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Stature Prediction from Toe and Finger Lengths among adult Kalabaris: an indigenous population of South-Southern Nigeria

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ABSTRACT

Physical anthropometry is relevant towards the advancement of biological anthropology. The aim of this study was to predict stature from the digit and toe lengths of adult Kalabari people of South-Southern Nigeria. This was a cross-sectional and descriptive study. 142 Kalabari adult subjects (72 males and 70 females) between the ages of 18 – 45 were consented and linear parameters such as height (stature), toe and finger (digit) length for both hands were obtained using stadiometer and metre rule.All collected data were analyzed using STATA statistical software version 12.The means of digit and toe length parameters were higher in males compared to females. A moderate positive relationship between stature and digit length in both sexes compared to toe length (at p < 0.05) was seen. For males, simple regression equations developed for R2D, R4D, L2D and L4D were -0.089 + 0.212 x R2D, 0.106 + 0.181 x R4D; 0.05 + 0.198 x L2D; and 0.247 + 0.167 x L4D, respectively. While R2T, R4T, L2T and L4T were 1.129 + 0.128 x R2T, 1.429 + 0.102 x R4T; 1.12 + 0.127 x L2T; and 1.444 + 0.094 x L4T, respectively. For females, simple regression equations developed for R2D, R4D, L2D and L4D were 0.681 + 0.116 x R2D, -0.221 + 0.218 x R4D; 0.281 + 0.168 x L2D; -0.376 + 0.239 x L4D, respectively. While R2T, R4T, L2T and L4T were 0.748 + 0.208 x R2T; 1.374 + 0.109 x R4T; 0.782 + 0.199 x L2T; 1.46 + 0.068 x L4T, respectively.Conclusively, both digit and toe lengths could predict the stature of the Kalabari adult population. Linear regression formulas can serve as forensic guides towards their identification.

Keywords*: Physical anthropometry, biological anthropology, stature, digit length, toe length.*

INTRODUCTION

Prediction of stature of an individual is an important aspect of forensic examinations and anthropological studies. Stature provides important evidence in the forensic investigation process to the establishment of personal identification. Anthropologists have always been of particular interest to assess the stature of an individual from different dimensions of the body and bones. However, different parts of the body and stature differ between human populations (Zaher et al., 2011; Raxter et al., 2018). A study by Agnihotri et al. (2007) reported that foot length is arelevant tool in the prediction of stature among Indo-Mauritians. Another similar study conducted on a particular Sudanese population as reported by Ahmed (2013),suggested that tibial length and foot length were highly significant in the estimation of stature.

Previous studies have been reported on the linear correlation between stature and body parts such as toe and finger lengths in various Caucasian and Mongoloid populations. Rastogi et al (2009) carried out a study on an Indian population to estimate stature using middle finger length. Another study by Habib and Kamal (2010) reported on the application of predictive regression models has been used by anthropologists to accurately predict stature using anthropometric measurements of body parts such as foot length and breadth (Kanchan et al., 2008; Sen and Ghosh, 2008; Ibeabuchi et al., 2018). With reference to morphological differences in sexual dimorphism, studies have been able to establish that the males have higher anthropometric dimensions compared to the females (Sen and Ghosh, 2008; Alabi et al., 2017; Ibeabuchi et al., 2018). Thus, the present study was carried out to predict stature from the digit and toe lengths of adult Kalabari people of South-Southern Nigeria. The Kalabari ethnic group belongs to a major part of the Ijaw tribe found in the Niger-Delta region of Nigeria (Wariboko, 1999).

MATERIALS AND METHODS

This was a cross-sectional, descriptive study. A calculated sample size of 142 Kalabari adult subjects (72 males and 70 females) was obtained using the Cochran sample size formula. The inclusion criteria for selection of participants were; all subjects were in the age range of 18 – 45 years and without any history of surgical operations on their limbs. After obtaining ethical approval from the University of Port Harcourt Research Ethics Committee, both primary and secondary data were obtained from these subjects. Biological profile such as age and sex represented the primary data while measurements such as finger (digit) and toe lengths, as well as height were the secondary data. The linear measurements obtained from subjects in this study were as follows;

- **Second toe length:** This is the measurement of the second toe from its crown to the region of the last phalangeal joint of the toe (Figure 1). This measurement was obtained using the digital vernier caliper.
- **Fourth toe length:** This is the measurement of the fourth toe from its crown to the region of the last phalangeal joint of the toe (Figure 2). This measurement was obtained using the digital vernier caliper. Both toe lengths were measured in line with Paul et al. (2018).
- **Second digit length:** This is the measurement of the second finger (thumb) from its crown to the region of the last phalangeal joint of the finger (Figure 3). This measurement was obtained using the digital vernier caliper.
- **Fourth digit length:** This is the measurement of the fourth finger from its crown to the region of the last phalangeal joint of the finger (Figure 4). This measurement was obtained using the digital vernier caliper. Both digit lengths were taken in line with Kumar et al. (2017).
- **Height (stature):** Stature is defined as the height of the individual (Figure 5). It is measured from the crown of the head to the sole of the feet with the aid of a stadiometer. Stature measurement was obtained in line with the protocol as reported by Oghenemavwe and Egwede (2022).

To test for reliability of the instruments, these measurements were obtained two times and the average score was calculated from them. All instruments were validated by calibrating them to 0.01m. The finger and toe lengths were obtained from both feet of a particular subject.

Figure 1. Second toe length

Figure 2. Fourth digit length

Figure 3. Second digit length

Figure 4. Fourth digit length

Figure 5. Stature (Height)

Statistical Analysis: Data obtained from this study were analyzed using STATA statistical software version 12. A Pearson's correlation coefficient was used to analyze relationships between stature and selected anthropometric measurements: toe lengths, and digit lengths for both sexes. Linear regression analyses were applied to analyze the relationship between stature and toe lengths and digit lengths. A statistical significance level of 0.05 was used. The results were expressed in means ± standard deviations and presented in tabular form.

RESULTS

Tables 1 and 2 showed the descriptive statistics for finger lengths of both hands in males, as well as the descriptive statistics for toe lengths of both toes in males. In table 1, the mean and standard deviation of the linear digit parameters such as R2D, R4D, L2D, and L4D were 8.41±0.43cm, 8.78±0.43cm, 8.33±0.42cm, and 8.68±0.39cm respectively. The mean value of the height of Kalabari males was 1.70±0.15m. Table 2 shows the mean and standard deviation of R2T, R4T, L2T, and L4T were 4.45±0.70cm, 2.61±0.63cm, 4.55±0.68cm, and 2.68±0.62cm, respectively.

Table 1: Descriptive statistics for finger lengths of both hands (in males)

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
R2D	72	8.41	0.43	7.21	9.00
R4D	72	8.78	0.43	7.48	9.72
L2D	72	8.33	0.42	7.18	8.99
L4D	72	8.68	0.39	7.61	9.20
Height	72	1.70	0.15	1.44	2.2

Note: (R2D = Right second digit, R4D = Right fourth digit, L2D = Left second digit, L4D = Left fourth digit).

Table 2: Descriptive statistics for toe lengths of both toes (in males)

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
R2T	72	4.45	0.70	3.00	6.11
R4T	72	2.61	0.63	1.56	4.09
L2T	72	4.55	0.68	2.99	6.09
L4T	72	2.68	0.62	1.54	4.11

Note: (R2T = Right second toe, R4T = Right fourth toe, L2T = Left second toe, L4T = Left fourth toe)

Tables 3 and 4 showed descriptive statistics for finger lengths of both hands and heights in females and descriptive statistics for toe lengths of both toes in females, respectively. As shown in table 3, the mean and standard deviation of the linear digit parameters such as R2D, R4D, L2D, and L4D was 8.01±0.45cm, 8.4±0.33cm, 7.94±0.38cm, and 8.30±0.32cm respectively. The mean value of the height of Kalabari females was 1.61±0.1m. While table 4 shows the mean and standard deviation of R2T, R4T, L2T, and L4T were 4.15±0.41cm, 2.20±0.48cm, 4.18±0.41cm, and 2.26±0.57cm, respectively.

Table 3: Descriptive statistics for finger lengths of both hands and height (in females)

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
R2D	70	8.01	0.45	7	8.94
R4D	70	8.4	0.33	7.97	9.13
L2D	70	7.94	0.38	7	8.69
L4D	70	8.30	0.32	7	9.06
Height	70	1.61	0.1	1.37	1.82

Note: (R2D = Right second digit, R4D = Right fourth digit, L2D = Left second digit, L4D = Left fourth digit)

Table 4: Descriptive statistics for toe lengths of both toes (in females)

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
R2T	70	4.15	0.41	2.98	5.03
R4T	70	2.20	0.48	1.32	3.63
L2T	70	4.18	0.41	3	5.06
L4T	70	2.26	0.57	1.68	4.98

Note: (R2T = Right second toe, R4T = Right fourth toe, L2T = Left second toe, L4T = Left fourth toe)

Table 5 shows the Pearson's linear relationship between height and the finger length variables for male category. Thus, the Pearson's correlation coefficient of the linear relationship between Height and digit lengths are; (R2D; r =0.5949 at p=0.0000), (R4D; r = 0.5085 at p=0.0001), (L2D; r = 0.5389 at p=0.0000) and (L4D; r = 0.4245 at p=0.0000). Generally, there was a statistical moderate positive relationship between height and digit lengths (p<0.05)

Table 5: Pearson correlation analysis among finger variables for male category

Variable	Test statistic	Height	R2D	R4D	L2D	L4D
Height	r	1.0000				
	p	0.0000				
R2D	r	0.5949*	1.0000			
	p	0.0000				
R4D	r	0.5085*	0.8746*	1.0000		
	p	0.0001	0.0000			
L2D	r	0.5389*	0.7929*	0.6966*	1.0000	
	p	0.0000	0.0000	0.0000		
L4D	r	0.4245*	0.7741*	0.7542*	0.7824*	1.0000
	p	0.0000	0.0000	0.0000	0.0000	

Note: R2D = Right second digit, R4D = Right second digit, L2D = Left second digit, L4D = Left fourth digit, * signifies statistical significance at p < 0.05

Table 6 shows the Pearson's linear relationship between height and the finger length variables for male category. Thus, the Pearson's correlation coefficient of the linear relationship between Height and digit lengths are; (R2T; r = 0.5811 at p = 0.0000), (R4T; r = 0.4223 at p = 0.0001), (L2T; r = 0.5632 at p = 0.0000) and (L4T; r = 0.3796 at p = 0.0000). Generally, there was a statistically positive relationship between Height and toe lengths (p<0.05).

Table 6: Pearson correlation analysis among toe variables for male category

Variable	Test statistic	Height	R2T	R4T	L2T	L4T
Height	r	1.0000				
	p	0.0000				
R2T	r	0.5811*	1.0000			
	p	0.0000				
R4T	r	0.4223*	0.6051*	1.0000		
	p	0.0001	0.0000			
L2T	r	0.5632*	0.9741*	0.6078*	1.0000	
	p	0.0000	0.0000	0.0000		
L4T	r	0.3796*	0.5628*	0.9633*	0.5866*	1.0000
	p	0.0000	0.0000	0.0000	0.0000	

Note: R2T = Right second toe, R4T = Right second toe, L2T = Left second toe, L4T = Left fourth toe, * signifies statistical significance at p < 0.05

Table 7 depicts the simple regression table that gives the fitted model. The coefficients of slope and y-intercept make up the parameters of the fitted model. For R2D, the coefficient of slope is 0.212 while the y-intercept is -0.089. Thus, our regression equation for **R2D** is approximately predicted; Height (m) = -0.089 + 0.212 x R2D. Therefore, the regression equations for other linear parameters are as follows;**R4D**; Height (m) = 0.106 + 0.181 x R4D; **L2D**; Height (m) = 0.05 + 0.198 x L2D; **L4D**; Height (m) = 0.247 + 0.167 x L4D

Table 7: Simple regression table for height estimation showing the fitted model for each digit variable (in males)

Variable	Linear regression equations	F	Prob> F	R^2	Adjusted R^2	Root MSE
R2D	-0.089 + 0.212 x R2D	38.34	0.000	0.354	0.345	0.124
R4D	0.106 + 0.181 x R4D	24.41	0.000	0.259	0.248	0.133
L2D	0.05 + 0.198 x L2D	28.65	0.000	0.290	0.280	0.130
L4D	0.247 + 0.167 x L4D	15.38	0.000	0.180	0.169	0.140

R2D = Right second digit, R4D = Right second digit, L2D = Left second digit, L4D = Left fourth digit, Root MSE = Root Mean Square Error, R^2= coefficient of determination

Table 8 depicts the simple regression table that gives the fitted model. The coefficients of slope and y-intercept make up the parameters of the fitted model. For R2T, the coefficient of the slope is 0.128 while the y-intercept is 1.129. Thus, our regression equation for **R2T** is approximately predicted; Height = 1.129 + 0.128 x R2T. Therefore, the regression equations for other linear parameters are as follows;**R4T**; Height (m) = 1.429 + 0.102 x R4T; **L2T**; Height (m) = 1.12 + 0.127 x L2T; **L4T**; Height (m) = 1.444 + 0.094 x L4T

Table 8: Simple regression table for height estimation showing the fitted model for each toe variable (in males)

Variable	Linear regression equations	F	Prob> F	R^2	Adjusted R^2	Root MSE
R2T	1.129 + 0.128 x R2T	35.69	0.000	0.338	0.328	0.126
R4T	1.429 + 0.102 x R4T	15.2	0.000	0.178	0.167	0.140
L2T	1.12 + 0.127 x L2T	32.51	0.000	0.317	0.307	0.128
L4T	1.444 + 0.094 x L4T	11.78	0.001	0.144	0.132	0.143

R2T = Right second toe, R4T = Right second toe, L2T = Left second toe, L4T = Left fourth toe, Root MSE = Root Mean Square Error, R^2 = coefficient of determination

Table 9 shows the linear relationship between height, R2D, R4D, L2D, and L4D in order to know whether any of the correlation coefficients from this relationship describes how well the best-fitting line fits. Thus, the Pearson's correlation coefficient of the linear relationship between Height and digit lengths are; (R2D; r = 0.5244 at p=0.0000), (R4D; r = 0.7303 at p=0.0000), (L2D; r = 0.6325 at p=0.0000) and (L4D; r = 0.7675 at p=0.0000). Generally, there was a statistical moderate positive relationship between height and the digit lengths (p<0.05)

Table 9: Pearson correlation analysis among finger variables for female category

Variable	Test statistic	Height	R2D	R4D	L2D	L4D
Height	r	1.0000				
	p	0.0000				
R2D	r	0.5244*	1.0000			
	p	0.0000				
R4D	r	0.7303*	0.7266*	1.0000		
	p	0.0000	0.0000			
L2D	r	0.6325*	0.8964*	0.7190*	1.0000	
	p	0.0000	0.0000	0.0000		
L4D	r	0.7675*	0.5454*	0.8567*	0.6642*	1.0000
	p	0.0000	0.0000	0.0000	0.0000	

Note: R2D = Right second digit, R4D = Right second digit, L2D = Left second digit, L4D = Left fourth digit, * signifies statistical significance at p < 0.05

Results from table 10 show the linear relationship between Height, R2T, R4T, L2T and L4T in order to know whether any of the correlation coefficient from this relationship describes how well the best-fitting line fits. Thus, the Pearson's correlation coefficient of the linear relationship between Height and toe lengths are; (R2T; r = 0.8621 at p = 0.0000), (R4T; r = 0.5185 at p = 0.0000), (L2T; r = 0.8252 at p = 0.0000) and (L4T; r = 0.3876 at p = 0.009).

Table 10: Pearson correlation analysis among toe variables for female category

Variable	Test statistic	Height	R2T	R4T	L2T	L4T
Height	r	1.0000				
	p	0.0000				
R2T	r	0.8621*	1.0000			
	p	0.0000				
R4T	r	0.5185*	0.6109*	1.0000		
	p	0.0000	0.0000			
L2T	r	0.8252*	0.9753*	0.6067*	1.0000	
	p	0.0000	0.0000	0.0000		
L4T	r	0.3876*	0.5035*	0.7657*	0.4752*	1.0000
	p	0.0091	0.0001	0.0000	0.0003	

Note: R2T = Right second toe, R4T = Right second toe, L2T = Left second toe, L4T = Left fourth toe, * signifies statistical significance at p < 0.05

Table 11 depicts the simple regressional table that gives the fitted model. The coefficients of slope and y-intercept make up the parameters of the fitted model. For R2D, the coefficient of the slope is 0.116 while the y-intercept is 0.681. Thus, our regression equation for **R2D** is approximately predicted as; Height (m) = 0.681 + 0.116 x R2D. Therefore, the regression equations for other linear parameters are as follows;**R4D**; Height (m) = -0.221 + 0.218 x R4D; **L2D**; Height (m) = 0.281 + 0.168 x L2D; **L4D**; Height (m) = -0.376 + 0.239 x L4D

Table 11: Simple regression table for height estimation showing the fitted model for each digit variable (in females)

Variable	Linear regression equations	F	Prob> F	R^2	Adjusted R^2	Root MSE
R2D	0.681 + 0.116 x R2D	25.8	0.000	0.275	0.264	0.086
R4D	-0.221 + 0.218 x R4D	77.7	0.000	0.533	0.527	0.069
L2D	0.281 + 0.168 x L2D	45.4	0.000	0.400	0.391	0.078
L4D	-0.376 + 0.239 x L4D	97.5	0.000	0.589	0.583	0.064

R2D = Right second digit, R4D = Right second digit, L2D = Left second digit, L4D = Left fourth digit, Root MSE = Root Mean Square Error, R^2= coefficient of determination

Table 12 depicts the simple regression table that gives the fitted model. The coefficients of slope and y-intercept make up the parameters of the fitted model. For R2T, the coefficient of slope is 0.208 while the y-intercept is 0.748. Thus, our regression equation for **R2T** is approximately predicted; Height = 0.748 + 0.208 x R2T. Therefore, the regression equations for other linear parameters are as follows;**R4T**; Height (m) = 1.374 + 0.109 x R4T; **L2T**; Height (m) = 0.782 + 0.199 x L2T; **L4T**; Height (m) = 1.46 + 0.068 x L4T

Table 12: Simple regression table showing the fitted model for each toe variable (in females)

Variable	Linear regression equations	F	Prob> F	R^2	Adjusted R^2	Root MSE
R2T	0.748 + 0.208 x R2T	196.79	0.000	0.743	0.739	0.051
R4T	1.374 + 0.109 x R4T	25.01	0.000	0.269	0.258	0.086
L2T	0.782 + 0.199 x L2T	145.12	0.000	0.681	0.676	0.057

L4T	1.46 + 0.068 x L4T	12.02	0.001	0.15	0.138	0.093

R2T = Right second toe, R4T = Right second toe, L2T = Left second toe, L4T = Left fourth toe,Root MSE = Root Mean Square Error, R^2= coefficient of determination

DISCUSSIONS

The present study was carried out to predict stature from the digit and toe lengths of adult Kalabari people of South-Southern Nigeria.In both male and female categories, there was a statistically moderate positive relationship between height (stature) and the digit lengths ($p<0.05$). For the males, the various correlation coefficients are; R2D (r =0.5949 at p=0.0000), R4D (r = 0.5085 at p=0.0001), L2D (r = 0.5389 at p=0.0000) and L4D (r = 0.4245 at p=0.0000). For the females, the various correlation coefficients were; R2D (r = 0.5244 at p=0.0000), R4D (r = 0.7303 at p=0.0000), L2D (r = 0.6325 at p=0.0000) and L4D (r = 0.7675 at p=0.0000). This is in concordance with related studies done across several populations (Rastogi et al., 2009; Ekezie et al., 2015; Oladipo et al., 2016). However, just like these studies, there was a stronger positive correlation in the males compared to the females.

A linear regression model was developed from this study to attest to the reliability of the data obtained from the sample population. In this study, both the simple and multiple regression equations were derived from the study population. It was observed that in both the linear and multiple regression equations that were derived from this study, the calculated estimated mean height (stature) for both sexes was almost the same as the actual stature mean. It was observed that the accuracy of predicted stature estimation from digit lengths in both regression models was significantly accurate for both males and females. This is in agreement with Ekezie et al (2015) and Oladipo et al(2016)

Several studies on the estimation of stature using foot measurements have shown the human feet to be reliable in the forensic identification of human remains (Ozdenet al., 2005; Krishan and Sharma, 2007; Kanchan et al., 2008; Zeybeket al., 2008; Krishanet al., 2011; Ekezieet al., 2014; Ibeabuchi et al., 2018). The application of predictive regression models has been used by anthropologists to accurately predict stature using anthropometric measurements of body parts such as foot length and breadth (Kanchan et al., 2008; Ibeabuchi et al., 2018; Paul et al., 2018). However, this study was objective towards estimating stature using toe lengths of adult Nigerian Kalabari population.

After comparing the level of correlations between stature and toe lengths for both sexes in this study, it was observed that although there were significant positive relationships between them for both sexes, the females had a higher significant positive correlation between height and toe lengths, especially the second toe lengths for both right and left foot (R2T; r = 0.8621 at p = 0.0000 and L2T; r = 0.8252 at p = 0.0000). The males had a correlation coefficients between height and second toe lengths (R2T; r = 0.5811 at p = 0.0000 and L2T; r = 0.5632 at p = 0.0000). This could be due to the fact that males tend to grow variably in their tarsal bone lengths compared to females.

CONCLUSIONS

It can be conclusively stated that both digit and toe lengths are statistically relevant in the prediction of the stature of the Kalabari adult population. The linear regression formula can serve as a forensic guide towards the physical identification of possible Kalabari subjects in cases of crime, disaster, and other forensics-related issues.

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AUTHORS' CONTRIBUTIONS

The first author designed the study, wrote its protocol and the first manuscript, while the second and third authors managed the literature research, assisted in collection of data and statistical analysis. All authors read and approved the final manuscript for submission.

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