Original Research Article

Multivariate Regression Model for Stature Estimation from Arm Span, Horizontal Fingertip Reach and Foot Length of Igbo Ethnic Group of Nigeria

Abstract

Background: Stature estimation is a major factor in biological profiling for identification of persons

Aim: To formulate stature estimation models from arm Span, horizontal fingertip reach, and foot length amongst the Igbo ethnic group of Nigeria.

Method: A total of 399 subjects, (200 females and 199 males) between the ages of 18-40 years were recruited for the study. Standardized anthropometric techniques were used to measure the standing height, arm span, and foot length. Data analysis was carried out using a statistical package for social sciences version 23 to calculate Pearson's coefficients of correlation and regression equation to formulate stature model variables.

Result: The correlation coefficients (R) for height against arm span, horizontal fingertip and foot length were 0.84 for all sampled subjects, 0.79 for male subjects, and 0.90 for female subjects. Multivariate regression models for stature estimation were Stature = 56.62 + AS (0.48 – HFTR (0.006) + FL(1.15) for all subjects; Stature = 62.92+AS(0.42)+HFTR(0.15)+FL(0.88) for male subjects; Stature = 47.73 + AS(0.50) - HFT(0.01) + FL(1.32) for female subjects.

Conclusion: This data will be useful to forensic anatomists and anthropologists.

Keywords: Regression, Models, forensics, stature, arm span, horizontal fingertip reach, foot length, Igbo.

Introduction

Anthropometry is the science that defines physical measures of a person's size, form, and functional capacities [1]. These physical characteristics include stature, weight, body mass index, hip circumference, waist circumference, foot length, arm span finger reach tip, etc. Standing height also referred to as stature, is an important anthropological parameter, as it provides valuable insights into the physical characteristics of a population [2]. Stature plays a big role in an

individual's identification in medico-legal scenarios, industrial design of fittings for the human body, furniture manufacturing, etc. [24]. Some conditions may hinder the direct measurement of standing height like spinal and limb deformities, amputations, fractures, scoliosis, paralysis, and pain; in these cases, segments body are used for estimating the standing of an individual [3].

Stature estimation from arm span, horizontal fingertip reach, and foot length are common in anthropometry and human biology. These measurements are often used as proxies for estimating an individual's height or stature when direct height measurements are not feasible or available. Udo and co [7] suggested that arm span is the reliable anthropometric parameter that predicts the body height of an individual and also plays an important role in assessing growth and development in children and adolescents. This position was supported by some population ethnic-based studies where sex differences in the arm span have also been established [7,8,9,10 & 11]. The horizontal fingertip reaches are the distances between the fingertips of an individual's outstretched arms when extended laterally which is an important parameter in furniture design. This measurement considers correlation with stature, as it reflects the width or breadth of an individual's skeletal structure [5]. Foot length, on the other hand, is the measurement from the heel to the tip of the longest toe, it may not provide a direct estimation of stature but can be used in conjunction with other measurements to improve the accuracy of the estimation [6]. Malina [12] posited that foot length and horizontal fingertip reach measurement are the most reliable predictors during adolescent age since ossification and maturation occur earlier in the foot than the long bones, and standing height could be more accurately predicted from foot measurement as compared to long bones during adolescent age [12].

Some studies have examined the relationship between stature and arm span Oguon et al., [21] and Anibor et [22], some have even established bivariate models for the estimation of height from either foot length or arm span in some ethnic groups [6,7]. Nonetheless, studies using multiple variables such as the foot length arm span, and finger reach tip to estimate stature are rare among the Igbo ethnic group of Nigeria. The use of many variables to estimate a parameter improves accuracy. Thus, this study aims to formulate a multivariate regression model for estimating height from arm span, foot length, and finger reach tip and foot length amongst the Igbo ethnic group of Nigeria.

Material and Method

The study was conducted at Owerri, a major Igbo city in eastern Nigeria. A total of 399 subjects, (200 females and 199 males) between the ages of 18 to 40 years have participated in the study. The inclusion criteria included that both parents and grandparents of participants must be from Igbo ethnic groups, and individuals with physical deformities that affected body height were excluded from the study. The minimum sample size for the study was determined using the Taro-Yamane formula. Ethical approval was obtained from the Research Ethics Committee, of the University of Port Harcourt. All subjects were adequately informed about the procedure of studies and they gave their consent in writing. Demographic data were collected through a structured, pretested interviewer-administered questionnaire to ascertain ethnicity and anthropometric parameters were taken by direct measurements. The following parameters were measured;

A. Standing Height

This was taken using a ZT-160 Goodcare stadiometer. The participants stood erect, and barefooted on the level platform of the stadiometer such that the back of their head, shoulder blade, buttocks, and heels touched the bar of the stadiometer. Participants were asked to relax with arms hanging by the side. Care was taken to avoid a sagging position.

B. Arm Span

This is a distance between the tips of the middle finger of both hands in a participant's perpendicular upright with both arms outstretched laterally at 90^0 shoulder height perpendicular to the body and parallel to the floor. It was measured using a mega-size calliper. It was best obtained when the participant was standing vertical wall to ensure the arms were accurately placed laterally.

C. Horizontal Fingertip Reach or Upper Limb Length

This is the distance from the acromion to the fingertip with the elbow and wrist stretched. It was measured using a mega-size calliper.

D. Foot Length

This is the distance from the most prominent part of the heel to the most distal part of the longest toe (great or second toe). It was measured on the AMRG Anthropometric footrest.

Data analysis and processing:

Data analysis was done using Statistical Package for Social Sciences Version 23. Pearson's coefficients of correlation and Regression analysis were used to formulate a model from the stature of the measured variables.

Result

The mean value of standing height is 169.41±7.91cm, arm span is 176.30±10.95cm, horizontal fingertip reach is 79.42±36.01cm and foot length is 25.29±1.73cm as shown in Table 1 and they were not statistically significant. The multivariate model for the estimation of stature, Pearson correlation coefficient, coefficient of determination, and standard error of estimate are presented in Table 2.).

Table 1, Descriptive Statistics for Standing Height, Arm span, Horizontal fingertip Reach, and Foot Length

Parameters	Mean ±Std. Deviation		
	ALL	MALE	FEMALE
S (cm)	169.41±7.92	169.78±7.84	169.05±8.00#
AS (cm)	176.31±10.95	176.43±11.13	176.18±10.80#
HFTR (cm)	79.42±36.02	77.60±7.15	81.23±50.37#
FL (cm)	25.30±1.73	25.28±1.74	25.31±1.73#

S= Stature, AS= Arm span, HFTR = horizontal finger reach tip, FL = foot length, # = not Significant

Table 2, Correlation, Coefficient of determination and Test for Fitness of Data for Formulation of Regression Model for Stature for all subjects

Subjects	Multivariate Model	R	R SQUARE	Std. Error of the Estimate	Sig F Change
All	Stature = 56.62 + AS(0.48) – HFTR(0.006) + FL(1.15)	0.84	0.707	4.30	0.00
Males	Stature = 62.92+AS(0.42)+HFT(0.15)+FL(0.88)	0.79	0.63	4.84	0.00
Females	Stature = 47.73 + AS(0.50) - HFTR(0.01) + FL(1.32)	0.90	0.81	3.49	0.00

S= Stature, AS= Arm span, HFTR = horizontal finger reach tip, FL = foot length

Discussion

This study has investigated the relationship between stature, arm span, horizontal fingertip reach, and foot length among the Igbo ethnic group of Nigeria. This showed significant correlations with stature, arm span, foot length, and horizontal fingertip reach. This indicated that stature could be predicted from these parameters and vice versa. These findings are important because applications of the stature in evaluating well-being display the growth of persons but can be used for establishing the identity of persons in forensic investigations and industrial designs.

Our study revealed that among the Igbo ethnic group of Nigeria between the ages of 20 to 40 years, stature, arm span, foot length, and horizontal fingertip reach showed no gender difference within the study population and this is in line with the study of Sharma et al., [14] and Dorjee and Sen, [15]. However, some studies reported that sexual dimorphism existed in these parameters. [13, 21]. The factors responsible for the lack of sexual difference in the measured parameters in the study were not evaluated, nevertheless, changing environmental factors such as nutrition, health, and lifestyle in recent times appear to have altered the growth pattern in most populations. Furthermore, some studies have shown that environmental factors also influence the expression of

genetic traits. While there was no significant difference in stature and arm span between males and females in the studied population, males had a higher mean value for stature and arm span than females. Some studies have shown that the onset of growth is faster in females but the duration of growth is limited because the fusion of the epiphyses of bones occurs earlier in females. [4, 7, 8, 13, 16, 23].

The arm span, horizontal finger-tip reach, and foot length were better predictors of human stature (males R=0.79, females R=0.90), this is important in forensic investigation. Some studies have explored the predictive power of these anthropometric parameters to stature. Mulu and Sisay [13] reported that Arm span showed the highest correlation value than any other anthropometric parameters for both sexes (R=0.843 for males and R=0.708 for females). Studies by Jakhar et al., [19] in Haryana and Patel et al., [20] in Gujarat also showed a significant correlation, consistent with our study. On the contrary, Udoh et al., [7] reported that males and females had moderate prediction using the studied anthropometric parameters.

Conclusion

In conclusion, the study has shown that arm span, horizontal fingertip reach, and foot length can adequately be used in estimating stature. There is no sexual **d**imorphism in these parameters. The findings of this research are important in forensic science and industrial anthropometry. Also, the applications of multivariate regression in forensic identification will be useful in DNA analysis, fingerprint analysis and facial recognition.

Ethical Approval:

Approved by the University of Port Harcourt Ethics Research Committee; UPH/ERC/2021/046

Disclaimer (Artificial intelligence)

Author(s) hereby, declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

References:

1. Warrier V, Krishan K, Shedge R, Kanchan T. Height assessment. StatPearls [Internet]. 2022 Sep 14.

2. Asiwe N, Irozulike FC, Wariboko LI, Adheke OM. Health Assessment of the Ikwerres and Okrikas Ethnic Group of Rivers State, Nigeria: Using Body Mass Index and Waist-to-Hip Ratio. Journal of Complementary and Alternative Medical Research. 2023 Jul 31;23(2):27-35.
3. Singh B, Krishan K, Kaur K, Kanchan T. Different predictive and accuracy models for sex and stature estimation from second-and fourth-digit lengths in the Kinnaur population of Himachal Pradesh, North India: Medico-legal and forensic implications. Medicine, Science and the Law. 2019 Jul;59(3):149-59.
4. Fawehinmi HB, Paul CW. Comparison of Anthropometric characteristics (height, arm span, knee height and foot length) between Ibo and Hausa adults). Biomec. Afri. 2008;6(1):2.
5. Ishak NI. Sex and stature estimation using hand and handprint measurements in a Western Australian population (Doctoral dissertation, University of Western Australia).
6. Oghenemavwe LE, Egwede OB. Estimation of living stature from foot dimensions in future indigenes of Abia state, Nigeria. European Journal of Medical and Health Sciences. 2022 Feb 10;4(1):67-71.
7. Udoh Uwemedimo G, Edem Gabriel D, Johnson Ekemini I. Relationship between height and Armspan length in adults of the Annang ethnic group of Nigeria. IJAR. 2017;3(12):175-9.
8. Iteire AK, Anibor E, Akpo ME. Estimation of Height Using Arm Span of The Itsekiris in the Delta State of Nigeria. Nigerian Journal of Basic and Applied Sciences. 2016 Apr 19;23(2):137-.
9. Popovic S, Bjelica D, Tanase GD, Milasinovic R. Body height and its estimation utilizing arm span measurements in Bosnian and Herzegovinian adults. Montenegrin Journal of Sports Science and Medicine. 2015 Mar 1;4(1):29.
10. Singh A, Kumar A, Chavali KH, Harish D. Use of arm-span and foot length for estimation of height of the person.
11. Quanjer PH, Capderou A, Mazicioglu MM, Aggarwal AN, Banik SD, Popovic S, Tayie FA, Golshan M, Ip MS, Zelter M. All-age relationship between arm span and height in different ethnic groups. European Respiratory Journal. 2014 Oct 1;44(4):905-12.

12. Malina RM, Bouchard C, Bar-Or O. Growth, maturation, and physical activity. Human kinetics; 2004.
13. Mulu A, Sisay B. Estimation of Stature from Arm Span, Arm Length and Tibial Length among Adolescents of Aged 15-18 in Addis Ababa, Ethiopia. Ethiopian Journal of Health Sciences. 2021 Sep 1;31(5).
14. Sharma S, Jain SK, Sharma N. Use of arm span as a proxy indicator of stature-an anthropometric study in Western UP.
15. Dorjee B, Sen J. Estimation of stature from arm span, arm length and tibial length among Bengalee. *Journal of Human Biological Review*. 2016; 5:128-145.
16. Malaviya SK, Saswihali S, Hathi M, Mehta SR. Stature estimation from arm span in living people of Terdal region. Indian Journal of Forensic and Community Medicine. 2023 Jan 22;6(1):37-9.
17. Krishan K, Sharma A. Estimation of stature from dimensions of hands and feet in a North Indian population. Journal of forensic and legal medicine. 2007 Aug 1;14(6):327-32.
18. Ozden H, Balci Y, Demirustu C, Turgut A, Ertugrul M. Stature and sex estimate using foot and shoe dimensions. Forensic Sc. Internet 2005; 147: 181- 184.
19. Jakhar JK, Pal V, Paliwal PK. Estimation of height from measurements of foot length in the Haryana region. Journal of Indian Academy of Forensic Medicine. 2010;32(3):231-3.
20. Patel SM, Shah GV, Patel SV. Estimation of height from measurements of foot length in Gujarat region. J Anat Soc India. 2007 Jan;56(1):25-7.
21. Ogoun TR, Fawehinmi HB, Okoseimiema SC. Determination of Armspan and Foot Length between the Ijaw and Ikwerre Ethnic Group in Nigeria. Asian Journal of Medical Sciences. 2013;5(6):113-6.
22. Anibor E, Ogbor-Omorie E, Nwagbara A. The use of arm span to estimate height among the Urhobos in the Delta state of Nigeria. African Journal of Cellular Pathology. 2014 Oct 31;3(10):16-9.
23. Nieves, J.W., Formica, C., Ruffing, J., Zion, M., Garrett, P., Lindsay, R. and Cosman, F., 2005. Males have larger skeletal size and bone mass than females, despite comparable body size. Journal of Bone and Mineral Research, 20(3), pp.529-535.
24. Ellingham, S., Adserias-Garriga, J., Zapico, S.C. and Ubelaker, D.H. eds., 2023. *Burnt Human Remains: Recovery, Analysis, and Interpretation*. John Wiley & Sons.