International Journal of Contemporary Pediatrics
Okumoko MA et al. Int J Contemp Pediatr. 2024 Jun;11(6):648-656
http://www.ijpediatrics.com
pISSN 2349-3283 | eISSN 2349-3291

DOI: https://dx.doi.org/10.18203/2349-3291.ijcp20241343

Original Research Article

The use of foot length and foot breadth in estimating standing height of adolescents in Yenagoa, Nigeria

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Received: 15 April 2024
Revised: 15 May 2024
Accepted: 20 May 2024

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ABSTRACT

Background: Previous studies have shown that when standing height is difficult to measure, the length of other body parts may be a reliable alternative. However, there is limited information about the use of foot length (FL) and foot breadth (FB) in estimating standing height in the African population. The objective of this study was to investigate the appropriateness of foot length and foot breadth in estimating standing height of adolescents in Yenagoa.
Methods: Using a multistage sampling technique, 1222 adolescents were recruited from secondary schools in the Yenagoa local government area. Height, foot length, and foot breadth were measured using standard techniques. Data was analysed and equations for prediction of standing height from foot length and foot breadth, were derived.
Results: The mean standing height of the females was significantly lower than that of males ($p<0.001$). The mean foot length and mean foot breath for males were significantly higher than those for females. The mean foot length and mean foot breadth were found to increase across all the stages of adolescence. There was a significant positive correlation between standing height and foot length ($r=0.700$; $p<0.001$), foot breadth ($r=0.543$; $p<0.001$), and age ($r=0.369$; $p<0.001$). Multiple linear regression was used to derive equations for the estimation of FL and FB.
Conclusions: This study found that FL and FB can be used in the estimation of standing height. For adolescents in Yenagoa, the equations derived are recommended for predicting the standing height of those who have difficulty standing upright.

Keywords: Estimation, Adolescence, Height, Foot length, Foot breadth, Nigeria

INTRODUCTION

Dimensional relationship between the body segments and the whole body have been of interest to artists, medical scientists, anatomists, anthropologists, and medico-legalists for a long time.[1] Anthropometric measurements and indices such as weight, weight-for-height/length, and mid-upper arm circumference are also frequently used to evaluate malnutrition in resource-poor clinical settings.[2]

Standing height responds the most to long term change in nutrition and is a vitally important variable in Paediatric practice because it can be used to assess nutritional status and the growth of children, evaluate the basic energy requirements, as well as in adjusting and predicting drug dosage.[2-5] However, according to Quanjer et al the exact standing height cannot always be measured in the traditional way in critically ill children, who cannot stand erect, in individuals with paralysis, fractures and amputations of the lower limbs, spinal deformities (scoliosis, kyphosis, lordosis) and various kinds of pain especially lower back pain.[6] In such individuals, an estimate of standing height is the alternative using other reliable anthropometric indices such as sitting height, skull and facial measurements as well as foot length and foot breadth.[7-9]

In different parts of the world, many studies, mostly on adult populations, have used anthropometric parameters to estimate standing height viz; standing height to foot length ratio, standing height to sitting height ratio, and standing height to tibia length ratio.[2,8-10] Many old methods of estimating stature are limited to measuring whole limb bone length and comparing with stature. Qamra et al, in 1990, carried out a study on the reconstruction of height from foot measurements in an adult population in North-West Indians, and reported that foot length (FL) or foot breadth (FB) correlated significantly with standing height.[11] However, this correlation was less accurate in FB compared to FL.

Factors like ethnicity, race, and nutrition play important roles in human growth and development and also influence the variation in physical growth of individuals from place to place. There is thus, the need for population-specific nomograms for different races or ethnic groups.[3-5,9] This study therefore aims to investigate the appropriateness of estimating standing height, using FL and FB.

METHODS

This was an analytical cross- sectional study carried out from October 2021-February 2022, among 1222 adolescents aged 10-19 years, living in and attending secondary schools located within Yenagoa local government area, Bayelsa State, Nigeria.

Ethical approval was obtained from the Ministry of Education, Ministry of Health as well as the Research and Ethics Committee of the Niger Delta University Teaching Hospital (NDUTH), Okolobiri.

Inclusion criteria

Adolescents aged 10-19 years attending public or private secondary schools in Yenagoa were included.

Exclusion criteria

Adolescents with following criteria were excluded (a) foot anomalies e.g., talipes equinovarus and high arched feet; (b) with spinal/lower limb deformities; and (c) with history of foot and/or spine trauma or surgery.

A pretested, validated and structured questionnaire was administered to the recruited participants to obtain information on sociodemographic characteristics of the participants and, factors that may affect height and foot measurements. Before taking the measurements of the foot, the participant was made to sit upright on a chair, the shoe and sock removed from the foot to be measured and the foot placed on a low stool. FL was measured with a non-elastic flexible measuring tape, as the maximum distance from the most prominent posterior point of the heel to the tip of the longest toe (Figure 1a).[12] FB was measured as the maximum distance between the most prominent point on the head of the first metatarsal and on the head of the fifth metatarsal, using a Vernier calliper (RDDC 708, 200 mm/8-inch digital model) (Figure 1b).[12]

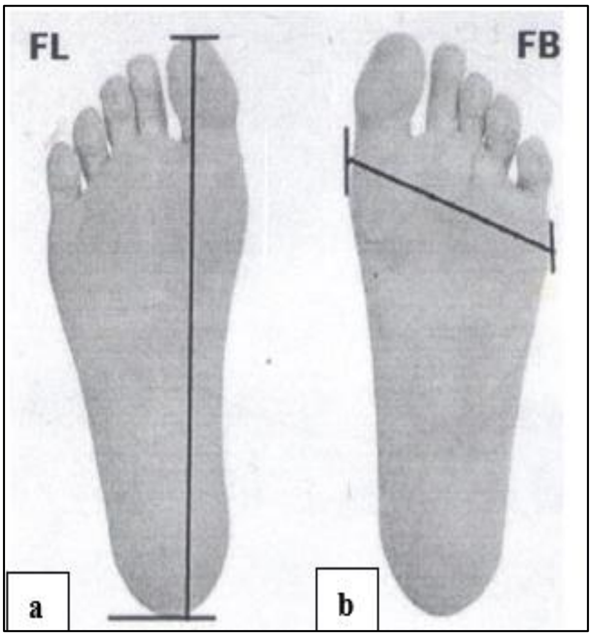

Figure 1: (a) Measurement of foot length (FL); and (b) measurement of foot breadth (FB).[12]

Standing height (SH) of each subject was measured to the nearest 0.1 cm using a portable Stadiometer, SECA model 220. The subject was made to stand with shoes off, with both feet together flat on the board and the back flattened against the measuring stand. The knees were straightened and the heels touching the back of the board. The head was positioned so that the eye sockets were at the same level as the external auditory meatus (Frankfurt plane). The head piece was then lowered on top of the subject's head and the measurement was read off to the nearest 0.1 cm.[5]

The SPSS computer software package version 25 was used for analysis. The Shapiro-Wilk test for normality showed that the data was normally distributed with the level of significance set at $p \leq 0.05$. Frequencies and percentages were calculated for categorical variables, while mean and standard deviation were calculated to identify the central tendencies and dispersion of the anthropometric variables. Using linear regression analysis, models (equations) defining the relationship between height and foot length and foot breadth respectively were generated.

Pearson's correlation coefficient was calculated to elicit the correlation between height and foot length and height and foot breadth. Analysis of variance (ANOVA) and t test were used to compare means. Chi-square test was used to test association between categorical independent variables and the dependent variables in the study.

RESULTS

As shown in Table 1, there were 547 (44.8%) males and 675 (55.2%) females giving a male to female ratio of 1:1.2. The mean age of all participants was 14.2±1.6 years. Two hundred and twenty-six (18.5%) participants were aged 10-13 years, eight hundred and twelve (66.5%) were 14-16 years while one hundred and eighty-four (15%) were 17-19 years. Of the 1,222 participants,66.5% attended private schools and about 67% lived in urban areas. Majority (51.7%) belonged to the lower socioeconomic class, 39% and 38.9% were from polygamous and single/separated families respectively.

Mean foot length and mean foot breadth of participants by stage of adolescence and gender

As shown in Table 2, the mean foot lengths for the participants in early, mid, and late adolescence were 24.04±1.43 cm, 24.96±4.18 cm, and 25.56±5.42 cm, respectively. The mean foot lengths of males were significantly higher than those of females across all stages of adolescence (p=0.004, <0.001, and 0.024 in early, mid, and late adolescence, respectively). The table also shows that, there was an increase in mean foot length of participants from 24.04±1.43 cm in early adolescence to 25.56±5.42 cm in late adolescence (p<0.001).

The mean foot breadths for participants in early, mid, and late adolescence were 83.62±5.31 mm, 85.32±5.53 mm and 89.90±8.31 mm respectively. The mean foot breadths of males were significantly higher than those of females in early (p=0.001), mid, and late adolescence (p=0.000 respectively). Also, the mean foot breadth for all participants steadily increased from early to late adolescence.

Mean height of participants by stage of adolescence and gender

Table 3 shows that the participants in late adolescence were taller than those in mid-adolescence, with mean heights of 168.58±6.89 cm and 161.95±7.37 cm respectively (p<0.001). Although the female participants in early adolescence were taller than their male counterparts, the difference was not significant (p=0.090). Irrespective of gender, the mean height of participants increased from early adolescence to late adolescence, 155.23±6.41 cm, 161.95±7.37 cm, and 168.58±6.89 cm, respectively (p<0.001).

Factors that may affect foot length and foot breadth

One hundred and thirty (10.6%) of the participants walked barefooted (Table 4).

The mean foot length of those participants who walked barefooted was significantly longer (24.89±2.16 cm) than those who did not (22.80±4.37 cm) (p<0.001). The mean foot breadth of participants who walked barefooted (84.86±0.48 mm), was significantly wider than that of those who did not (68.34±3.25 mm) (p<0.001).

Two hundred and eighty-four (23.2%) participants wore tight covered shoes consistently and had lower mean foot length (21.20±4.06 cm) than those who did not (24.52±2.24 cm) with p<0.001.

The participants who wore tight covered shoes also had significantly lower mean foot breadth (74.46±4.48 mm) than those who did not (86.42±1.51 mm) (p<0.001).

Pearson correlation between standing height and foot length, foot breadth and age

There was a significant positive correlation between standing height and foot length, foot breadth and age; p<0.001 (Table 5). However, the strength of the linear relationship between standing height and foot length (r=0.700) was stronger than that between standing height and foot breath (r=0.543) while the strength of the linear relationship between standing height and age was weak (r=0.369).

Figure 2 and 3 further display the correlation between standing height and foot length, and standing height and foot breadth respectively, in scatter plots. Each dot on the scatterplot represents one individual from the data set. The locations of the points on the graph indicate that standing height of the participants increase as the foot length and breadth increase.

Regression analysis to determine the relationship and prediction of standing height from foot length, foot breadth, age, and sex

Table 6 displays the parameters estimated by the six different linear regression models developed to express relationship and predict height from foot length, foot breadth, age, and sex and their respective statistical significance. The size of the coefficient (β) for each variable (foot length, foot breadth, age, and sex), which depicts the magnitude of the variable's effect on standing height, was statistically significant for all the models fitted.

The R-squared, which is the coefficient of determinant of the predictors and represents the goodness of model fit, is also as shown in Table 6.

Model 1, shows the goodness of fit for foot length, and has the R-squared (0.49) while model 2, shows the goodness of fit for foot breadth, and has the R-squared (0.29).

From model 1 and 2, the equation that predicts standing height can be expressed as follows:

$$Height = (\beta_1 \text{ x } foot\ length) + constant$$

$$Height = (\beta_2 \text{ x } foot\ breadth) + constant$$

Where:

β_1 *is the coefficient for foot length in centimetre*

β_2 *is the coefficient for foot breadth in millimetres*

Height = [3.53×foot length (cm)] + 73.4 using model 1

Height = [0.57×foot breadth (mm)] + 111.9 using model 2

With approximation of the coefficients to the nearest whole number, the equation can be written as:

Height=3.5 FL (cm)+73

Height=0.6 FB (mm)+112

Table 1: Sociodemographic characteristics of participants.

Variables	No. of respondents (n=1222)		Male (n=547)		Female (n=675)	
	N	%	N	%	N	%
Age (years)						
10-13	226	18.5	103	18.8	123	18.2
14-16	812	66.5	364	66.5	448	66.4
17-19	184	15.0	80	14.6	104	15.4
Type of school						
Public	409	33.5	181	33.1	228	33.8
Private	813	66.5	366	66.9	447	66.2
Place of residence						
Urban	821	67.2	363	66.4	458	67.9
Rural	401	32.8	184	33.6	217	32.1
Family type						
Monogamous	270	22.1	122	22.3	148	21.9
Polygamous	477	39.0	202	36.9	275	40.7
Single/separated/divorced	475	38.9	223	40.8	252	37.3
Socioeconomic class (SEC) of parents						
Lower SEC	632	51.7	289	52.8	343	50.8
Middle SEC	362	29.6	172	31.4	190	28.2
Upper SEC	228	18.7	86	15.7	142	21.0

Table 2: Mean foot length and foot breadth of participants by stage of adolescence and gender.

Stage of adoles-cence	N	Foot length (cm)					Foot breath (mm)				
		Range	Mean±SD	MD†	t	P value	Range	Mean±SD	MD†	t	P value
Early (10-13 years)											
Male	103	19.50-27.30	24.39±1.67	0.56	2.92	0.004*	74.40-96.95	85.01±5.96	2.81	3.36	<0.001*
Female	123	19.22-26.40	23.83±1.21				60.21-92.30	82.20±6.50			
Total	226	19.22-27.30	24.04±1.43				60.21-96.95	83.62±5.31			
Mid (14-16 years)											
Male	364	22.15-31.28	25.41±1.54	1.07	9.95	<0.001*	66.50-101.10	90.06±8.29	7.41	14.14	<0.001*
Female	448	21.60-29.00	24.34±1.51				67.24-98.65	82.65±6.64			
Total	812	21.60-31.28	24.96±4.18				66.50-101.10	85.32±5.53			
Late (17-19 years)											
Male	80	25.00-34.50	25.70±6.95	1.59	2.28	0.024*	74.40-114.16	92.96±6.61	9.22	8.81	0.000*
Female	104	22.60-28.40	24.11±1.39				67.89-101.29	83.74±7.35			
Total	184	22.60-34.50	25.56±5.42				67.89-114.16	89.90±8.31			

Note: MD- mean difference, †-Difference between male and female mean values, *-Significant p values, t - Student's t-test.

Table 3: Mean height of participants by stage of adolescence and gender.

Stage of adolescence	N	Range (cm)	Mean±SD (cm)	MD†	t	P value
Early (10-13 years)						
Male	103	135.0-169.0	154.97±9.23	1.81	-1.71	0.090
Female	123	139.0-168.0	156.78±6.68			
Total	226	135.0-169.0	155.23±6.41			

Stage of adolescence	N	Range (cm)	Mean±SD (cm)	MD†	t	P value
Mid (14-16 years)						
Male	364	155.0-174.0	164.12±8.49	4.56	8.78	<0.001*
Female	448	151.0-171.0	159.56±6.30			
Total	812	151.0-174.0	161.95±7.37			
Late (17-19 years)						
Male	80	168.0-198.0	169.06 ±8.19	9.74	8.59	<0.001*
Female	104	156.0-178.5	159.82±7.16			
Total	184	156.0-198.0	168.58±6.89			

Note: MD- mean difference, †-Difference between male and female mean values, *-Significant p values, t - Student's t-test.

Table 4: Factors that may affect foot length and foot breadth.

Characteristics	N (%)	Foot length (cm)		Foot breadth (cm)	
		Mean±SD	P value	Mean±SD	P value
Walking bare footed?					
Yes	130 (10.6)	24.89±2.16	<0.001**	84.86±0.48	<0.001**
No	1092 (89.4)	22.80±4.37		68.34±3.25	
Frequency of walking bare footed (N=130)					
Twice weekly	38 (29.3)	24.30±2.07	<0.001**	86.34±2.64	<0.001**
3-4 times per week	18 (13.8)	24.62±5.06		86.62±2.53	
5-6 times per week	9 (6.9)	24.48±4.28		86.40±1.77	
Everyday	65 (50.0)	25.30±3.18		87.71±4.38	
Wearing tight covered shoes					
Yes	284 (23.2)	21.20±4.06	<0.001**	74.46±4.48	<0.001**
No	938 (76.8)	24.52±2.24		86.42±1.51	
Frequency of wearing tight cover shoes (N=284)					
Twice weekly	147 (51.8)	23.50±4.37	0.016**	86.33±4.25	<0.001**
3-4 times per week	28 (9.8)	22.23±4.88		81.96±4.42	
5-6 times per week	35 (12.3)	22.03±4.16		81.04±4.38	
Everyday	74 (26.1)	22.12±3.22		78.22±4.15	

Note: **-Significant p value

Table 5: Pearson correlation between standing height and foot length, foot breadth and age.

Variables	Correlation coefficient (r)	P value
Foot length (cm)	0.700	<0.001
Foot breadth (mm)	0.543	<0.001
Age (years)	0.369	<0.001

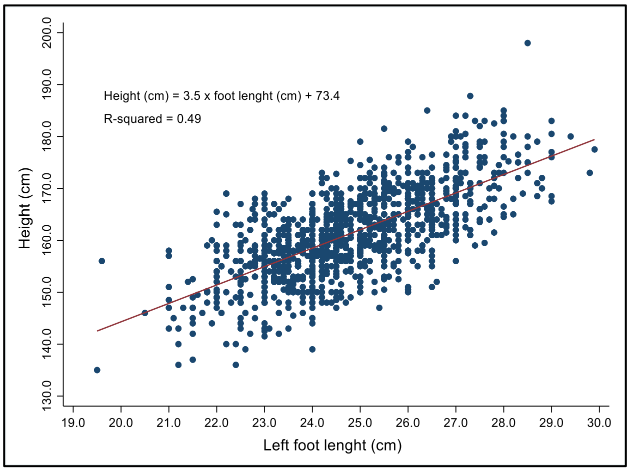

Figure 2: Relationship between standing height and foot length among participants.

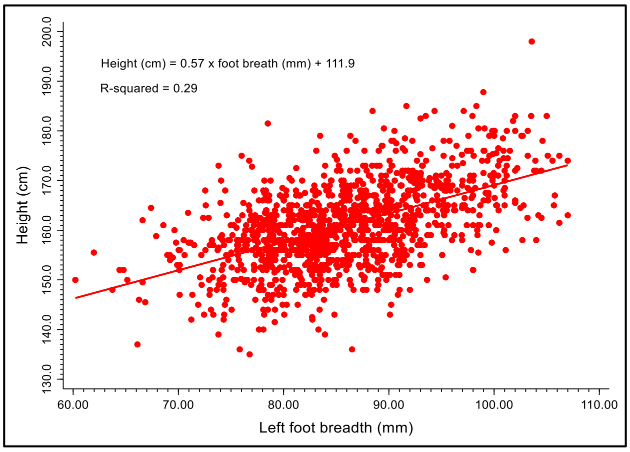

Figure 3: Relationship between standing height and foot length among participants.

Table 6: Estimates of Linear regression models for relationships between height and foot length, foot breadth.

Variable	Coefficient (β)	95% CI of β	t-value	**P value	*R-squared
Model 1					
Foot length (cm)	3.53	3.33, 3.73	34.22	<0.001	0.49
Constant	73.47	68.73, 78.75	28.85	<0.001	
Model 2					
Foot breath (mm)	0.57	0.52, 0.62	22.56	<0.001	0.29
Constant	111.91	107.93, 116.45	51.62	<0.001	
Model 3					
Foot length (cm)	2.92	2.68, 3.16	23.96	<0.001	0.52
Foot breath (mm)	0.22	0.17, 0.27	8.82	<0.001	
Constant	69.72	64.77, 74.66	27.65	<0.001	
Model 4					
Foot length (cm)	3.10	2.86, 3.35	24.71	<0.001	0.53
Foot breath (mm)	0.26	0.21, 0.30	9.95	<0.001	
Sex (M=1, F=2)	2.00	1.25, 2.75	5.23	<0.001	
Constant	59.05	52.73, 65.37	18.33	<0.001	
Model 5					
Foot length (cm)	2.76	2.52, 2.99	23.19	<0.001	0.55
Foot breath (mm)	0.19	0.15, 0.24	7.89	<0.001	
Age (years)	0.97	0.77, 1.18	9.22	<0.001	
Constant	61.56	56.47, 66.65	23.73	<0.001	
Model 6					
Foot length (cm)	2.99	2.70, 3.18	23.92	<0.001	0.56
Foot breath (mm)	0.20	0.18, 0.27	9.02	<0.001	
Age (years)	0.99	0.75, 1.16	9.15	<0.001	
Sex (M=1, F=2)	1.98	1.17, 2.62	5.13	<0.001	
Constant	51.97	45.26, 57.90	16.01	<0.001	

Note: **P values are for the hypothesis test using the t-test to find how each estimated coefficient is significantly different from zero, *R-squared is the numerical value for fraction of the variation in the dependent variable that can be explained by the independent variables.

DISCUSSION

The mean foot length of adolescent school children in Yenagoa LGA showed a steady increase from early adolescence to late adolescence. This study further found that the mean foot length of male participants was longer than that of the females in all stages of adolescence. This is similar to reports from the study on stature estimation from the length of the growing foot in North Indian adolescents by Krishan et al who found that height and individual foot measurements increased with age especially between 13-18 years.[13,14] This can be attributed to advanced pubertal development and accelerated bone maturation in this age group, particularly in females.[15-17] Findings by Ozden et al and Zeybek et al are also comparable, though their studies were on adult Turks.[18,19]

In this study, the mean foot breadth of male participants was wider than that of the female participants in all stages of adolescence. The foot breadth increased in both sexes from early adolescence to late adolescence. These findings are similar to studies carried out by Tomassoni et al in Italy, Danborno and Elukpo in Zaria, Northern Nigeria and Egwu et al in South-Eastern Nigeria.[20-22] The process of foot development as individuals grow results in differences in shape and function. This in turn leads to alterations in the bone, ligament, tendon and skeletal muscles.[23,24] In addition, as individuals grow older, the flexible and articulated structure of the foot required for body support and balance begins to lax, also functional and morphological changes develop due to the continuous demands of standing and walking resulting in flatter and wider feet.[24]

The finding that the females in early adolescence were taller than their male counterparts is attributable to the fact that girls attain puberty at an earlier age than boys.[15-17] In mid and late adolescence however, the males were taller than the females. This may be due to accelerated growth in males at these stages of puberty.[16,17] This is similar to findings by Tanko et al in Kaduna, Udoh et al in Akwa Ibom in Nigeria and Patel et al and Pinhas et al on Asian children.[23,25-27] They found that target height can be influenced by gender associated genetic factors like parental height and hormonal factors like growth, thyroid and sex hormones.[28-30] Testosterone and oestrogen are very important for growth during puberty. Adolescent males tend to have a major growth spurt at the onset of puberty, about 2 years after their female counterparts, but they may continue to grow for longer than females. This is because as the females attain menarche, their growth velocity reduces and may subsequently stop by 16-17 years of age when their growth plates are thought to fuse.[33-35]

The present study observed that participants who walked bare footed had significantly longer and wider feet which may be attributed to less restriction by shoes.[31,32] The main developmental result of growing up wearing shoes appears to be narrower feet and by contrast, those who grow up, most of the time barefooted, have wider feet.[31] This finding is similar to that of Trinkaus and Shang, whose study portrayed increased foot length and foot width among those who walked barefooted.[32] Peter and Simon et al also found that walking barefooted resulted in increased foot length and also wider feet.[31-33] Walking barefooted for prolonged periods causes the foot ligaments to become lax, the plantar fascia then becomes weak and may result in a flat arch (flat foot).[33-35]

Another finding in this study is that those adolescents who wore tight covered shoes had shorter foot length and smaller foot breadth. Wearing tight - fitting shoes for long periods of time, may result in restriction of muscle and bone growth, thereby, causing a narrowing effect of the forefoot.[31,33] This is because the morphology of children and adolescent feet is such that, their feet are more malleable than adult feet, and also do not stop growing till age 20-21 years.[35] Therefore, wearing the correct shoe size is of paramount importance, as constantly wearing tight covered shoes will negatively impact on the growth of their feet and thus affect the foot length and foot breadth.

In the index study, foot length was found to have a strong linear relationship and better correlation with standing height (r=0.700) compared to foot breadth (r=0.543). This indicates that foot length provides a higher reliability and accuracy than the foot breadth in estimating height in the study population. This finding agrees with that of Tanko et al and Paul et al in Kaduna and Imo states, Nigeria, respectively.[23,36] Mansur et al in Nepal and Sanli et al in Turkey also reported similar findings.[37,38] Patel et al in India, also noticed foot length as a better predictor for standing height though in adults.[26]

Various researchers have derived regression equations for calculating standing height from different parameters such as armspan, femur and humerus and foot measurements.[10,39-42] Foot measurements however, have rarely been used in adolescents especially in Bayelsa and Nigeria as a whole. In this study, regression models were formulated for standing height prediction using foot length and foot breadth, with regression coefficients of 3.5 derived for foot length and 0.6 for foot breadth. This finding is similar to that of Qamra et al in Northwest Indian adults, Patel et al, Singh et al in North Indian Rajputs and Sanli et al in Turks.[11,26,38,44]

The equations derived from the data for the estimation of standing height are similar to those of Trotter et al and Sjovold et al who developed regression equations for the estimation of standing height though they used skeletal long bones instead of foot dimensions.[10,43]

Limitations

A limitation in this study was that, out of school adolescents were not sampled so results may not be representative of the general adolescent population in Yenagoa.

CONCLUSION

In conclusion, the mean height, foot length and foot breadth increase across all stages of adolescence in both genders. There is a linear association between standing height and foot length and foot breadth of adolescents in Yenagoa LGA.

Recommendations

It is therefore recommended that, clinicians should adopt the use of foot length and foot breadth in estimating standing height of adolescents, in situations where actual height cannot be measured. The derived formulae may also be used to estimate standing height in Nigerian adolescents especially in critically ill children and those with spinal deformities.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

REFERENCES

1. Baten J, Komlos J, Anthropometric research, and the development of social science history. Soc Sci Hist. 2004;28:191-210.
2. Frison S, Kerac M, Checchi F, Prudhon C. Anthropometric indices and measures to assess change in the nutritional status of a population; A systematic literature review. BMC Nutr. 2016;76(2):1-11.
3. Malina RM, Katzmarzyk PT. Validity of the body mass index as an indicator of the risk and presence of overweight in adolescents. Am J Clin Nutr. 1999;70(1):131S-6S.
4. Woodruff BA, Duffield A. Anthropometric assessment of nutritional status in adolescent populations in humanitarian emergencies. Eur J Clin Nutr. 2002;56(11):1108-18.
5. Eke CB, Ubesie AC, Ibe BC. Comparison of actual (measured) weights and height with the standard formula methods of estimation among children in Enugu. Niger J Paediatr. 2014;41(4):307-11.
6. Quanjer PH, Capderou A, Mazicioglu MM, Aggarwal AN, Banik SD, Popovic S, et al. All-age

relationship between arm span and height in different ethnic groups. Eur Respir J. 2014;44(4):905-12.
7. Eboh DEO, Ohaju-Obodo JO. Height estimation from head dimensions in South-South Nigeria. Egypt J Forens Sci. 2019;62(9):52-64.
8. Eboh DEO, Igbigbi PS. Stature estimation from cephalometric parameters of young adults in five Nigerian ethnic groups. Italian J Anat Embryo. 2017;122:98-109.
9. Masanovic B, Arifi F, Gardasevic J. Standing height and its estimation utilizing sitting height measurements in adolescents from the western region in Kosovo. Sport Mont J. 2019;17(3):3-7.
10. Trotter M, Gleser GC. Estimation of stature from long bones of American Whites and Negroes. Am J Phys Anthropol. 1952;10(4):463-514.
11. Qamra SR, Jit I, Deodhar SD. A model for reconstruction of height from foot measurements in an adult population of North West India. Indian J Med Res. 1980;71:77-83.
12. Mohamed HM. Measurement of foot and hand dimensions and their correlation with height in adult upper Egyptians. Al-Azhar Assuit Med J. 2013;10(4):300-16.
13. Krishan K, Kanchan T, Passi N, DiMaggio JA. Stature estimation from the lengths of the growing foot-a study on North Indian adolescents. Foot (Edinb). 2012;22(4):287-93.
14. Ibegbu AO, Tosin DE, Hamman WO, Umana UE, Musa SA. Nutritional evaluation using different anthropometric variables in Nigerian school children. J Experimen Clin Anat. 2013;12(2):42-9.
15. He Q, Karlberg J. BMI in childhood and its association with height gain, timing of puberty, and final height. Pediatr Res. 2001;49(2):244-51.
16. Pinhas-Hamiel O, Benary D, Mazor-Aronovich K, Ben-Ami M, Levy-Shraga Y, Boyko V, et al. Advanced bone age and hyperinsulinemia in overweight and obese children. Endocr Pract. 2014;20(1):62-7.
17. Puentes E, Wang F, Behrman JR, Cunha F, Hoddinott J, Maluccio JA, et al. Early life height and weight production functions with endogenous energy and protein inputs. Econ Hum Biol. 2016;22:65-81.
18. Ozden H, Balci Y, Demirüstü C, Turgut A, Ertugrul M. Stature and sex estimate using foot and shoe dimensions. Forensic Sci Int. 2005;147(2-3):181-4.
19. Zeybek G, Ergur I, Demiroglu Z. Stature and gender estimation using foot measurements. Forensic Sci Int. 2008;181(1-3):54-5.
20. Tomassoni D, Traini E, Amenta F. Gender and age related differences in foot morphology. Maturitas. 2014;79(4):421-7.
21. Danborno B, Elukpo A. Sexual dimorphism in hand and foot length, indices, stature-ratio and relationship to height in Nigerians. Int J Forens Sci. 2007; 3(1):1-5.
22. Egwu OA, Nto NJ, Bello EF, Egwu EO, Ukoha UU, Ajah DT. Stature estimation from foot dimensions of an adult Nigerian population. J Anat Karnataka. 2012;6:8-12.
23. Tanko M, Ahmadu W, Agbon AN, Bauchi ZM, Sadeeq AA, Musa M. Determination of stature using anthropometric parameters in adolescents from selected secondary schools, Samaru - Zaria, Kaduna State, Nigeria. Dutse J of Pure and Allied Sci. 2020;6(4):57-66
24. Arnold BJ, Menz BH. The aging foot. Foot Ankle Biomech. 2023;37(1):595-610.
25. Udoh UG, Peter AI, Thomas DF, Johnson EI. Estimation of stature of the Annang ethnic group of Nigeria using knee height. Int J Healthcare Med Sci. 2017;3(9):55-61.
26. Patel L, Clayton P. Normal and disordered growth. in: Brook C.G.D. Clayton P. Brown R. Brook's clinical paediatric endocrinology. Blackwell; 2005:90-112.
27. Pinhas-Hamiel O, Benary D, Mazor-Aronovich K, Ben-Ami M, Levy-Shraga Y, Boyko V, et al. Advanced bone age and hyperinsulinemia in overweight and obese children. Endocr Pract. 2014;20(1):62-7.
28. Warrier V, Krishan K, Shedge R, et al. Height Assessment. StatPearls. Treasure Island, FL: StatPearls Publishing; 2024.
29. Christesen HT, Pedersen BT, Pournara E, Petit IO, Júlíusson PB. Short Stature: Comparison of WHO and National Growth Standards/References for Height. PLoS One. 2016;11(6):e0157277.
30. Stovitz SD, Demerath EW, Hannan PJ, Lytle LA, Himes JH. Growing into obesity: patterns of height growth in those who become normal weight, overweight, or obese as young adults. Am J Hum Biol. 2011;23(5):635-41.
31. Peter F. Children should spend more time barefoot to encourage a healthier foot structure. Conversations. 2018;1(12):8-12
32. Trinkaus E, Shang H. Anatomical evidence for the antiquity of human foot wear: Tianyuan and Sunghir. J Archaeol Sci. 2008: 35(7):1928-33.
33. Franklin S, Grey MJ, Heneghan N, Bowen L, Li FX. Barefoot vs common footwear: A systematic review of the kinematic, kinetic and muscle activity differences during walking. Gait Posture. 2015;42(3):230-9.
34. Frey C, Thompson F, Smith J, Sanders M, Horstman H. American Orthopaedic Foot and Ankle Society women's shoe survey. Foot Ankle. 1993;14(2):78-81.
35. Buldt AK, Menz HB. Incorrectly fitted footwear, foot pain and foot disorders: a systematic search and narrative review of the literature. J Foot Ankle Res. 2018;11:43.
36. Paul CW, Osuchukwu IW, Aigbogun EO, Ekezie J. Stature estimation from foot dimensions of Igbo indigenes of Imo state extraction in Nigeria. Int J Rec Sci Res. 2018;9(1):23323-7.
37. Mansur DI, Haque MK, Karki RK, Khanal K, Karna R. Estimation of stature from foot length in adult

Nepalese population and its clinical relevance. Kathmandu Univ Med J (KUMJ). 2012;10(37):16-9.
38. Sanli SG, Kizilkanat ED, Boyan N, Ozsahin ET, Bozkir MG, Soames R, et al. Stature estimation based on hand length and foot length. Clin Anat. 2005;18(8):589-96.
39. Fatmah M. Predictive equations for estimation of stature from knee height, arm span and sitting height in Indonesian Javanese elderly people. Int J Med Sci. 2009;1:456-61.
40. Singh B, Krishan K, Kaur K, Kanchan T. Stature estimation from different combinations of foot measurements using linear and multiple regression analysis in a North Indian male population. J Forensic Leg Med. 2019;62:25-33.
41. Kanchan T, Menezes RG, Moudgil R, Kaur R, Kotian MS, Garg RK. Stature estimation from foot length using universal regression formula in a North Indian population. J Forensic Sci. 2010;55(1):163-6.
42. Didia BC, Nduka EC, Adele O. Stature estimation formulae for Nigerians. J Forensic Sci. 2009;54(1):20-1.
43. Sjovold T. Stature estimation from the skeleton. Encycl of Forens Sci. 2000; 1:276-84.
44. Singh B, Krishan K, Kaur K, Kanchan T. Stature estimation from different combinations of foot measurements using linear and multiple regression analysis in a North Indian male population. J Forensic Leg Med. 2019;62:25-33.

Cite this article as: Okumoko MA, Akinbami FO, Peterside O, Orimadegun AE. The use of foot length and foot breadth in estimating standing height of adolescents in Yenagoa, Nigeria. Int J Contemp Pediatr 2024;11:648-56.