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The occurrence of the third trochanter and its correlation to certain anthropometric parameters of the human femur

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The purpose of the study was to analyse the occurrence of the third trochanter and its correlation with the morphology of the human femur. The third trochanter was found in 38 of 622 (6.2%) human femora taken from 3 excavation sites. 36 of these were included in the study and were compared to the femora without the third trochanter. The bones with the third trochanter were characterised by a greater superior sagittal diameter and diaphysis platymetry index as well as a larger greater trochanter. These results suggest that the third trochanter is not a progressive morphological feature of the skeleton. Rather it is connected with an altered gluteal muscle function.

Key words: osteometry, human skeleton, third trochanter, femur

INTRODUCTION

The third trochanter (*trochanter tertius*, Fig. 1) of the human femur is a descriptive term for the prominent structure frequently localised under the greater trochanter in the superior part of the gluteal tuberosity. The structure is defined as an osseous prominence, tubercule or, alternatively, as a variation of the gluteal tuberosity with its superior part better developed [2, 11, 13, 19, 22]. Some studies, however, refer to an osseous, cartilaginous and tendinous complex [18]. According to the study, the material analysed and the definition of the third trochanter used by the authors, the incidence of the third trochanter varies significantly from 17% to 72% [13, 18].

In anthropometric studies on various populations the third trochanter is the commonly used non-metric variation in the post-cranial skeleton [4]. Together with the hypotrochanteric fossa it serves for descriptive studies of the proximal femur. Many of these studies have revealed significant differences among ethnic groups as well as between male and female skeletons of the same population. A higher incidence of the third trochanter in females has been reported in many studies on various human populations [1, 6, 19, 21].

Similar structures are present in various species of mammals, including rats, rabbits, the Eocene ancestors of whales, some primates and many others [7, 12, 13, 20]. Comparative studies of the third trochanter led their authors to various conclusions. There is no unanimity concerning the homology between this structure in humanoids and other mammals. Additionally, the third trochanter is frequently present and well developed in Neanderthal femora but not in the femora of many other anthropoid species. Consequently, the evolutionary interpretation of the third trochanter of the human femur is still open to doubt. In general, it is debatable whether the structure is regressive or progressive in charac-

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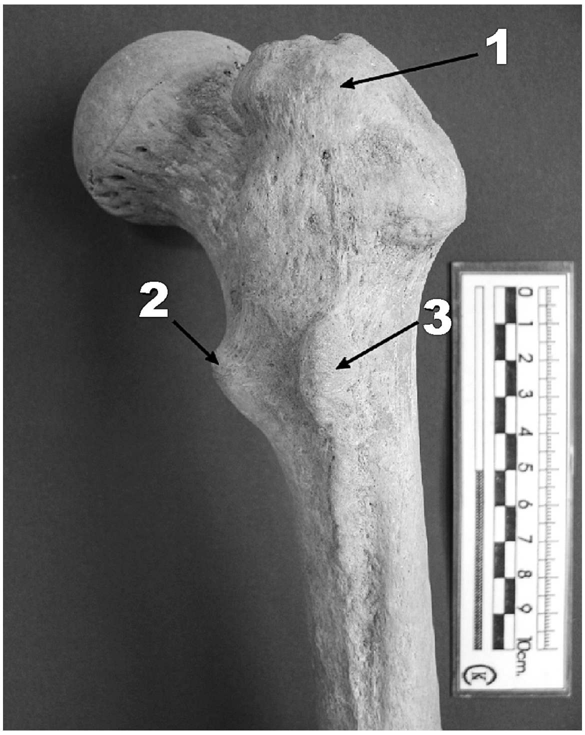

Figure 1. The trochanters of the human femur; 1 — greater trochanter; 2 — lesser trochanter; 3 — third trochanter.

ter, although authors of more recent contributions to the subject favour the latter view [2, 13, 19, 21].

The majority of authors describe the role of the third trochanter as the insertion area for the *gluteus maximus* muscle. Its presence, therefore, would be the consequence of the relative strengthening of this muscle in humanoids in comparison with other primates. An additional role of the third trochanter is probably to alternate the direction of the insertion tendon of the *gluteus maximus* muscle. In this case the prominent structure at the superior end of the gluteal tuberosity serves as the trochlea, alternating the direction of the tendon before it inserts to the other parts of the tuberosity [18].

Apart from anthropometric, comparative and functional studies, the third trochanter is a structure of minor importance in humans. The clinical significance of this structure as the insertion of the *gluteus maximus* muscle is similar to that of the gluteal tuberosity of the femur, the iliotibial tract of the *fascia lata* and the lateral femoral intermuscular septum. However, in some species of laboratory mammals the third trochanter plays an important role as a useful landmark for biomechanical studies and densitometry and as the access point of choice for the medullar cavity [7, 12, 17].

The most interesting issue concerning the third trochanter in humans is whether it is a structure homologous to the third trochanter of other mammals and, if so, why it is absent in many primates, including apes, yet still frequent in humans. If, on the other hand, this structure is developmentally progressive and connected to the motor function of the *gluteus maximus*, why is there so much variation in its occurrence in human populations? The correlation between the presence of the third trochanter and other progressive features of the femur should support one of the above-mentioned alternatives. If the correlation is positive (in other words, if the third trochanter occurs together with other progressive features), the progressive character of the structure can be proved. A negative correlation should, in turn, lead to the opposite conclusion. The best documented progressive anthropometric parameters of the human femur are a low diaphysis platymetry index (DPI), a high shaft pilastry index (SPI) and the evidence of the *linea aspera* [14, 19]. The lack of recent studies on the correlation between these parameters and the occurrence of the third trochanter is the basic reason for the present study.

The goals of the study are:

1. To determine the frequency of the third trochanter in a population not previously studied for the occurrence of this structure.
2. To determine certain anthropometric measurements and indices of the femora in the presence of and in the absence of the third trochanter, with special attention to progressive morphological features of the bones.
3. To make an anthropometric comparison between femora with the third trochanter and those without this structure.

MATERIAL AND METHODS

For the purpose of the present study the third trochanter is defined as the osseous tubercule in the superior part of the gluteal tuberosity. It is localised in the majority of cases laterally to the line connecting the top of the greater trochanter with the superior bifurcation of the *linea aspera* (a). The term tubercule refers to certain measurable features of the structure: the length/width ratio of the tubercule does not exceed 5.0 (the structure is oval-shaped, but not linear) (b) and the minimum height/width ratio of the tubercule is 0.05 (the mean declination of the transverse slope is not less than 10%) (c).

To include any femur to the group with the third trochanter its gluteal tuberosity prominence has to refer simultaneously to all three conditions, (a), (b) and (c).

The osteometric measurements and their symbols (M2–M19), as well as the definition of the femoral indices were taken directly and without alteration from the standard anthropometry handbook [15] with the exception of two trochanteric diameters defined as follows (Fig. 2):

1. The sagittal length of the greater trochanter (SG) — the maximum result of the longitudinal measurements taken in the sagittal plane of the greater trochanter.
2. The coronal length of the lesser trochanter (CL) — the maximum result of the longitudinal measurements taken in the coronal plane of the lesser trochanter.

A total of 622 human femora were included in the study to determine the incidence of the third trochanter. The bones were taken from 3 previously excavated skeletal findings in central Poland dated from the 13th to the 19th century.

The exact distribution of the femora studied is as follows:

— 338 bones (including 21 with the third trochanter) from the "Św. Duch" site in Brześć Kujawski, located close to the medieval hospital which functioned from the 13th or 14th century. The site also contains later skeletons of the church cemetery (16th–19th centuries) and was explored during excavations (1960 and 1964–77) led by Z. Kapica;

— 122 bones (including 4 with the third trochanter) from Tum village near Łęczyca. The excavations date from the 13th to 17th century;

— 162 "Fara" site bones (including 13 with the third trochanter) from the 17th–18th century church cemetery in Brześć Kujawski, explored during the 1970–1971 excavations carried out under Z. Kapica.

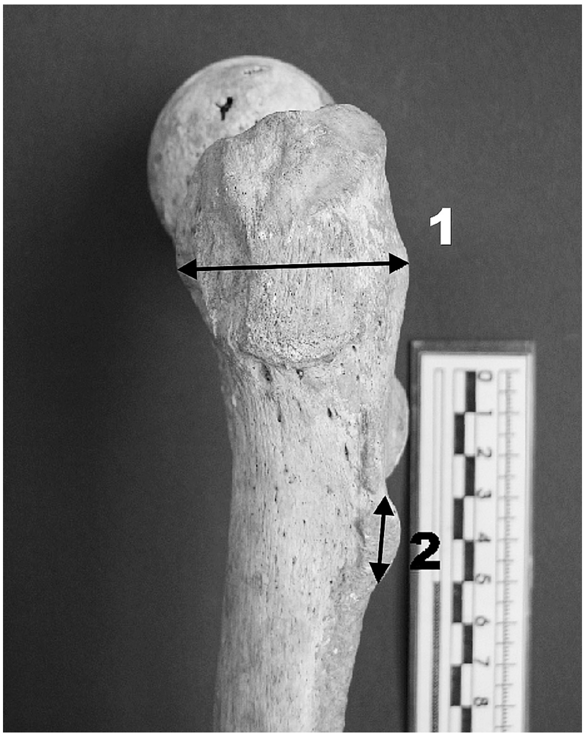

Figure 2. Trochanter diameters; 1 — sagittal length of greater trochanter (SG); 2 — coronal length of lesser trochanter (CL).

All three excavation sites (Św. Duch, Tum and Fara) have previously been analysed and described in a number of works which focus on population anthropometry issues [5, 8, 9, 10].

A total of 36 femora with the third trochanter (19, 4 and 13 from, respectively, the Św Duch, Tum and Fara sites) were included in the study for the osteometric measurements referred to. There were 2 femora which, although with the third trochanter, were excluded as a result of excessive damages to the bones, which made reliable measurements impossible. Another 36 femora without the third trochanter were randomly assigned to the comparative group. The bones without the third trochanter were chosen randomly to equal in number those with the trochanter. This was done independently for each excavation site. The random assignment applied also to the ratio of left and right bones. This procedure enabled a comparative group to be made up identical to the previous one in terms of origin and body side. The characteristics of the third trochanter group are given in Table 1.

The osteometric measurements were carried out according to standard definitions and using procedures, precision and equipment as described elsewhere [3, 15, 16]. Each femur was measured for the following (Fig. 3):

1. Natural femur length (M2)
2. Femoral shaft length (M5)

Table 1. Femora with the third trochanter included in the osteometric analysis

Excavation site	Analysed femora trochanter	Femora with third	Side (left:right) study	Femora excluded from osteometric
Duch	338	21 (6.2%)	8:13	2
Tum	122	4 (3.3%)	2:2	–
Fara	162	13 (8.0%)	5:8	–
Total	622	38 (6.1%)	15:23	2

3. Sagittal femoral shaft diameter (M6)
4. Transverse femoral shaft diameter (M7)
5. Middle shaft circumference (M8)
6. Superior transverse diameter (M9)
7. Superior sagittal diameter (M10)
8. Anterior femoral head and neck length (M14)
9. Femoral neck circumference (M17)
10. Femoral head height (M18)
11. Femoral head width (M19)

Two additional measurements were taken, the definitions of which were evaluated for the purposes of this study (Fig. 2):

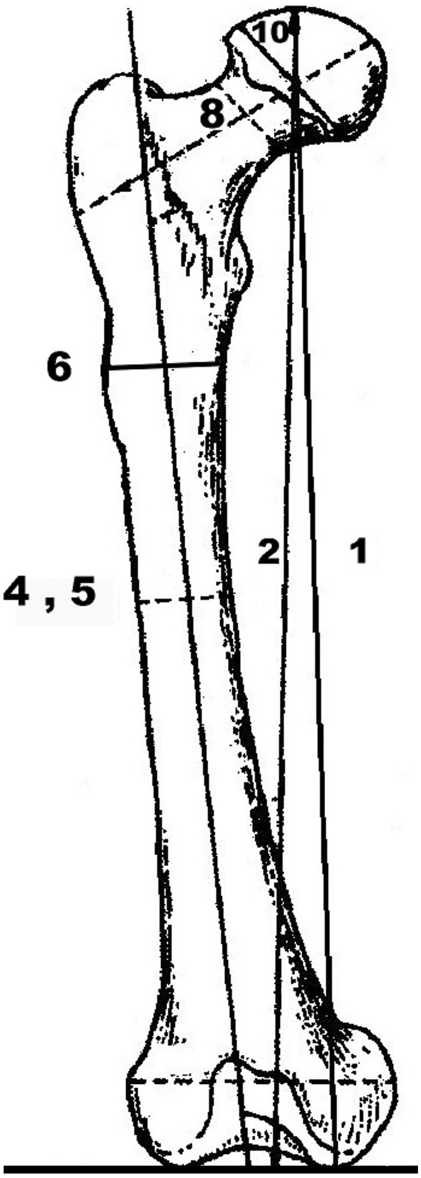

Figure 3. Osteometric measurements of the human femur; 1 — maximal femur length; 2 — natural femur length; 4 — transverse femoral shaft diameter; 5 — middle shaft circumference; 8 — anterior femoral head and neck length; 10 — superior sagittal diameter [15].

12. Sagittal length of the greater trochanter (SG)
13. Coronal length of the lesser trochanter (CL)

The total number of measurements taken during the study was approximately 1,000.

The following indices were calculated using given values:

1. Femoral Massiveness Index (FMI)
   FMI = (M8/M5) × 100%
2. Shaft Massiveness Index (SMI)
   SMI = (M8/M5) × 100%
3. Shaft Pilastry Index (SPI)
   SPI = (M6/M7) × 100%
4. Diaphysis Platymetry Index (DPI)
   DPI = (M10/M9) × 100%
5. Neck Length Index (NLI)
   NLI = (M14/M2) × 100%
6. Neck Massiveness Index (NMI)
   NMI = (M17/M5) × 100%
7. Femoral Head Index (FHI)
   FHI = (M19/M2) × 100%
8. Head Massiveness Index (HMI)
   HMI = [(M18+M19)/M2] × 100%

According to the SPI, the level of "pilastry" (the development of the *linea aspera*) was divided into 4 groups: absent, weak, medium and high. The level of "platymetry" (flattening of the superior femoral diaphysis) was divided into 4 groups in relation to the DPI: hyperplatymetry, platymetry eurymetry and stenometry (Table 2).

RESULTS

Occurrence of the third trochanter (Table 1)

The third trochanter was present in 38 of the 622 femora analysed (6.1%). The incidence observed in

Table 2. Shaft pilastry index (SPI) and diaphysis platymetry index (DPI) and [15]

Development of *linea aspera* (pilastry)	**SPI range (min-max)**
No pilastry	Less than 100.0
Weak pilastry	100.0–109.9
Medium pilastry	110.0–119.9
High pilastry	120.0 and more
Flattening of superior femoral diaphysis	**DPI range (min-max)**
Hyperplatymetry	Less than 75.0
Platymetry	75.0–84.9
Eurymetry	85.0–99.0
Stenometry (transverse platymetry)	100.0 and more

the groups from the various excavations was 21/338 (6.2%), 4/122 (3.3%) and 13/162 (8.0%) for the Św. Duch, Tum and Fara sites respectively. The difference between the Duch and Fara groups was significant ($p < 0.05$). The third trochanter was found in 15 left and 23 right femora. The difference between the left and right sides of the body in third trochanter incidence was not significant.

Osteometric measurements

The results of the basic osteometric measurements are given in Table 3. The only significant difference between the groups was the superior sagittal diameter (M10), with a mean value of 32.2 cm in the third trochanter group versus 27.4 cm in the comparative group. The differences between the left and right sides of the body were not significant when the analysis was performed separately within each and on all the femora measured.

The SG and CL measurements are shown in Table 4. The sagittal length of the greater trochanter was significantly higher in the femora with the third trochanter but there was no difference between the groups in the coronal length of the lesser trochanter.

Morphometric indices

The results of the calculation of the morphometric indices are given in Table 5. In general, the mean and median values of the indices were similar in both groups. The only significant difference concerns the mean DPI, the index correlated with the flattening of the superior end of the femur.

Table 4. Sagittal length of the greater trochanter (SG) and coronal length of the lesser trochanter (CL) measurements performed on femora with the third trochanter and in the comparative group [cm]

Measurement	Greater trochanter	Lesser trochanter
Femora with third trochanter		
Mean	39.0	21.5
Standard deviation	3.7	3.1
1st quartile	37.4	19.0
Median	39.5	21.5
3rd quartile	41.8	23.6
Femora without third trochanter		
Mean	36.3	21.4
Standard deviation	2.9	3.9
1st quartile	34.4	18.9
Median	35.3	20.9
3rd quartile	37.7	22.3
Significance	$p < 0.05$	–

The difference in the mean value of the DPI is due to less frequent hyperplatymetry and platymetry and more frequent stenometry in the group of femora with the third trochanter. The incidence of eurymetry was, in contrast, similar in both groups (Fig. 4).

Discussion

The incidence of the third trochanter in our study is lower than that reported in previous works. The

Table 3. Results of basic osteometric measurements in femora with the third trochanter and in the comparative group [cm]

Measurement:	M2	M5	M6	M7	M8	M9	M10	M14	M17	M18	M19
Femora with third trochanter (n = 36)											
Mean	439.0	335.4	27.9	28.1	87.8	34.5	32.2	73.2	102.9	47.4	47.0
Standard deviation	26.6	20.2	3.1	2.4	6.0	3.7	2.7	7.4	9.4	4.5	4.3
1st quartile	417.0	318.8	26.1	26.3	83.0	32.3	30.0	68.2	99.5	44.2	43.8
Median	438.0	332.5	27.8	27.9	87.5	34.7	32.3	73.9	106.0	48.8	48.2
3rd quartile	462.3	351.3	29.2	29.7	92.0	36.1	34.1	79.2	110.0	50.9	50.2
Femora without third trochanter (n = 36)											
Mean	432.8	332.8	27.8	27.3	86.3	32.9	27.4	71.3	98.9	45.5	45.1
Standard deviation	25.3	23.7	2.7	2.8	6.6	2.7	3.2	4.8	8.4	3.8	3.8
1st quartile	417.0	315.0	26.0	25.5	81.8	31.2	25.0	68.5	90.0	42.6	42.1
Median	426.0	327.0	27.6	27.2	85.0	33.0	26.9	70.9	100.0	46.4	45.3
3rd quartile	448.5	351.5	29.5	28.2	90.0	34.6	28.6	73.3	105.0	47.8	47.4
Significance	–	–	–	–	–	–	$p < 0.05$	–	–	–	–

Table 5. Morphometric indices for the femora analysed

Index	FMI	SMI	SPI	DPI	NLI	NMI	FHI	HMI
Femora with third trochanter (n = 36)								
Mean	20.0%	26.2%	99.7%	94.2%	16.7%	30.5%	99.1%	21.5%
Standard deviation	1.0%	1.3%	10.2%	11.9%	1.3%	2.4%	2.5%	1.3%
1st quartile	19.3%	25.1%	93.6%	84.2%	15.6%	29.1%	98.1%	20.6%
Median	20.0%	26.2%	100.0%	94.1%	16.9%	30.9%	99.3%	21.6%
3rd quartile	20.7%	26.9%	105.4%	101.3%	17.4%	31.9%	100.2%	22.5%
Femora with third trochanter (n = 36)								
Mean	20.0%	26.0%	102.4%	83.4%	16.5%	29.8%	99.1%	20.9%
Standard deviation	1.2%	1.5%	10.4%	8.3%	1.0%	2.0%	2.5%	1.1%
1st quartile	19.3%	25.2%	94.7%	78.1%	15.9%	28.5%	98.3%	20.6%
Median	19.9%	26.0%	101.5%	81.6%	16.5%	29.7%	99.1%	21.0%
3rd quartile	20.9%	26.9%	109.1%	86.9%	17.2%	31.2%	100.5%	21.6%
Significance	–	–	–	$p < 0.05$	–	–	–	–

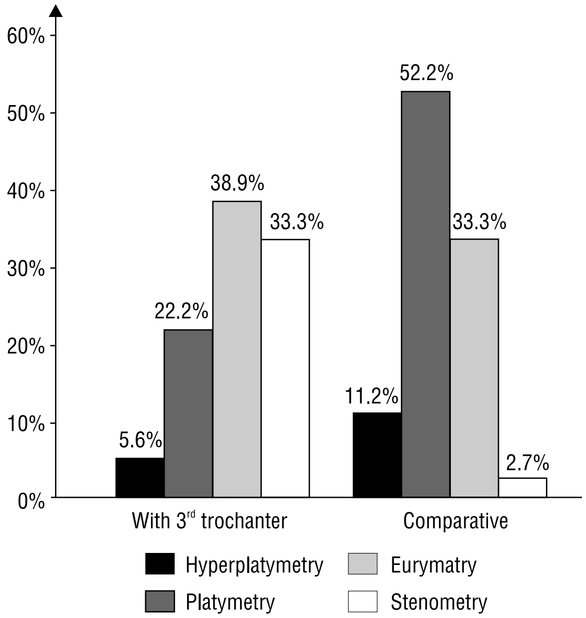

Figure 4. Platymetry in the analysed femora (see also Table 2).

highest incidence (8.0%), found in the Fara group, is still less than a half the minimum cited by other authors [13, 18]. This fact is not explained by the age and character of the material analysed, as other studies based on excavated femora have also reported a higher incidence of the third trochanter [21, 22]. The third trochanter, according to some studies, is more frequent in female femora. Therefore, hypothetically, the over-representation of male skeletons in the group could result in an underestimate of the total incidence of the third trochanter. We did not evaluate the sex of the femora analysed, although some of the results for the osteometric measurements in the study suggest that the majority of the group consisted of male femora. The first quartile of M2 and M18 measures are significant for male femora according to some authors [15, 19]. The sexual differences between skeletons are not a satisfactory explanation of the difference between our study and those based exclusively on male femora, which also report a higher incidence of the third trochanter [1, 21]. The definition of the third trochanter used is the most likely reason for the low frequency of the structure in our study. The quantitative features allowed us to define restrictively the subjective term "osseus tubercule" used in other works [4]. The problem of trochanter definition has already been discussed as a factor influencing the results of the studies. The descriptive terms used by Oliver for the differing morphology of the trochanter stressed that the form with the "round tubercule" is significantly rare in comparison with the form with an "elongated tuberosity" and "crest" [19]. This could explain the difference between the results of our study and those performed on other populations of the same area. Trochanter incidence in the Św. Duch group (6.2%) differs significantly (16.6–37.4%) from that found in the femora of the Jewish cemetery in the same settlement of Brześć Kujawski [22]. The definition of the third trochanter used in that study was "hypertrophic gluteal tuberosity", which is obviously different from "tubercule". However, the other possible explanation is the genetic or environmental difference between the Polish and Jewish populations occupying this area.

The group of femora with third trochanter was morphologically similar to the comparative group with the exception of a higher superior sagittal diameter (M10) and Diaphysis Platymetry Index (DPI), as well as the sagittal length of the great trochanter (SG). A multi-variant analysis shows that the differences in DPI value are not only M10-dependent. They are partially a result of the relatively lower M9 in the third trochanter group (although M9 differs insignificantly between the groups as an independent variable). This contrasts with the hypothesis of an over-representation of male femora. Hence the DPI is higher in the female [15, 19].

The lower DPI value in the group with the trochanter and the insignificant difference in SPI (which is the index of *linea aspera* development) between the groups shows that the third trochanter does not correlate with progressive osteometric features. Our study also shows that the third trochanter is connected with a shift in the morphology of the superior end of femur (including the great trochanter) but not in the general construction of the bone or its shaft. The lesser trochanter (*iliopsoas* insertion) did not correlate with third trochanter incidence. All these findings suggest that the third trochanter is not the direct result of excessive walking, nor is it a progressive human feature. Rather it is the result of an altered morphology or function of the gluteal muscles, as both the greater and the third trochanter are the insertion points for these [2, 13]. This conclusion is similar to that drawn from a previous study on the third trochanter and the gluteal muscles [18].

CONCLUSIONS

1. The incidence of the third trochanter in the femora analysed was 6.1%.
2. The third trochanter was correlated with transverse flattening of the superior end of the femur.
3. The third trochanter was not correlated with any morphological feature of the femoral head, neck and shaft.
4. Femora with the third trochanter showed a better developed greater trochanter than femora without the third trochanter.
5. There was no difference between the groups of femora in the morphology of the lesser trochanter.
6. The study does not support the hypothesis that the third trochanter is a progressive morphological feature of the human skeleton.
7. The results of the study suggest that the third trochanter is a structure which is correlated with an altered gluteal muscle function.

REFERENCES

1. Apostolakis G (1931) Le troisieme trochanter de l'homme. L'Anthropologie, 41: 501–516.
2. Bochenek A, Reicher M (2002) Anatomia człowieka. PZWL, Warszawa.
3. Brothwell DR (1981) Digging up bones. The examination, treatment and study of human skeletal remains. Oxford University Press.
4. Finnegan M (1976) Non-metric variation of the infracranial skeleton. J Anat, 125: 23–37.
5. Gładykowska-Rzeczycka J (1999) Materiał kostny z obiektów archeologicznych jako źródło informacji o biostrukturze i zwyczajach dawnych populacji. Szkice Prahistoryczne. Źródła-Metody, Interpretacje, Toruń, pp. 285–315.
6. Goździkowski S (1960) Kość udowa — rozwój, architektura, budowa i znaczniki biochemiczne. Przegl Antrop, 26: 165–177.
7. Gratz S, Rennen HJ, Boerman OC, Oyen WJ, Burma P, Corstens FH (2001) 99mTc-interleukin-8 for imaging acute osteomyelitis. J Nucl Med, 42: 1257–1265.
8. Kapica Z (1968) Dotychczasowy stan badań antropologicznych Regionu Brześcia Kujawskiego, Monografia powiatu włocławskiego, Włocławek, pp. 21–48.
9. Kapica Z (1970) Człowiek w regionie Brześcia Kujawskiego. Studium archeologiczno-antropologiczne. In: Głębowicz B. (ed.). Monografia Brześcia Kujawskiego, Polskie Towarzystwo Historyczne we Włocławku, Włocławek, pp. 7–52.
10. Kapica Z (1970) Główne problemy współczesnych badań etnogenetycznych. Zeszyty Naukowe Uniwersytetu Łódzkiego, Nauki Matem Seria II, 40: 93–122.
11. Krechowiecki A (1989) Kości uda. In: Sokołowska-Pituchowa J. (ed.). Anatomia człowieka. 6 Ed. PZWL, Warszawa, pp. 132–134.
12. Kurth AHA (2001) The evaluation of a rat model for the analysis of densitometric and biomechanical properties of tumor-induced osteolysis. J Orthop Res, 19: 200–205.
13. Loth E (1955) Odmiany mammalogeniczne w budowie człowieka. Przegl Antrop, 21: 258–280.
14. Loth E (1957) Cechy eugeniczne w budowie człowieka. Przegl Antrop, 23: 259–312.
15. Malinowski A, Bożiłow W (1997) Podstawy antropometrii (metody, techniki, normy). PWN, Łódź.
16. Malinowski A, Wolański N (1988) Metody badań w biologii człowieka. Wybór metod antropologicznych. PWN, Warszawa.
17. Meyer RA, Tsahakis PJ, Martin DF, Banks DM, Harrow ME, Kiebzak GM (2001) Age and ovariectomy impair both the normalization of mechanical properties and the accretion of mineral by the fracture callus in rats. J Orthop Res, 19: 428–436.

18. Murawski E (1968) Przyczyna występowania krętarza trzeciego u człowieka. Ann Acad Med Stetinensis (Szczecin), 14: 127–133.
19. Olivier G (1960) Pratique antropologique. Paris "Le femur", pp. 236–244.
20. Gingerich PD, Haq MV, Zalmoust IS, Khan IH, Malkani MS (2001) Origin of whales from early artiodactyls: Hands and feet of Eocene Protocetidae from Pakistan. Science, 293: 2239–2243.
21. Pittard E, Manuila L, Manuila A (1946) Troisième trochanter et fosse hypotrochantérienne chez 500 fémurs humains (250 de chaque sexe) provenant de la région de Genève. Caractères fonctionnels ou caractères reversifs? Actes de la Soc. Helvet. des Sc. Nat, 175–176.
22. Regierová J (1979) Materiały kostne z cmentarzyska ludności żydowskiej z Brześcia Kujawskiego. Szkielet pozaczaszkowy. Przegl Antrop, 45: 65–73.