Original Research Article

International Journal of Anatomy and Research,
Int J Anat Res 2017, Vol 5(1):3638-43. ISSN 2321-4287
DOI: https://dx.doi.org/10.16965/ijar.2017.127

A PRELIMINARY ANTHROPOMETRIC STUDY OF HEIGHT AND SEX DETERMINATION USING PERCUTANEOUS ULNAR AND FEMORAL LENGTHS

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ABSTRACT

Osteometric indices have a direct relationship with sex, height, age and race of an individual. These factors play a pivotal role in the identification of an individual. There are very few reports in Ghana on the use of bones for personal identification as compared to the developed world. Therefore the present study sought to use the ulna and femur as models for height and sex determination. One hundred undergraduate students of the Kwame Nkrumah University of Science and Technology, Kumasi made up of 55% males and 45% females between the ages of 18 - 45 years were recruited for the study. The total standing height, ulnar and femoral lengths were measured. The data was analysed using excel and SPSS version 20.0. In the present study, males were taller than females ($p < 0.05$). Ulnar and femoral lengths were significantly higher in the male participants than in the females. Ulnar length was the better index for estimating height and the right femoral length was the better model for sex determination in the participants. Therefore the ulnar and right femoral lengths can serve as preliminary useful tools for height and sex determination. The results of this study serve as baseline data for future studies.

KEY WORDS: Height, Percutaneous, Sex, Ulna, Femur.

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Access this Article online

Quick Response code

DOI: 10.16965/ijar.2017.127

Web site: International Journal of Anatomy and Research
ISSN 2321-4287
www.ijmhr.org/ijar.htm

Received: 27 Jan 2017
Peer Review: 28 Jan 2017
Revised: None

Accepted: 02 Mar 2017
Published (O): 31 Mar 2017
Published (P): 31 Mar 2017

INTRODUCTION

Sex, height, race, age and form of an individual play important roles in personal identification. These identifying features have been reported to be directly associated with osteometric indices of the long bones [1]. Determination of height and sex of an individual is of particular importance in forensic medicine in order to provide accurate information to medico-legal systems during road traffic accidents and incidents of disasters [2-4]. Anthropometric studies of the pelvis and the skull tend to be the most accurate methods for sexing an individual [3]. However, percutaneous measurements of the long bones also serve as alternative accurate methods of sex determination when the skull and pelvis are not available. [4]. In situations where the height of an individual cannot be measured directly due to old age/frail patients or patients with limb and/or vertebral column deformity and in mass disasters with dismembered remains, height estimation using percutaneous measurements of long bones becomes very necessary [1,4]. In the developed countries, regression formulae have been generated for height and sex determination. These formulae are population specific, therefore it is inappropriate to apply the derived formulae for sex and height determination of one population to another population [5]. However, in Ghana, such population specific formulae are not available and there are very few reports on osteometric assessment of height and sex using bones of Ghanaian skeletal remains. Therefore, the aim of the present study was to use the percutaneous measurement of ulna and femur as models for height and sex determination and specifically sought to:

· Measure height in both male and female participants.

· Measure ulnar and femoral lengths in both male and female participants.

· Determine the better index for height estimation using the ulnar and femoral lengths.

· Determine the better model for sex determination using the ulna and femur.

MATERIALS AND METHODS

The present study was conducted at the Anatomy Department, School of Medical Sciences, Kwame Nkrumah University of Science and Technology (KNUST) with participants' informed consent and Ethical approval from the Committee on Human Research, Publications and Ethics of the Kwame Nkrumah University of Science and Technology, School of Medical Sciences and the Komfo Anokye Teaching Hospital in Kumasi, Ghana. A total of one hundred undergraduates (55%male; 45% females) between the ages 18 – 45 years were recruited for the study from January, 2016 to April, 2016. Participants without lower and upper limb deformities were included in this study and those with upper and lower limbs deformities as well as amputees were excluded from the study. Ulnar length was measured from the tip of the olecranon process to the styloid process of the ulna using Stanley's paper tape measure (U.S.A). Femoral length was measured from the greater trochanter to the lateral epicondyle of the femur. The standing height of each participant was measured using Shahe's stature meter (Shanghai, China). The data collected were analysed using excel and SPSS version 20.0. Regression analysis was used for height estimation using the right and left ulnar and femoral lengths. Binary logistic regression analysis was used to determine sex from the right and left ulnar and femoral lengths.

RESULTS

Descriptive statistics of participants: The mean age of males was 22.47 ± 4.25 years (range: 19 – 33 years) and that of females was 22 ± 2.52 years with a range of 18 - 45 years.

The mean measured standing height of the participants was 167.00 ± 7.34 cm. The mean measured heights of males and females were 170.87 ± 6.43 cm and 162.29 ± 5.41 cm respectively. Males were significantly taller than females ($p < 0.05$). The mean right ulnar length (RUL) of all participants was 28.54 ± 1.91 cm and the mean left ulnar length (LUL) was 28.51 ± 1.88 cm. The male participants recorded a mean of 29.30 ±1.38 cm and 29.25 ± 1.33 cm for the RUL and LUL respectively. The mean RUL of females was 27.54 ± 2.04 cm and the mean LUL was 27.54 ± 2.03 cm with a range of 23.90 cm - 37.50 cm. Male participants had significantly longer right and left ulnae than females ($p < 0.05$). The mean right femoral length (RFL) of all participants was 41.47 ± 4.57 cm and the mean left femoral length (LFL) was 41.48 ± 4.71 cm. The mean right and left femoral lengths of males were 43.82 ± 4.42 cm and 43.81 ± 4.38 cm respectively. The mean RFL of females was 38.26 ± 2.62 cm and the mean LFL was 38.31 ± 2.61 cm. Males had significantly longer femorae than females ($p < 0.05$) (table1).

Table 1: Ulnar and femoral lengths stratified by sex.

PARAMETER	SEX	MEAN	RANGE	p-value
RUL (cm)	MALES	29.25 ± 1.33	25.80-32.00	0.000*
	FEMALES	27.54 ± 2.03	23.90-37.50	
LUL (cm)	MALES	29.25 ± 1.33	26.00-32.10	0.000*
	FEMALES	27.54 ± 2.04	24.00-37.50	
RFL (cm)	MALES	43.82 ± 4.42	37.40-55.20	0.000*
	FEMALES	38.26 ± 2.62	33.20-45.70	
LFL (cm)	MALES	43.81 ± 4.38	37.00-55.40	0.000*
	FEMALES	38.31 ± 2.61	33.00-22.00	

*(**LUL** = left ulnar length; **RUL** = right ulnar length; **RFL**= right femoral length, **LFL**= left femoral length **cm** = centimetre), Significant level (P < 0.05)*

Correlation between height, ulnar and femoral length: There was a statistically significant ($p < 0.05$) correlation between the measured height and ulnar length of all participants (r RUL = 0.682 and r LUL = 0.689). However, males exhibited a greater correlation between the measured height and ulnar length (r RUL = 0.66 and r LUL= 0.70) as compared to the female right ulnar length (r = 0.52) and left ulnar length (r = 0.53). There was a statistically significant ($p < 0.05$) correlation between the measured height and left (r = 0.55) and right (r = 0.56) femoral lengths of all participants. For both males and females, there were statistically significant ($p<0.05$) correlations between femoral length and measured height. Females showed a greater correlation between the measured height and femoral length (r RFL = 0.39 and r LFL = 0.36) as compared to the right femoral length (r = 0.29) and left femoral length (r = 0.28) of males (Table 2).

Table 2: Correlation between height, ulna and femur lengths in males and females.

VARIABLE	ALL PARTICIPANTS		MALES		FEMALES	
	r	p-value	R	p-value	r	p-value
RUL	0.68	0.000*	0.66	0.000*	0.52	0.000*
LUL	0.69	0.000*	0.7	0.000*	0.53	0.000*
RFL	0.56	0.000*	0.29	0.030*	0.39	0.010*
LFL	0.55	0.000*	0.28	0.040*	0.36	0.020*

*(**LUL** = left ulnar length; **RUL**= right ulnar length; **RFL**= right femoral length, **LFL**= left femoral length; **r** = correlation co-efficient of analysis) Significant level (P < 0.05)*

Inter-population comparison of ulnar and femoral lengths: The mean ulnar length of Ghanaian males and females differed significantly ($p < 0.05$) from those reported for Indians in the Gujarat region and Greeks [6,7]. The mean femoral length of Ghanaian males differed significantly ($p < 0.05$) from that reported for South African Whites [8] and the mean femoral length of Ghanaian females also differed significantly from the means reported for South African Whites and Indians [8,9]. These differences could result from the differences in race, nutritional status and occupation which all have been shown to contribute significantly to inter-population variation [10].

Regression analysis for height estimation: The regression equation of the ulnar length appeared to be a better estimator of height in both males and females. The right ulnar length was able to correctly predict the height of 43% and 26% of the male and female population respectively. The left ulnar length was able to correctly predict the height of 48% and 26% of the male and female population respectively. The right femoral length on the other hand was able to correctly estimate the height of 7% and 13% of the male and female participant respectively and the left femoral length was able to correctly predict the height of 6% and 11% of the male and female population respectively (Table 3).

Table 3: Linear regression equation for height estimation in males and females.

SEX	PARAMETER	REGRESSION EQUATION	p-value	$AdjR^2$
MALES	RIGHT ULNAR LENGTH	Y=80.22 + (3.10)X	0.000*	0.43
	LEFT ULNAR LENGTH	Y=72.58 + (3.36)X	0.000*	0.48
	RIGHT FEMORAL LENGTH	Y=152.13 + (0.43)X	0.030*	0.07
	LEFT FEMORAL LENGTH	Y=152.64 + (0.42)X	0.040*	0.06
FEMALES	RIGHT ULNAR LENGTH	Y=124 + (1.40)X	0.000*	0.26
	LEFT ULNAR LENGTH	Y=123.78 + (1.40)X	0.000*	0.26
	RIGHT FEMORAL LENGTH	Y=131.55 + (0.80)X	0.010*	0.13
	LEFT FEMORAL LENGTH	Y=134 + (0.74)X	0.020*	0.11

*(**Y** = dependent variable (estimated height) and **X** = independent variable (left and right femoral length and left and right ulnar length; adjR^2 = adjusted co-efficient of determinant) Significant level (P < 0.05)*

Binary logistic analysis for sex determination: The right femoral length was the only parameter which showed statistically significant ($p < 0.05$) sexual dimorphism. Binary logistic regression was employed to derive an equation Y = 23.809 – (0.594 × Right Femoral Length), where Y is the sex of participant. The equation derived was able to determine the sex of about 80% of the male population and 80% of the female population with overall sex determination percentage of 80% ($p < 0.05$). The prediction probability of the derived equation is positive for females and negative for males. This observation is in agreement with the findings of Ozer and Katayama, who used the femu to predict sex and concluded that it is sexually dimorphic with prediction accuracy of 75% [11].

DISCUSSION

Ulnar length and height: There was a statistically significant correlation between ulnar length and height ($p < 0.05$). Ulnar length correlates with height better in males than in females. Male participants had longer ulnae than female participants. The shorter length of the female ulna could be due to the effect of high levels of oestrogen during puberty which causes early cessation of bone growth. Oestrogen causes fusion of the proximal epiphysis with the shaft of the ulna in the 14th year and fusion of the distal epiphysis with the shaft in the 18th year [12]. In contrast, the high levels of testosterone in males during puberty allows bone growth up to 21 years thereby prolonging the growth phase of the long bones which results in longer male bones [13]. Moreover, the difference in ulnar length between males and females could also be due to males indulging in more physical activities such as weeding, climbing, farming, etc. than females, thereby causing the extension of their ulnae as a means of adaptation to the excessive stretching of the hand during weeding and other vigorous exercises [14].

The results of the present study are similar to the findings of a study conducted by Barbosa *et al*. in Portugal where ulnar length was used to predict height in 507 English and Portuguese individuals with a mean age of 61.8 ± 18.9 years [15]. They concluded that, there was a strong positive correlation between ulnar length and estimated height ($r = 0.724$, $p < 0.05$), with correlation being highest in male participants than in female participants. Several authors have reported that there is a statistically significant ($p < 0.05$) positive correlation between ulnar length and height [16-18].

The mean ulnar length of Ghanaian males and females differed significantly from the mean ulnar lengths reported for Indians in the Gujarat region and Greeks [6,7]. The difference in occupation and physical activities of the participants could serve as contributory factors to inter-population variation [2,14].

Femoral length and height: In the present study, there was a statistically significant correlation between height and femoral length lower correlation. These lower correlation coefficients here indicate that the femur is a weak estimator of height in the present study compared to the ulna. Males had statistically significant longer femorae than females. The shorter length of the female femur could be due to the earlier closure of both the distal and proximal epiphyseal plates of the femur mostly by the age of 18 years due to the effect of oestrogen during their puberty stage. In males, high levels of testosterone during puberty allows bone growth up to 21 years which causes males to have longer femorae and greater bone mass than females [13]. The findings of the present study are in line with the reports of similar studies [2,5]. They reported that, there was a statistically significant ($p<0.05$) positive correlation between maximum femoral length and stature of male and female participants with the correlation being highest in males than in females.

Inter-population comparison of mean femoral length: Mean femoral length of the present study was compared to the means of similar studies in other populations such as South African Whites and Indians. The mean femoral length of Ghanaian males differed significantly from the mean reported for South African Whites [8]. This difference might result from the differences in geographical area and nutrition which have been shown to contribute significantly to inter-population variation [13,14]. However, there was no statistically significant difference between the mean femoral length of Ghanaian males and the mean reported for Indians [9]. Unlike males, there was a statistically significant lower difference between the mean femoral length of Ghanaian females and means reported for South African Whites and Indians [8,9]. Again, these differences could result from the differences in ethnicity and race which have been shown to contribute immensely to inter-population variation. African women have been found to have wider pelves than women from other populations. The wider nature of their pelves cause them to have greater carrying angle of the femur which leads to the shorter length of the femur generally seen among African women as compared to women of other populations [13].

Height estimation using regression analysis: Different and various methods have been generated to estimate stature from long bones but the most convenient and easiest way of estimating stature from long bones is by regression analysis [19-21]. Femoral and ulnar lengths have been used by several researchers among various populations to estimate stature using regression analysis and have concluded that, ulnar and femoral lengths have statistically significant ($p < 0.0001$) positive correlation with stature [21- 23]. The derived regression equations are specific for the study population. The findings of the present study are in agreement with that of Singh *et al.* who suggested that, regression analysis is a useful and accurate method for stature estimation when used only in specific populations where it is derived [14].

Sex determination using binary logistic analysis: In the determination of sex, the findings of this study showed that right femoral length was the only statistically significant sex determinant ($p < 0.05$, $R^2 = 0.547$). Its prediction accuracy for males and females was 80%. The right and left ulnar lengths as well as the left femoral length yielded no statistically significant ($p > 0.05$) models for sex determination. The findings of the present study is consistent with the findings of a study by Soni*et al.* who used discriminant function analysis to determine sex from femur. Seven parameters of the femur were measured and it was noted that maximum length of the femur was sexually dimorphic with an accuracy of 85% in males and 72.5% in females [24]. Steyn and Yasar used the femur and tibia to determine sex in South African whites and reported that, the maximum lengths of both femur and tibia were sexually dimorphic [8].

CONCLUSION

It has been shown in the present study that males are taller than females. The ulnar and femoral lengths were significantly higher in male participants than in females. It has been shown that, the mean ulnar lengths of the study population differed significantly from those reported for Indians and South Eastern Asians. In addition, the mean femoral length of Ghanaian males differed significantly from the mean reported for South African Whites. Unlike males, the mean femoral length of Ghanaian females differed significantly from those reported for South African White and Indians. Ulnar length was the better estimator for height and the right femoral length was the better measurement for sex determination in both males and females. Therefore, the ulnar and right femoral lengths can serve as useful tools for height and sex determination.

Conflicts of Interests: None

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How to cite this article:

Emmanuel Owusu Ansah, Chrissie Stansie Abaidoo, Thomas Diby, Joshua Tetteh, Atta Kusi Appiah, Obed Ohene-Djan Atuahene, Nancy Darkoa Darko. A PRELIMINARY ANTHROPOMETRIC STUDY OF HEIGHT AND SEX DETERMINATION USING PERCUTANEOUS ULNAR AND FEMORAL LENGTHS. Int J Anat Res 2017;5(1):3638-3643. **DOI:** 10.16965/ijar.2017.127