



Research Article

Regression Model for Estimating Femur Length from Its Morphometry in South-West Nigerian Population

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SUMMARY

Objective: This study reports on the morphometry of the femur and the estimation of its maximum length using linear regression model in South west Nigerian population.

Methods: The maximum femur length and proximal femur breadth were measured using an osteometric board. The proximal angle breadth, neck vertical diameter, medial lateral mid-shaft diameter, neck transverse diameter, vertical head diameter, horizontal head diameter, anterior posterior sub-trochanteric diameter, medial lateral sub-trochanteric diameter, anterior posterior mid-shaft diameter, femur epicondylar breadth, anterior posterior diameter of the lateral condyle, anterior posterior diameter of the medial condyle, medial condylar length and Lateral condylar length were measured using a digital vernier caliper while sub-trochanteric circumference, femur mid-shaft circumference were measured using fibre glass tape.

Results: Following data analysis using SPSS, linear and multiple regressions equations were derived for predicting maximum femur length ($p < 0.05$). The best predictor was vertical head diameter, two landmarks on the left femur, and three bony markers from combined analysis irrespective of the sides. The femur length was estimated with higher degree of accuracy from the measures of its bony markers on the right femur, on the left femur and from combined analysis irrespective of the sides.

Conclusion: Study provides useful baseline information for future studies on femur length estimation using regression models in the South-west Nigerian population.

INTRODUCTION

An increasing body of literature, summarized in Ibeabuchi *et al.*[1] describes recent morphologic technologies and imaging procedures that have enabled positive identification of unknown human remains including osteologic anthropometry, analogue and digital spatial cranio-facial reconstruction, DNA analysis, and radiologic analysis. Because there is strong positive correlation between stature and length of long bones, stature estimation by these methods have become standard today. Thus, application of anthropometric techniques permits the use of either complete or incomplete skeletal remains of known as well as unknown persons to estimate their stature.[2]

While intact long bones are preferable for estimation of the stature of unidentified individual, where natural or man-made disasters present bone fragments, or when the skeletal remains are fragmentary, as may be the case during excavation of ancient burial sites, protocols have been developed to estimate the stature from these bones.[2-10]

In previous studies, the morphology of part or the whole femur has been characterized and employed in determining its maximum length. [10-14] A review of the literature suggests a growing interest among Nigerian

anatomists and anthropologists in the forensic sciences. We previously characterized the gross morphology and derived predictive regression models for the estimation of the maximum length of the ulna,[1] humerus[15] and the radius bone.[16] However, aside the singular study on the proximal femur morphology in an adult Hausa sample in the Kano area of northern Nigeria,[17] the morphology of the femur and estimation of its length using regression equations in the Nigerian population has scarcely been explored. The present study, therefore, described the morphology of the entire femur and evaluated segmental anthropometric correlates with maximum femoral length to formulate a predictive regression model for estimating the maximum length of the femur.

METHODS

Institutional Approval and Ethical Clearance

Ethical clearance for the study followed the procedure previously described in Ibeabuchi *et al.*[1,16] This included written approval from the Health Research Ethics Committee of the Department of Anatomy, College of Medicine of the University of Lagos prior to the commencement of specimen collection and processing. Furthermore, approval was sought and obtained from the Health Research and Ethics Committee

of the College of Medicine of the University of Lagos at the inception of the study (Approval Reference number: CM/COM/8/VOL.XI/2014).

This study was carried out on 44 dry specimens of adult femurs (right side nos. 22; left side nos. 22) of undetermined sex, selected from the cadaveric skeletal collection in the Department of Anatomy, College of Medicine of the University of Lagos.

Using an osteometric board, the maximum femur length (FML) and proximal femur breadth (FPB) were estimated. Using a vernier caliper, the proximal angle breadth (PAB), neck vertical diameter (NVD), medial lateral mid-shaft diameter (MLMSD), neck transverse diameter (NTD), vertical head diameter (VHD), horizontal head diameter (HHD), anterior posterior sub-trochanteric diameter (APSTD), medial lateral sub-trochanteric diameter (MLSTD), anterior posterior mid-shaft diameter (APMSD), femur epicondylar breadth (FEB), anterior posterior diameter of the lateral condyle (APDLC), anterior posterior diameter of the medial condyle (APDMC), medial condylar length (MCL) and lateral condylar length (LCL) were estimated. The sub-trochanteric circumference (STC) and femur mid-shaft circumference (FMSC) were measured using a customized fibre glass tape (see plates 1-3).

For measurements of the femur, the anthropometric protocols were pooled from various sources developed by previous workers and re-iterated in Byrne [18] after originally compilation by Moore-Jansen *et al.* [12]. However, the list includes anthropometric measurements introduced by more recent authorities. Thus:

1. Femur maximum length (FML) - the distance from the most superior point on the head of the femur to the most inferior point on the distal-medial condyle using osteometric board. [10, 12]
2. Greater trochanter-subtrochanteric with gluteal tuberosity (GTSTG) - the distance between the tip of the greater trochanter to the point of the greatest lateral expansion of the femur below the lesser trochanter including the gluteal tuberosity. [12]
3. Femur proximal breadth (FPB) - the maximum width from the head of the femur to the greater trochanter perpendicular to the osteometric board. [19]
4. Proximal angled breadth (PAB) - the measurement taken posteriorly from the inferior-lateral point of the greater trochanter to the most medial point on the femoral head. [12]
5. Neck vertical diameter (NVD) - the minimum diameter of the neck of the femur at the superior inferior direction. [19, 20]
6. Neck transverse diameter (NTD) - the minimum diameter of the neck of the femur at the anterior-posterior direction. [19]
7. Vertical diameter of head (VHD) - the maximum diameter of the femoral head taken in the vertical plane that passes through the axis of the neck. [21]
8. Horizontal diameter of head (HHD): The maximum diameter of the femoral head taken in the horizontal plane perpendicular to the vertical diameter of the head. [21]
9. Anterior-posterior subtrochanteric diameter with gluteal tuberosity (APSTDG): The anterior-posterior diameter measured at the point of greatest

- lateral expansion of the femur below the lesser trochanter including the gluteal tuberosity. [12]
10. Medial-lateral subtrochanteric diameter with gluteal tuberosity (MLSTDG): The medial-lateral diameter measured at the point of greatest lateral expansion of the femur inferior to the lesser trochanter including the gluteal tuberosity. [18]
11. Subtrochanteric circumference with gluteal tuberosity (STCG): The circumference measured on the shaft inferior to the lesser trochanter at the same level of the sagittal and transverse subtrochanteric diameters including the gluteal tuberosity.
12. Anterior-posterior subtrochanteric diameter (APSTD): The anterior-posterior diameter measured at the point of the greatest lateral expansion of the femur inferior to the lesser trochanter, avoiding the gluteal tuberosity. In cases where this cannot be determined, this measurement is recorded within 2-5 cm inferior to the lesser trochanter. [12]
13. Medial-lateral subtrochanteric diameter (MLSTD): The transverse diameter measured at the point of greatest lateral expansion of the femur inferior to the lesser trochanter, avoiding the gluteal tuberosity. In cases where this cannot be determined, this measurement is recorded within 2-5 cm inferior to the lesser trochanter. [12]
14. Subtrochanteric circumference (STC): The circumference measured on the shaft below the lesser trochanter at the same level of the sagittal and transverse subtrochanteric diameters, avoiding the gluteal tuberosity.
15. Anterior-posterior diameter at mid-shaft (APMSD): The anterior-posterior diameter measured approximately at the midpoint of the diaphysis, at the highest elevation of the linea aspera. This measurement is perpendicular to the ventral surface. [12]
16. Medial-lateral diameter at mid-shaft (MLMSD): Measurement taken at right angles to the anterior-posterior diameter of the mid-shaft. The linea aspera should be midway between the two branches of the caliper. [22]
17. Circumference at mid-shaft (FMSC): The circumference measured at the midshaft at the same level of the sagittal and transverse diameters. Note: that if the linea aspera is strongly accentuated at the midshaft and not across a larger part of the diaphysis, this measurement should be recorded approximately 10 mm superior to the midshaft. [12]
18. Epicondylar breadth (FEB): The maximum distance from the most lateral point on the lateral condyle to the most medial point on the medial condyle taken parallel to the infracondylar angle. [12]
19. Femur anterior-posterior diameter of the lateral condyle (APDLC): Measurement taken of the projected distance between the most posterior point on the lateral condyle and lip of the patellar surface perpendicular to the axis of the shaft.
20. Measurement of Anterior-Posterior Diameter of the medial condyle (APDMC): Measurement taken of the projected distance between the most posterior point on the medial condyle and lip of the patellar surface

- perpendicular to the axis of the shaft.
21. Measurement of Femur Bi-condylar Breadth (FBCB); this is the most lateral and posterior projection of the lateral condyle, to the most medial and posterior projection of the medial condyle.[10]
 22. Medial Condylar Length (MCL): linear distance between the most anterior and the most posterior points on the medial condyle.
 23. Lateral Condylar Length (LCL): is the linear distance on the lateral condyle measured in an antero-posterior direction.

All measurements were expressed in centimeters. The data were analyzed using SPSS, correlation of each measured parameter to FML was obtained and regression equations were derived from highly correlated bony parameters at $p < 0.05$.



Figure 1: Measurement of Maximum Femur Length using an osteometric board



Figure 2: Measurement of Sub-Trochanteric Circumference with Gluteal Tuberosity (STCG) using digital vernier caliper



Figure 3: Measurement of Femoral Epicondylar Breadth (FEB) using digital vernier caliper

RESULTS

Tables 1, 2 and 3 present the estimates for twenty-three different femoral parameters for the right and left femurs as well as the aggregated values irrespective of sex and side respectively. Mean length of the left femur FML was estimated as 47.62 ± 2.67 cm while that of the right femur was 47.17 ± 2.5 cm and ranged between 51.70 cm and 42.20 cm.

Only the best regression equations with reasonable application are presented. All the measured variables showed significant positive Pearson's product moment correlation coefficient 'r' with FML. Generally, a low to moderate degree of correlation was observed. Of the measured variables, the APMSD showed the strongest correlation with FML ($r = 0.709$) for the right femur group, while APDLC showed a stronger correlation ($r = 0.729$) with FML for the left femur in individual analysis. The regression equations were derived using only the variables with a high correlation at $p < 0.05$ (see figures 1-3).

Table 1: Descriptive statistics of the femoral parameters irrespective of side

Variables	Mean. $\pm$ S.D (cm)	Min. value (cm)	Max value (cm)
FML	47.40 ± 2.59	42.15	1.7
GTSTG	7.45 ± 0.51	6.6	8.8
FPB	9.08 ± 0.66	6.9	10
PAB	8.87 ± 0.46	7.9	10
NVD	3.20 ± 0.34	2.7	3.9
NTD	2.62 ± 0.29	2.1	3.2
VHD	4.53 ± 0.28	3.9	5.1
HHD	4.49 ± 0.32	3.9	5.3
APSTDG	3.03 ± 0.30	2.5	4
MLSTDG	3.03 ± 0.25	2.6	3.7
STCG9	$.28 \pm 0.68$	7.7	10.8
APSTD	2.62 ± 0.20	2.2	3
MLSTD	2.61 ± 0.22	2.1	3.20
STC	8.56 ± 0.68	7.3	9.90
APMSD	2.89 ± 0.30	2.4	3.50
MLMSD	2.58 ± 0.25	2.1	3.30
FMSC	8.54 ± 0.67	7.3	10.00
FEB	7.85 ± 0.52	6.4	9.10
APDLC	6.38 ± 0.38	5.4	7.10
APDMC	6.32 ± 0.45	5.1	7.30
FBCB	6.27 ± 0.36	6.27	8.26
MCL	6.27 ± 0.36	5.86	7.24
LCL	6.42 ± 0.29	6.05	6.98

Values are mean $\pm$ s.d (Range)

KEY TO VARIABLE ABBREVIATIONS

FML = Femur maximum length; GTSTG = Greater trochanter - subtrochanteric with gluteal tuberosity; FPB = Femur proximal breadth; PAB = Proximal angled breadth; NVD = Neck vertical diameter; NTD = Neck transverse diameter; VHD = Vertical diameter of head; HHD = Horizontal diameter of head; APSTDG = Anterior-posterior subtrochanteric diameter with gluteal tuberosity; MLSTDG = Medial-lateral subtrochanteric diameter with gluteal tuberosity; STCG = Subtrochanteric circumference with gluteal tuberosity; APSTD = Anterior-posterior subtrochanteric diameter; MLSTD = Medial-lateral subtrochanteric diameter; STC = Subtrochanteric circumference; APMSD = Anterior-posterior diameter at mid-shaft; MLMSD = Medial-lateral diameter at mid-shaft; FMSC = Circumference at mid-shaft; FEB = Femur Epicondylar breadth; APDLC = Anterior Posterior Diameter of the Lateral Condyle; APDMC = Anterior-Posterior Diameter of the medial condyle; FBCB = Measurement of Femur Bi-condylar Breadth; MCL = Medial Condylar Length; LCL = Lateral Condylar Length

Table 2: Descriptive statistics of the morphometric variables for the Right femur

Variables	Mean $\pm$ S.D (cm)	Min. value (cm)	Max value (cm)
FML	47.40 $\pm$ 2.59	42.15	1.7
GTSTG	7.45 $\pm$ 0.51	6.6	8.8
FPB	9.08 $\pm$ 0.66	6.9	10
PAB	8.87 $\pm$ 0.46	7.9	10
NVD	3.20 $\pm$ 0.34	2.7	3.9
NTD	2.62 $\pm$ 0.29	2.1	3.2
VHD	4.53 $\pm$ 0.28	3.9	5.1
HHH	4.49 $\pm$ 0.32	3.9	5.3
APSTDG	3.03 $\pm$ 0.30	2.5	4
MLSTDG	3.03 $\pm$ 0.25	2.6	3.7
STCG	9.28 $\pm$ 0.68	7.7	10.8
APSTD	2.62 $\pm$ 0.20	2.2	3
MLSTD	2.61 $\pm$ 0.22	2.1	3.20
STC	8.56 $\pm$ 0.68	7.3	9.90
APMSD	2.89 $\pm$ 0.30	2.4	3.50
MLMSD	2.58 $\pm$ 0.25	2.1	3.30
FMSC	8.54 $\pm$ 0.67	7.3	10.00
FEB	7.85 $\pm$ 0.52	6.4	9.10
APDLC	6.38 $\pm$ 0.38	5.4	7.10
APDMC	6.32 $\pm$ 0.45	5.1	7.30
FBCB	7.14 $\pm$ 0.34	6.27	8.26
MCL	6.27 $\pm$ 0.36	5.86	7.24
LCL	6.42 $\pm$ 0.29	6.05	6.98

Values are mean $\pm$ s.d (Range)

KEY TO VARIABLE ABBREVIATIONS

FML=Femur maximum length; GTSTG= Greater trochanter -subtrochanteric with gluteal tuberosity; FPB= Femur proximal breadth; PAB= Proximal angled breadth; NVD=Neck vertical diameter; NTD= Neck transverse diameter; VHD=Vertical diameter of head; HHD = Horizontal diameter of head; APSTDG = Anterior-posterior subtrochanteric diameter with gluteal tuberosity; MLSTDG = Medial-lateral subtrochanteric diameter with gluteal tuberosity; STCG = Subtrochanteric circumference with gluteal tuberosity; APSTD = Anterior-posterior subtrochanteric diameter; MLSTD = Medial-lateral subtrochanteric diameter; STC = Subtrochanteric circumference; APMSD = Anterior-posterior diameter at mid-shaft; MLMSD = Medial-lateral diameter at mid-shaft; FMSC = Circumference at mid-shaft; FEB = Femur Epicondylar breadth; APDLC = Anterior Posterior Diameter of the Lateral Condyle; APDMC = Anterior-Posterior Diameter of the medial condyle; FBCB = Measurement of Femur Bi-condylar Breadth; MCL = Medial Condylar Length; LCL = Lateral Condylar Length

Table 3: Descriptive statistics of the morphometric variables for the left femur

Variables	Mean. $\pm$ S.D (cm)	Range Min. value (cm) Max. value (cm)	
FML	47.62 $\pm$ 2.67	42.10	51.00
GTSTG	7.31 $\pm$ 0.46	6.60	8.30
FPB	9.23 $\pm$ 0.54	8.00	10.00
PAB	8.89 $\pm$ 0.53	7.90	10.00
NVD	3.15 $\pm$ 0.31	2.70	3.70
NTD	2.60 $\pm$ 0.26	2.10	3.10
VHD	4.53 $\pm$ 0.26	3.90	5.00
HHH	4.48 $\pm$ 0.31	3.90	5.10
APSTDG	3.00 $\pm$ 0.26	2.50	3.40
MLSTDG	3.07 $\pm$ 0.29	2.70	3.70
STCG	9.33 $\pm$ 0.62	8.20	10.80
APSTD	2.62 $\pm$ 0.20	2.30	3.00
MLSTD	2.61 $\pm$ 0.19	2.20	3.00
STC	8.66 $\pm$ 0.68	7.50	9.90
APMSD	2.88 $\pm$ 0.29	2.40	3.50
MLMSD	2.58 $\pm$ 0.24	2.10	3.20
FMSC	8.51 $\pm$ 0.62	7.40	10.00
FEB	7.89 $\pm$ 0.45	6.90	9.00
APDLC	6.43 $\pm$ 0.33	5.70	7.00
APDMC	6.41 $\pm$ 0.42	5.50	7.10
FBCB	7.29 $\pm$ 0.37	6.73	8.26
MCL	6.38 $\pm$ 0.35	5.92	6.82
LCL	6.50 $\pm$ 0.38	6.05	6.98

Values are mean $\pm$ S.D

KEY TO VARIABLE ABBREVIATIONS

FML=Femur maximum length; GTSTG= Greater trochanter -subtrochanteric with gluteal tuberosity; FPB= Femur proximal breadth; PAB= Proximal angled breadth; NVD=Neck vertical diameter; NTD= Neck transverse diameter; VHD=Vertical diameter of head; HHD = Horizontal diameter of head; APSTDG = Anterior-posterior subtrochanteric diameter with gluteal tuberosity; MLSTDG = Medial-lateral subtrochanteric diameter with gluteal tuberosity; STCG = Subtrochanteric circumference with gluteal tuberosity; APSTD = Anterior-posterior subtrochanteric diameter; MLSTD = Medial-lateral subtrochanteric diameter; STC = Subtrochanteric circumference; APMSD = Anterior-posterior diameter at mid-shaft; MLMSD = Medial-lateral diameter at mid-shaft; FMSC = Circumference at mid-shaft; FEB = Femur Epicondylar breadth; APDLC = Anterior Posterior Diameter of the Lateral Condyle; APDMC = Anterior-Posterior Diameter of the medial condyle; FBCB = Measurement of Femur Bi-condylar Breadth; MCL = Medial Condylar Length; LCL = Lateral Condylar Length

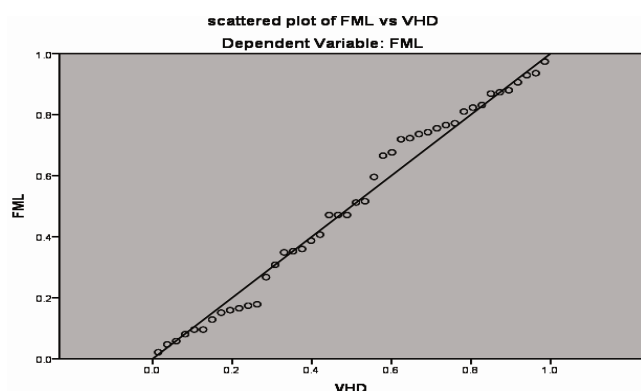


Figure 4: Scatterplot of maximum length of the femur (FML) against the Vertical diameter of Head (VHD)

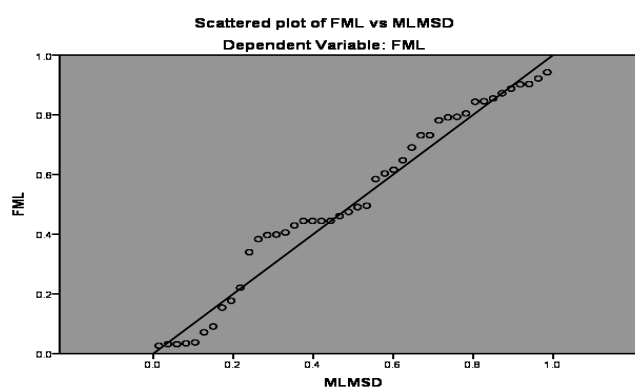


Figure 5: Scatterplot of maximum length of the femur (FML) against the Medial-lateral diameter at mid-shaft (MLMSD)

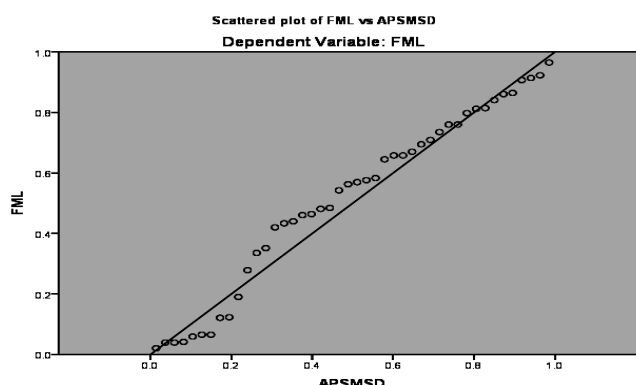


Figure 6: Scatterplot of maximum length of the femur (FML) against the Anterior-posterior diameter at mid-shaft (APMSD) Medial-lateral diameter at mid-shaft (MLMSD)

Table 4: Univariate analysis of the right, left, and both sides of the femur as correlated with the various bony markers

	LEFT				RIGHT				BOTH			
	A	SE	B	P.V	A	SE	B	PV	A	SE	B	P.V
GTSTG	39.038	0.202	9.345	0.001*	24.767	0.603	6.636	0.001*	33.480	0.365	5.488	0.001*
PFB	14.898	0.722	7.032	0.057	34.938	0.398	6.331	0.001*	28.387	0.534	4.654	0.001*
PAB	30.103	0.389	9.300	0.004*	42.233	0.085	12.992	0.004*	34.136	0.264	7.485	0.001*
NVD	38.657	0.331	5.749	0.001*	37.489	0.419	4.722	0.001*	38.625	0.355	3.583	0.001*
NTD	42.423	0.198	5.833	0.001*	39.764	0.362	4.299	0.001*	40.998	0.277	3.440	0.001*
VHD	16.684	0.673	7.637	0.051	22.367	0.663	5.671	0.004*	19.304	0.663	4.899	0.001*
HHD	25.647	0.568	7.113	0.002*	30.02	20.507	6.541	0.001*	28.189	0.531	4.748	0.001*
APSTDG	36.969	0.343	6.545	0.001*	34.347	0.545	4.433	0.001*	35.963	0.432	3.700	0.001*
MLSTDG	39.563	0.281	6.182	0.001*	35.986	0.296	8.114	0.001*	38.100	0.292	4.706	0.001*
STC+G	43.003	0.115	8.914	0.001*	25.340	0.687	5.175	0.002*	32.473	0.421	4.972	0.001*
APSTD	34.180	0.393	7.064	0.001*	30.273	0.524	6.164	0.001*	32.230	0.454	4.603	0.001*
MLSTD	43.621	0.111	8.027	0.001*	45.883	0.047	6.143	0.001*	44.995	0.077	4.810	0.001*
STCG	29.314	0.538	6.440	0.001*	31.711	0.491	6.150	0.001*	30.476	0.520	4.302	0.001*
APMSG	30.840	0.640	4.526	0.001*	30.107	0.709	3.813	0.001*	30.555	0.668	2.908	0.001*
MLMSD	41.725	0.202	6.405	0.001*	38.218	0.373	5.008	0.001*	39.749	0.289	3.921	0.001*
FMSC	34.189	0.368	7.617	0.001*	26.197	0.707	4.713	0.001*	29.768	0.537	4.287	0.001*
FEB	25.831	0.467	9.230	0.011*	28.591	0.549	6.343	0.001*	27.455	0.510	5.201	0.001*
APDLC	10.042	0.729	7.891	0.218	20.572	0.707	5.967	0.003*	16.673	0.712	4.688	0.001*
APDMC	22.964	0.607	7.231	0.005*	25.241	0.652	5.716	0.001*	24.543	0.631	4.348	0.001*
FBCB	48.193	0.01	11.721	0.001*	52.806	-0.072	17.571	0.001*	46.849	0.019	8.428	0.001*
MCL	43.171	0.092	10.825	0.001*	38.425	0.270	7.482	0.001*	44.709	0.059	6.979	0.001*
LCL	42.262	0.118	10.067	0.001*	40.002	0.151	6.493	0.023*	43.542	0.068	8.677	0.001**

Significant at $p < 0.05$; values are mean $\pm$ S.D; SE = Standard error; PV = p value*

KEY TO VARIABLE ABBREVIATIONS

FML= Femur maximum length; GTSTG= Greater trochanter -subtrochanteric with gluteal tuberosity; FPB= Femur proximal breadth; PAB= Proximal angled breadth; NVD= Neck vertical diameter; NTD= Neck transverse diameter; VHD= Vertical diameter of head; HHD = Horizontal diameter of head; APSTDG = Anterior-posterior subtrochanteric diameter with gluteal tuberosity; MLSTDG = Medial-lateral subtrochanteric diameter with gluteal tuberosity; STCG = Subtrochanteric circumference with gluteal tuberosity; APSTD = Anterior-posterior subtrochanteric diameter; MLSTD = Medial-lateral subtrochanteric diameter; STC = Subtrochanteric circumference; APMSD = Anterior-posterior diameter at mid-shaft; MLMSD = Medial-lateral diameter at mid-shaft; FMSC = Circumference at mid-shaft; FEB = Femur Epicondylar breadth; APDLC = Anterior-Posterior Diameter of the Lateral Condyle; APDMC = Anterior-Posterior Diameter of the medial condyle; FBCB = Measurement of Femur Bi-condylar Breadth; MCL = Medial Condylar Length; LCL = Lateral Condylar Length

When both the left and right side parameters of a particular bony marker obtained were combined to form a single predictor parameter for each bony marker, the regression equations were obtained for both left and right femur for each of the correlated parameter.

The dimensions APMSD, APDLC, VHD, APDMC and FPB of the left femur showed a significant positive correlation with the length of the femur ($p < 0.05$). For the right femur APMSD, FMSC, APDLC, STCG, VHD, APDMC, GTSTG, FEB, APSTDG shows a significant correlation with the length of the femur ($p < 0.05$). For both side, GTSTG, FPB, VHD, HHD, APSTD, APMSD, FMSC, FEB, APDLC and APDMC showed a significant correlation with the length of the femur.

Multiple linear regression models were developed

using stepwise method after the exclusion of highly correlated bony markers. The dimension VHD was the best marker for predicting the length of the femur on the right side. For the right femur, dimensions FEB and MLMSD were the best markers to predict the length of femur by multivariate analysis. For the femur of both sides, the APMSD, STC and MLMSD were the best bony marker to predict the length of the femur (Table 6).

The multivariate linear regression equations to identify the dimension that best predicted the length of radius are given thus:

$$\text{RIGHT FML} = 22.367 + 5.671\text{VHD}$$

$$\text{LEFT: } L = 17.322 + 3.541\text{FEB} + 1.631\text{MLMSD}$$

$$\text{BOTH } L = 12.841 + 2.281\text{APSMG} + 2.442\text{STCG} + 2.648\text{MLMSD}$$

Table 5: Summary of simple regression equations derived for right, left, and both Sides of the femur, relating maximum Femoral Length (FML) with the bony markers

LEFT	RIGHT	BOTH
L=39.038+9.345GTSTG	L=24.767+6.636GTSTG	L=33.480+5.488GTSTG
L=30.103+(9.300PAB	L=34.938+6.331FBB	L=28.387+4.654PFB
L=38.657+5.749NVD	L=42.233+12.992PAB	L=34.136+7.485PAB
L=42.423+5.833NTD	L=37.489+4.722NVD	L=38.625+3.583NVD
L=25.647+7.113HHD	L=39.764+4.299NTD	L=40.998+3.440NTD
L=36.969+6.545APSTDG	L=22.367+5.671VHD	L=19.304+4.899VHD
L=39.563+6.182MLSTDG	L=30.022+6.541HHD	L=28.189+4.748HHD
L=43.003+8.914STCG	L=34.347+4.433APSTDG	L=35.963+3.700APSTDG
L=34.180+7.064APSTD	L=35.986+8.114MLSTDG	L=38.100+4.706MLSTDG
L=43.621+8.027MLSTD	L=25.340+5.175STC+G	L=32.473+4.972STC+G
L=29.314+6.440STC	L=30.273+6.164APSTD	L=32.230+4.603APSTD
L=30.840+4.526APMSD	L=45.883+6.143MLSTD	L=44.995+4.810MLSTD
L=41.725+6.405MLMSD	L=31.711+6.150STC-G	L=30.476+4.302STC-G
L=34.189+7.617FMSC	L=30.107+3.813APMSD	L=30.555+2.908APSMG
L=25.831+9.230FEB	L=38.218+5.008MLMSD	L=39.749+3.921MLMSD
L=22.964+9.231APDMC	L=26.197+4.713FMSC	L=29.768+4.287FMSC
L=48.193-11.721FBCB	L=28.591+6.343FEB	L=27.455+5.201FEB
L=43.171+10.825MCL	L=20.572+5.967APDLC	L=16.673+4.688APDLC
L=42.262+10.067LCL	L=25.241+5.716APDMC	L=24.543+4.348APDMC
	L=52.806-17.571FBCB	L=46.849+8.428FBCB
	L=38.425+7.482MCL	L=44.709+6.979MCL
	L=40.002+6.492LCL	L=43.542+8.677LCL

Table 6: Summary of stepwise regression analysis to identify the best marker for predicting FML for right, left and both sides

	Variable	Model	Standard Error	PValue	Number of Bones
BOTH	CONSTANT	12.841	0.942	0.035	44
	APSMG	2.281	0.863	0.009	44
	STC	2.442	0.622	0.018	44
	MLMSD	2.648	1.021	0.032	44
LEFT	FEB	3.541	0.533	0.010	22
	MLMSD	1.631	0.499	0.026	22
RIGHT	VHD	5.671	0.663	0.004	22

DISCUSSION

The femur articulates proximally with the acetabulum of the hip bone to form the hip joint and distally with tibia by its condyles to form the knee joint. Lundy and Feldesman[23] and Trotter and Gleser[24] previously recommended that all formulae used to estimate stature should be population specific. Thus, the regression formulae presented in the present study describe specifically the south-west Nigerian population, although their relevance for comparison with those of other populations in forensic anthropology and human anatomy are obvious. The maximum femoral length estimates obtained using the formulae derived from the present study represent, in all probability, the first reported data from this section of the Nigerian population.

Previous studies have estimated the living stature from the humeral length in the absence of more appropriate long bones as the femur or the tibia.[11] Some studies have also shown that femoral length estimates provide the most reliable predictive models among all long bone irrespective of age with respect to stature estimates of a given population. [13,14,25]

While regression analysis, as a valid method for correlating length of long bones with living stature of individuals and predicting maximum bone length from fragment dimensions is fundamental to forensic anthropology, [26] within-population diversity remains a major confounder of the applicability and interpretation of regression models. Clearly the linear regression models derived from the various studies for predicting maximum length of long bones from measurement of its fragments must necessarily be population specific.[27-32]

In the current study, APMSD, APDLC, VHD, APDMC and FPB of the left femur showed a significant correlation with the length of the femur ($p < 0.05$). For the right femur APMSD, FMSC, APDLC, STCG, VHD, APDMC, GTSTG, FEB, APSTDG, shows a significant correlation with the length of the femur ($p < 0.05$). For the both side, GTSTG, FPB, VHD, HHD, APSTD, APMSD, FMSC, FEB, APDLC and APDMC showed a significant correlation with the length of the femur. Linear and multiple regressions equations were derived from all the correlated bony markers ($p < 0.05$). The best correlated linear regression equations to femoral maximum length was later derived from one landmark of the right femur (VHD), two landmarks on the left femur (FEB and MLMSD) and three bony markers from combined analysis irrespective of the sides (APMSD, STC, and MLMSD).

After formulating the regression equations, the FML was estimated from the linear regression equations and compared with the observed measurements and the differences were noted. The accuracy of linear regression equation was found to be +1.96 to -3.5 for the left femur, +2.38 to -1.6 for right femur, +2.24 to -2.2 (table 10-12). The regression equation derived for the right femur produced less error compared to the remaining two equations and should therefore be used as preference to estimate FML.

The maximum length of femur can be used to estimate the stature of an individual from the regression equations, conversion tables and multiplying factors that are used in forensic anthropometry. Though various factors such as age, sex and ethnicity have to be borne in mind when estimating the stature of an individual, the statistically highly

significant formulae provide a means for establishing the stature of an individual with adequate accuracy. The greatest accuracy in estimating living stature from long bones length will be obtained when sex and ethnic identity are available. Thus it is possible to estimate stature of individuals from the femoral fragments with reasonable accuracy by these regression equations in South west Nigerian population. Necessary correction for soft tissue can be made to obtain the living stature in practical cases of forensic interest in a population specific geographic area. The results are reliable, but further works need to be designed to get more accurate estimates in a larger sample considering the age factor as well. It can be considered as a pilot study in obtaining the regression equation to estimate the maximum femoral length from femoral fragments in a population specific sample.

CONCLUSION

The results of this study concludes that it is possible to estimate the maximum length of the femur from the measures of one marker on the right femur (VHD), two landmarks on the left femur (FEB and MLMSD) and three bony markers from combined analysis irrespective of the sides (APMSD, STC, and MLMSD).

Such an estimate of femur length and stature has potential application in physical and forensic anthropology. This study is valuable in forensic, anthropometric and also archaeological investigations for the identification of the remains of unknown bodies using regression equations in a Nigerian Population.

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Declaration

We wish to declare that there is no conflict of interest with this documentation.

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