings indicate the existence of gender-related variations in TT characteristics, emphasizing the importance of incorporating this factor into the design of pre-contoured femoral plates and surgical planning. The average length of the femur was determined to be 41.23 mm, while the average width was 27.05 mm. The Greater Trochanter exhibited a length of 45.27 mm and a width of 38.66 mm. Similarly, the Lesser Trochanter was observed to have a length of 24.89 mm and a width of 17.78 mm. In the subset of femurs where the TT was identified, the mean length and diameter were calculated to be 39.46 mm and 26.01 mm, respectively. Among those with TT, the Greater Trochanter displayed an average length of 44.63 mm and a width of 38.28 mm. For TT-identified femurs, the Lesser Trochanter had a length of 22.52 mm and a width of 16.32 mm. These precise measurements provide valuable insights into the morphometric characteristics of the femur and its trochanters, which can be crucial for various orthopedic and anatomical studies. The total gluteal tuberosity length was measured at 66.68 mm, while the gluteal tuberosity length in dry femurs with a TT was found to be 45.80 mm.

The distance between the greater trochanter and TT was determined to be 12.41 mm, while the lesser trochanter to TT distance was calculated as 10.78 mm. The significance of the parameters were presented in Table 2. In the females, the average TT length and width were 27.55 mm and 10 mm, respectively. The distance between the greater trochanter and TT in females was 13.20 mm, and the lesser trochanter to TT distance was 10.83 mm. In

Table 3. The correlation analysis of parameters.

	The diameter of femur	The length of greater trochanter	The diameter of greater trochanter	The length of lesser trochanter	The diameter of lesser trochanter	The length of third trochanter	The diameter of third trochanter	Greater trochanter-TT (distance)	Lesser trochanter-TT (distance)	Gluteal tuberosity
The diameter of femur	1	0.429926292	0.536144367	0.314261789	0.47768827	-0.225189947	0.068302	0.196351	-0.08116	0.319857
The length of greater trochanter	0.429926292	1	0.561104491	0.361167366	0.374776446	-0.253481523	0.186355	-0.0756	-0.17916	0.2117
The diameter of greater trochanter	0.536144367	0.561104491	1	0.393918701	0.433537644	-0.002410171	0.418879	0.255189	-0.25663	0.243492
The length of lesser trochanter	0.314261789	0.361167366	0.393918701	1	0.641114651	-0.079707772	0.286129	-0.26692	-0.19023	0.278654
The diameter of lesser trochanter	0.47768827	0.374776446	0.433537644	0.641114651	1	-0.077838896	0.473846	-0.39944	-0.46558	0.385993
The length of third trochanter	-0.225189947	-0.253481523	-0.002410171	-0.079707772	-0.077838896	1	0.65645	-0.02266	0.196329	0.017127
The diameter of third trochanter	0.068301726	0.186355493	0.418878983	0.286128587	0.473845648	0.656450314	1	-0.22667	-0.21497	-0.04225
Greater trochanter-tt (distance)	0.196350729	-0.075600421	0.255189438	-0.266924613	-0.399435762	-0.022663256	-0.22667	1	0.060759	0.163835
Lesser trochanter-tt (distance)	-0.081160404	-0.179158784	-0.256634162	-0.1902348	-0.465576198	0.196329026	-0.21497	0.060759	1	-0.01398
Gluteal tuberosity	0.319857157	0.211699979	0.24349237	0.278654298	0.385992588	0.017126555	-0.04225	0.163835	-0.01398	1

Pearson correlation analysis.

Table 4. The prevalance of third trochanter according to the gender.

	Female	Male	χ^2	p
Third Trochanter (+)	9 (6.34%)	27 (19.01%)		
Third Trochanter (-)	30 (21.13%)	76(53.52%)	9.195	0.027
Total	39.00 (27.46%)	103.00 (72.54%)		

*Chi Square Test.

males, the mean TT length and width were 26.28 mm and 10.65 mm, respectively. The distance between the greater trochanter and TT in males was 11.55 mm, and the lesser trochanter to TT distance was 10.72 mm.

These measurements contribute to our understanding of the morphometric characteristics of the gluteal tuberosity and trochanters, providing valuable data for anatomical and orthopedic research. In the correlation analysis, a weak positive correlation (ranging from approximately 0.19 to 0.66) was observed between the length of the third trochanter and the diameter of the third trochanter, the greater trochanter-TT distance, and the lesser trochanter-TT distance. Conversely, there was a very weak or non-significant correlation found between the length of the third trochanter and the remaining variables. Similarly, a weak positive correlation (ranging from approximately 0.18 to 0.66) was identified between the diameter of the third trochanter and the length of the third trochanter, the greater trochanter-TT distance, and the lesser trochanter-TT distance. Likewise, no significant correlation or only very weak correlations were observed between the diameter of the third trochanter and the other variables (Table 3). Among females, 9 individuals (6.34%) exhibited a third trochanter, while in males, 27 individuals (19.01%) showed the same feature (χ2=9.195;p=0.027). This indicates a statistically significant association between gender and the presence of a third trochanter, as the p-value is less than the conventional significance level of 0.05. The absence of a third trochanter was observed in 30 females (21.13%) and 76 males (53.52%). The total number of females in the study was 39 (27.46%), while the total number of males was 103 (72.54%) (Table 4).

Discussion

In the present study, it was observed that 9 females (6.34%) exhibited a third trochanter, compared to 27 males (19.01%) who displayed this anatomical feature (χ^2 = 9.195; p = 0.027). This finding indicates a significant gender difference in the prevalence of the third trochanter, suggesting that males may have a higher propensity for this anatomical variation. These femurs manifesting the TT exhibited distinctive attributes, including an increased superior sagittal diameter, increased diaphysis platymetry index, and an enlarged greater trochanter. These findings are in line with previous studies, as they demonstrated that the third trochanter did not appear to be an inherent or progressive morphological trait of the skeletal structure. Instead, it appeared to be associated with an altered functionality of the gluteal muscles [1, 10, 20-22]. Variations such as Allen's fossa, Poirier's facet, plaques, trochanteric fossa, exostoses, and the third trochanter can be observed in the upper portion of the femur [6].

In a study conducted by Akgun et al. on 107 femurs [58 left and 49 right] of young adult males dating back to the 13th century Byzantine period, various variations were identified. In their study, the occurrence of the third trochanter was observed in 16 out of 107 femurs, with 8 found on the right side [16.3%] and 8 on the left side [13.8%] [6]. The higher incidence of the third trochanter and exostoses in the trochanteric fossa in males was attributed not so much to genetic factors but rather to challenging living conditions and squatting habits. Notably, Bolanowski [10] reported a parallel prevalence rate of 6.2% for the third trochanter in a broader dataset of 622 dry femurs obtained from three separate excavation sites. Chhaparwal [15] had previously reported a comprehensive assessment of the prevalence of TT within the central Indian population, revealing a total incidence rate of 14%. It was noteworthy that a higher incidence was recorded on the left side, approximately 16%, whereas on the right side, it was approximately 12%.

Examination of the third TT's average dimensions on the right side unveiled a length of roughly 7.69 mm and a width of 4.90 mm. Conversely, on the left side, the average length measured approximately 15.48 mm, and a width of 7.52 mm [15]. Sadaf et al [22]. previously reported an incidence rate of 14.28% for the TT, with a predilection

for the right side at 10.71%. The mean dimensions of the TT were measured at 17.87 mm in length and 7 mm in width.

Rajad et al. [23] documented the incidence rate of TT was 13%. Specifically, they found that TT occurred in 13.46% of left femurs and 12.5% of right femurs. Additionally, the average vertical length measured 15.80+ 4.37 mm, while the mean breadth was recorded at 8.48+ 2.48 mm. The authors pointed out that the presence of TT may have a potential impact on the trajectory of fracture lines in pertrochanteric fractures. Therefore, when designing precontoured femoral plates, it is imperative to account for the presence of TT [23]. Likewise, in a parallel study conducted in the Northern Tamil Nadu region, the incidence of the TT was documented at a rate of 13.72% within a sample of 153 dry femurs [24]. The mean measurements for TT in terms of length and width were reported as 19.80 ± 5.22 mm and 7.63 ± 1.75 mm, respectively. Interestingly, a higher prevalence of TT was observed on the right side, potentially attributed to functional disparities between the right and left gluteus maximus muscles [24]. It was observed that femurs possessing the third trochanter exhibited a more developed greater trochanter and displayed higher values in all osteometric measurements compared to those lacking this feature.

Additionally, the higher incidence on the right side was suggested as an indication of dominance in most individuals. These femurs displayed a uniformly bulkier morphology, indicative of adaptations to meet functional demands. Lozanoff [12] previously suggested that the occurrence of the third trochanter was linked to shorter femurs characterized by robust proximal diaphyses. The role of the gluteus maximus muscle was indicated as a primary determinant influencing the expression of the third trochanter. Moreover, this discrete infracranial trait was deemed to be highly suitable for inclusion in studies related to human taxonomy [12]. Ogut [1] suggested that the development of the TT could be attributed to the gluteus maximus muscle development, influenced by factors such as posture and bipedal locomotor activity.

Additionally, he proposed an alternative explanation for TT formation, wherein inactivation, deficiency, or mutations of specific genes may lead to modifications in the proximal femoral structure. It was posited that this adaptation could potentially be an evolutionary response, possibly arising from alterations in muscle activity, increased mechanical forces, and reduced stress on the femoral shaft.

It has been highlighted that the significance of considering the TT in genomic studies pertaining to the evolution of mammals [1]. Individuals harboring variants such as the presence of a TT may exhibit lower extremity anomalies, accessory osseous structures, and diverse protrusions within the lower limb [25]. Sylvia et al [20] reported that the presence of the third trochanter did not exhibit any significant correlation with morphological features of the femoral head, neck, or shaft. However, a correlation was observed between the third trochanter and the transverse flattening of the superior end of the femur. These findings from the study suggest that the presence of the third trochanter may be associated with altered gluteal muscle function.

Numerous studies have previously demonstrated the impact of a range of environmental and biological factors on postcranial non-metric traits, including aspects such as age, sex, side dependence, and nutritional factors [1, 26, 27]. The enhanced development of the greater trochanter in femurs bearing a third trochanter [1]. This observation suggests that the presence of the TT potentially serves to augment the attachment surface area for the gluteal musculature, thereby indicating medio-lateral reinforcement and the ability to withstand increased mechanical stresses associated with an erect posture and locomotion. Furthermore, it has been noted that the identification of the TT through imaging techniques can serve as a valuable anatomical landmark in the context of biomechanical and densitometry studies. This landmark can be chosen as the preferred access point for approaches to the medullary cavity, making it particularly relevant for procedures such as intramedullary nailing, reaming, bone marrow aspirations, and catheterization [22].

Conclusion

In conclusion, our study of 144 dry femurs of Turkish origin identified the third trochanter in 25.35% of cases, with notable gender differences favoring males. These femurs exhibited specific morphological characteristics, including an increased superior sagittal diameter, elevated diaphysis platymetry index, and an enlarged greater trochanter. These findings suggesting that the third trochanter is not an inherent skeletal trait but rather linked to altered gluteal muscle functionality. Additionally, the presence of the third trochanter may reflect adaptations to mechanical forces and evolutionary changes, making it a valuable trait for anatomical and genomic studies, as well as surgical procedures that require access to the femoral medullary cavity.

Ethical approval

Ethical approval for the study was granted by the Ethics Committee of Akdeniz University School of Medicine (13.09.23/739).

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