Rwanda Medical Journal RMJ

ORIGINAL ARTICLE Open Access

Body Weight and Height Estimation from Second- and Fourth-Digits Length in Nigerian Children

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ABSTRACT

INTRODUCTION: Accurate body weight and height estimation is crucial for paediatric healthcare, nutrition assessment, and forensic investigations. Traditional methods often rely on direct measurements, which may not always be feasible, especially in emergency or resource-limited settings. The present study aimed to develop regression equations for predicting body weight and height from the length of the second and fourth digits in male and female children in Nigeria.
METHODS: 318 male children and 336 female children between the ages of 7-15 years selected from three primary schools in Zaria local government, Kaduna state, Nigeria, were used in the study. The height of each participant was measured using a stadiometer, while body weight was measured using a bathroom scale. The length of the second digit (2D) and fourth digit (4D) of both hands in each participant was measured as the distance from the basal crease of the digit to the tip of the digit using a Vernier Calliper.
RESULTS: The result revealed that female children have significantly ($P<0.05$) longer 2D and 4D in both hands when compared to male children. It also showed that the body weight and height of children can be significantly ($P < 0.001$) predicted from the lengths of right and left 2D and 4D.
CONCLUSION: Body weight and height can be estimated from the lengths of the right and left 2D and 4D.

Keywords: Body segments, Anthropometry, Personal identification, Prediction, Subadult

INTRODUCTION

Determination of the body weight and height in children is essential for estimating the BMI [Body Mass Index], assessing growth, diagnosing certain physical growth disorders, evaluating nourishment status, ascertaining drug dosages, intravenous liquid administration, and for adequacy of clinical mediations [1,2]. The most accurate method of determining a child's weight and height is to weigh

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Received: 9th June 2024; **Initial decision given:** 21st June 2024; **Revised manuscript received:** 2nd August 2024; **Accepted:** 12th November 2024.
 Publisher: Rwanda Biomedical Centre (RBC)/Rwanda Health Communication Center, P. O. Box 4586, Kigali. ISSN: 2079-097X (print); 2410-8626 (online)

Citation for this article: F. O. Opoola; S. S. Adebisi; A. O. Ibegbu, et al. Body Weight and Height Estimation from Second- and Fourth-Digits Length in Nigerian Children. Rwanda Medical Journal, Vol. 81, no. 4, p. 47-54, 2024. https://dx.doi.org/10.4314/rmj.v81i4.7

the child on a standard machine with calibrated scales and an Infantometer or stadiometer, respectively, 'the gold standard'. This technique ought to be adopted in children to attain their actual weight and height if feasible [3].

However, its usefulness may be difficult in children who are seriously ill or immobilized. Though there is special equipment, such as scales integrated into hospital beds and health centre beds, this gear is high priced and not without difficulty handy in many hospitals in middle and low-income countries [4]. Therefore, there is a need to advance methods that can be used to estimate weight and height from body segments in children. There are a number of methods to estimate weight in children when digital measurements cannot be made. Most involve a father or mother or fitness care issuer guessing the child's weight through a weight-estimation formulation consisting of the Advanced Paediatric Life Support [APLS] formula, the Leffler formula, and Theron formula [5]. Others include the use of some tape-based systems like the Broselow tape and PAWPER tape [6,7]. Developing a straightforward anthropometric apparatus for fast weight and height assessment in children would be valuable in restricted asset settings like the low and middle-income countries with the highest percentage of worldwide under-five mortality and where current weight assessment devices are not consistently reliable [8].

Debacles like flooding, tsunamis, earthquakes, plane accidents, train crashes, and terrorist assaults, as a rule, lead to an assemblage of fragmentary and mutilated human remains [9]. Setting up personality in such cases is difficult for legal anthropologists. Hence, the determination of race, sex, and stature of an individual from the length of the missing skeleton fragments and disintegrating human remains are of specific significance to forensic anthropologists [10]. A few examinations have revealed huge affiliation and assessed height from anthropometry of various body pieces like hand length, second and fourth digit length, foot length, tibial length, and malleolar expansiveness, among others [11-13].

The fourth digit or ring finger of the human hand is the second most ulnar finger situated between the middle finger and the little finger, while the second digit or index finger of a human hand lies between the thumb and the middle finger and is usually the most skillful and delicate [14,15]. Males have been revealed to have longer fourth digits compared to their second digits, indicating a lower 2D:4D ratio than females who on average, have a higher 2D:4D proportion [9]. The general lengths of the digits are set before birth, and the 2D:4D proportions has been accounted to be negatively correlated with testosterone levels and positively associated with estrogen levels in adults [16,17]. This distinction in the length of the digits in both sexes necessitates its use in the derivation of formulas that can be used to estimate boundaries like height and weight that have likewise been accounted for to be subject to the sex.

Although assessment of height from various body fragments is standard in adults, they are generally utilized in assessing age in sub-adults and children [18]. All things considered, estimation of height and sex from accessible portions in children and young adults may be of importance and critical in some cases as the lengths of the femur and humerus have been used for the identification of young adults during a criminological examination [19,20]. Accordingly, setting up principles for the assessment of height in young adults and children populace is fundamental since equations inferred for adult height prediction can't be applied to young adults and children [21]. In addition, as these principles become populace explicit, it becomes basic to gather information from more populaces to make a far-reaching data set, as there are numerous inborn populace contrasts across various populaces [22]. Hence, there is a need to make assessments for various populations. Therefore, this study was conducted to generate regression equations for the prediction of weight and height from the length of the second and fourth digits in male and female children in Nigeria.

METHODS

Study Design and Population

A total of 654 participants comprising three hundred eighteen (n = 318) male children and three hundred and thirty-six (n = 336) female children selected from Ahmadu Bello University Staff School, Jethro Academy, and Amina Primary School, LEA in Zaria Local Government, Kaduna State, Nigeria were used in the study. Data was collected through self-administered questionnaires with an attached copy of the consent form for their parents to indicate interest in participating in the study. Only children without any form of deformity in any of the hands between the ages of 7-15 years and in primary 3 to 6, whose parents or guardians gave written consent through their signature, were allowed to participate in the study. Non-primary school children, children with deformities in any of the hands, children not within the age range of 7-15 years, and children whose parents or guardians didn't give their informed consent were excluded from the study.

Ethical approval certificate was acquired from the Health Research Ethics Committee, Ahmadu Bello University Teaching Hospital (ABUTH), Shika, Zaria, with Ethical Certificate number ABUTH/HREC/TRG/36. This study was also approved by appropriate authorities overseeing the primary schools and parents or guardians of the children.

Anthropometry

The standing Height (HT) of each participant was measured to the nearest 0.5 cm using the vertical scale of a stadiometer with the participant in an erect position without shoes, feet together, arms by the side, heels, buttocks, and upper back in contact with the vertical scale and head held in the Frankfort plane [23]. Each participant's body weight was measured to the nearest 0.1kg on a bathroom scale, with the participant lightly clothed [24].

The length of the second digit (2D) and fourth digit (4D) of the right and left hand of each participant was taken with the digit fully extended by placing a Vernier calliper on the ventral surface of the hand from the basal crease of the digit to the tip of the second and fourth digits in both right and left hands as described by Danborno, et al. [13]. To decrease observation errors, anthropometric measurements were read twice independently, and the mean of the two estimations was taken as the actual value.

Statistical Analysis

Descriptive statistics were presented as mean ± standard deviations, frequencies and ranges (minimum-maximum). An unpaired sample t-test was used to test for sexual dimorphism in age and anthropometric variables. Linear and multiple linear regression models were used to test for association between digit length, body weight and stature and were also used to generate predictive expressions. Data management and analyses were conducted using Statistical Package for Statistical Product and Service Solutions (IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp). All tests were two-tailed with a P-value <0.05 set as the limit of statistical significance.

RESULTS

Descriptive statistics of all the parameters taken during the study in all subjects and based on their sex are shown in (Table 1). The age range of the study participants is between 7 – 15 years. A total of 654 (318 boys, 336 girls) schoolchildren in Zaria, Kaduna State, were enrolled in the study. The mean age for the combined subjects was 10.75 ± 1.42 years, whereas for boys and girls, it was 10.75 ± 1.43 and 10.76 ± 1.41 years, respectively.

Table 1: Descriptive statistics of age and all anthropometric variables of all the subjects (n = 654) and according to the sex

	All		Males		Females	
Parameters	**Mean ± SD**	**Min - Max**	**Mean ± SD**	**Min - Max**	**Mean ± SD**	**Min - Max**
n	654	-	318	-	336	-
Age (yrs.)	10.75 ± 1.42	7.00- 15.00	10.75 ± 1.43	8.00- 15.00	10.76 ± 1.41	7.00- 15.00
BW (kg)	32.84 ± 6.82	20.00- 75.00	32.48 ± 6.97	20.00- 75.00	33.18 ± 6.66	21.00- 63.00
HT (cm)	141.43 ± 8.39	118.00- 169.00	140.96 ± 8.24	122.00- 169.00	141.88 ± 8.52	118.00- 166.00
RT 2D	6.06 ± 0.55	4.30- 7.90	6.01 ± 0.51	4.30 ± 7.50	6.11 ± 0.58	4.40 ± 7.90
RT 4D	6.33 ± 0.59	4.10- 8.30	6.29 ± 0.56	4.10 ± 8.30	6.38 ± 0.61	4.10 ± 7.80
LT 2D	6.11 ± 0.56	4.10- 8.30	6.04 ± 0.51	5.00 ± 8.30	6.17 ± 0.59	4.10 ± 7.80
LT 4D	6.32 ± 0.55	4.20- 7.70	6.27 ± 0.52	4.70 ± 7.70	6.36 ±0 .57	4.20 ± 7.70

BW: body weight, HT: height, RT 2D: Right 2nd digit, RT 4D: Right 4th digit, LT 2D: Left 2nd digit, LT 4D: Left fourth digit

Results of the unpaired sample t-test revealed sexual dimorphism in the RT 2D (t = 2.45, P = 0.020), and RT 4D (t = 1.97, P = 0.040). Similarly, the results also revealed sexual dimorphism in the LT 2D (t = 2.83, P <0.005) and LT 4D (t = 2.02, P = 0.040). A comparison of these digits between both sexes showed that girls consistently have higher digits than boys. In contrast, no significant sexual dimorphism was observed in body weight and stature (P > 0.05).

Table 2 shows derived equations that can be used for the estimation of body weight from digit length. The model revealed that RT 2D, RT 4D, LT 2D, and LT 4D are significant (P <0.001) independent predictors of BW in all subjects regardless of sex. The RT 2D, RT 4D, LT 2D, and LT 4D models had moderate to large predictive effects based on the coefficient of determination (r2) ranging from 15

Table 2: Linear Regression of Body weight from digit lengths of male and female children and all subjects

	Parameters	Predictive equation	R	R^2	SEE	P
Male children (n = 318)	RT 2D	-8.931 + (6.892 × RT 2D)	0.50	0.25	6.03681	<0.001
	RT 4D	-2.846 + (5.618 × RT 4D)	0.45	0.21	6.22511	<0.001
	LT 2D	-9.050 + (6.870 × LT 2D)	0.51	0.26	6.01675	<0.001
	LT 4D	-6.933 + (6.282 × LT 4D)	0.47	0.22	6.18076	<0.001
Female children (n = 336)	RT 2D	1.900 + (5.118 × RT 2D)	0.44	0.20	5.98506	<0.001
	RT 4D	5.958 + (4.268 × RT 4D)	0.39	0.15	6.14685	<0.001
	LT 2D	2.982 + (4.897 × LT 2D)	0.43	0.19	6.01226	<0.001
	LT 4D	2.096 + (4.888 × LT 4D)	0.42	0.18	6.05064	<0.001
All subjects (n = 654)	RT 2D	-2.793 + (5.878 × RT 2D)	0.47	0.22	6.02013	<0.001
	RT 4D	1.873 + (4.889 × RT 4D)	0.42	0.18	6.18941	<0.001
	LT 2D	-2.110 + (5.722 × LT 2D)	0.47	0.22	6.02943	<0.001
	LT 4D	-1.952 + (5.5.7 × LT 4D)	0.44	0.20	6.11758	<0.001

Predictive equation of body weight from the parameters used. RT 2D: Right 2nd digit, RT 4D: Right 4th digit, LT 2D: Left 2nd digit, LT 4D: Left fourth digit, SEE: standard error of the estimate, R: correlation coefficient; R2: coefficient of determination, P<0.05 was considered significant.

Table 3: Linear Regression of Body weight from digit lengths of male and female children and all subjects

	Parameters	Predictive equations	R	R^2	SEE	P
Male children (n = 318)	RT 2D	83.231 + (9.607 × RT 2D)	0.59	0.35	6.65654	<0.001
	RT 4D	91.647 + (7.842 × RT 4D)	0.53	0.29	6.98168	<0.001
	LT 2D	84.056 + (9.413 × LT 2D)	0.59	0.35	6.68329	<0.001
	LT 4D	85.833 + (8.786 × LT 4D)	0.55	0.30	6.89857	<0.001
Female children (n = 336)	RT 2D	84.625 + (9.367 × RT 2D)	0.63	0.40	6.60262	<0.001
	RT 4D	86.402 + (8.699 × RT 4D)	0.62	0.39	6.69027	<0.001
	LT 2D	85.534 + (9.137× LT 2D)	0.63	0.40	6.60217	<0.001
	LT 4D	84.211 + (9.068× LT 4D)	0.61	0.37	6.74637	<0.001
All subjects (n = 654)	RT 2D	84.059 + (9.464 × RT 2D)	0.62	0.38	6.61908	<0.001
	RT 4D	88.684 + (8.328 × RT 4D)	0.58	0.40	6.82815	<0.001
	LT 2D	85.044 + (9.232 × LT 2D)	0.61	0.38	6.63274	<0.001
	LT 4D	84.840 + (8.957 × LT 4D)	0.59	0.34	6.81118	<0.001

Predictive equation of height from the parameters used. RT 2D: Right 2nd digit, RT 4D: Right 4th digit, LT 2D: Left 2nd digit, LT 4D: Left fourth digit, SEE: standard error of the estimate, R: correlation coefficient; R2: coefficient of determination, P <0.05 was considered significant.

Table 4: Multiple linear regression for body weight from digit lengths

	Predictive equations	R	R^2	SEE	P
Male children (318)	-14.069 + (3.131 x RT 2D) + (0.225 x RT 4D) + (2.981 x LT 2D) + (1.323 x LT 4D)	0.53	0.28	5.95247	<0.001
Female children (336)	-1.164 + (3.003 x RT 2D) + (-1.282 x RT 4D) + (1.280 x LT 2D) + (2.667 x LT 4D)	0.46	0.22	5.93716	<0.001
All subjects (654)	-7.079 + (3.109 x RT 2D) + (-0.554 x RT 4D) + (1.906 x LT 2D) + (2.048 x LT 4D)	0.49	0.24	5.95023	<0.001

Predictive equation of body weight from the parameters used. RT 2D: Right 2nd digit, RT 4D: Right 4th digit, LT 2D: Left 2nd digit, LT 4D: Left fourth digit, SEE: standard error of the estimate, R; correlation coefficient; R2: coefficient of determination, P <0.05 was considered significant.

– 26%. We also observed that the RT 2D and LT 2D had the largest predictive effect with the smallest standard error of the estimate.

The result also revealed that RT 2D, RT 4D, LT 2D and LT 4D had stronger predictive effects in male children when compared to their female counterparts. The result also revealed that RT 2D, RT 4D, LT 2D, and LT 4D are significant (P <0.001) independent predictors of height in all subjects regardless of sex. Concerning the prediction of stature from digit length, the results revealed that digit lengths are good predictors of stature. Between 29 to 40% (P <0.001) of the variability in stature were explained by digit length (Table 3).

Table 4 presents three multiple regression equations for predicting body weight from the lengths of the right and left second and fourth digits in male and female children, as well as when all subjects are considered together. The values of the correlation coefficient suggest a moderate linear correlation between digit lengths and body weight. Results of the coefficient of determination (R2), on the other hand, indicated that the digit lengths explain about 22% to 28% of the variance in body weight, which is a moderate amount, implying that other factors also play significant roles in determining body weight. Taken together, the moderate R and R^2 values suggest that while digit lengths are useful predictors, they are not the sole determinants of body weight, and additional variables should be considered for more accurate predictions. The standard error of the estimate, which reflects the average distance that the observed values fall from the regression line, is similar across all models, indicating consistent prediction accuracy.

DISCUSSION

Despite the fact that the determination of body weight and height is a standard cycle in clinical practice, its determination becomes difficult in extremely ill patients or in cases of mass disaster where identification is vital [4, 10]. Although the size of a few body fragments has been utilized to approximate weight and height in adults [25], there is paucity of information on the assessment of weight and stature in children. This is likely because of the concern that children are still developing, and as such, their development may influence the assessment of anthropometric variables. Anyway, children are not exempted from restrictions of direct measurement in instances of mass disaster

Table 5: Multiple linear regression equation for estimating height from digit lengths

	Predictive equations	R	R^2	SEE	P
Male children (318)	76.104 + (4.811 x RT 2D) + 0.217 x RT 4D) + (3.296 x LT 2D) + (2.336 x LT 4D)	0.62	0.38	6.51026	<0.001
Female children (336)	77.027 + (3.950 x RT 2D) + 2.241 x RT 4D) + (2.410 x LT 2D) + (1.817 x LT 4D)	0.67	0.45	6.36078	<0.001
All subjects (654)	76.850 + (4.252 x RT 2D) + (1.242 x RT 4D) + (2.905 x LT 2D) + (2.090 x LT 4D)	0.65	0.42	6.41661	<0.001

Predictive equation of body weight from the parameters used. RT 2D: Right 2nd digit, RT 4D: Right 4th digit, LT 2D: Left 2nd digit, LT 4D: Left fourth digit, SEE: standard error of the estimate, R: correlation coefficient, R2: coefficient of determination, P <0.05 was considered statistically significant and in extremely ill patients. Therefore, the present study was done to develop regression equations that can predict body weight and height from the length of right and left 2D and 4D.

The result revealed that female children have longer 2D and 4D in both hands when compared to male children. This is contrary to the reports of Ibegbu et al. [14] and Mutluay and Bozkır [22], who reported longer 2D and 4D in both hands in males when compared to female adults. It was also observed that both male and female children have shorter 2D than 4D in both hands. This could mean that ossification starts in the second digit before the fourth digit in both sexes. This is similar to the work of Danborno et al. [13], who also observed shorter lengths of second digits when compared to the fourth digit in both fingers in both male and female adults in Nigeria but dissimilar to the work of Manning et al. [17] who reported longer 2D in females when compared to the length of the fourth digit.

The length of the 2D in both hands in male and female children, as well as in all subjects, had the largest predictive effect with smallest standard error estimate, indicating that the length of the second digit is a better predictor of BW and height than the fourth digit. This is similar to the work of Mutluay and Bozkır [22], who reported that the right and left 2D lengths of males and females, respectively, have the highest correlation with stature. The result also revealed that right and left 2D and 4D had a stronger predictive effect on body weight in male children when compared to female children, implying that digit lengths are better predictors of BW in male children than in female children. This is in accordance with the investigation of Danborno et al. [13], who r revealed that the length of the right and left 2D and 4D are better predictors of weight in adult males than in females. The length of the right and left 2D and 4D had a stronger predictive effect on height in female children when compared to male children, indicating that both the second and fourth digits are better predictors of height in female children than in male children. This is dissimilar to the result of Danborno and colleagues. This is in line with the work of Christal et al. [26] and Sen et al. [27], who revealed that the correlation between the length of the digits and the stature was higher in women than in men. However, this is dissimilar to the work of Danborno et al. [13] and Raju et al. [28], who reported that the length of the right and left 2D and 4D are better predictors of height in adult males than in females.

As a result, both regression models can be used to estimate the body weight and height from the second and fourth finger lengths in both male and female children. The regression models herein are particularly significant in fields like anthropometry, where body measurements are crucial; forensic science is used to identify unknown individuals; and ergonomic design is used to ensure that products can be tailored to fit various body dimensions. This predictive approach leverages easily measurable physical attributes to provide valuable height and weight estimations without requiring full—body measurements, thus enhancing its practical utility.

The present study has several limitations, including moderate predictive accuracy of 0.38 to 0.45 for height and 0.22 to 0.28 for weight. This means there is still a considerable portion of variance unexplained by the models, such as nutrition and genetic predispositions, which are not included or controlled in the models. Potential measurement errors in digit length lengths can affect the accuracy of the predictive models. The cross-sectional study design limits the ability to infer causation or changes over time. Finally, the study is based on a specific sample (male and female children). The results might not be generalizable to adults or children from different regions, ethnic or racial backgrounds. Therefore, future studies are warranted in different populations and age groups to ensure the generalizability of the findings. Also, future studies should incorporate other potentially influential variables (e.g., genetic factors, environmental influences) to improve the accuracy of the height and weight prediction models. Larger sample sizes can enhance the reliability of the results and provide a more robust estimation model. Implementation of longitudinal studies to track changes over time and observe how predictive accuracy evolves with age. Finally, future studies should explore practical applications of these predictive models in fields like paediatrics, anthropology, and ergonomics to maximize the utility of the findings.

CONCLUSION

In conclusion, the present study's findings provide evidence that second and fourth-digit lengths can be used to estimate the stature and body weight of children aged 7 – 15. The regression equations provide a statistically significant method for the prediction of height and weight from digit lengths in male and female children as well as when all subjects are considered together. The moderate R and R^2 values suggest that while digit lengths are useful predictors, they are nevertheless the sole determinants of body weight and height. Additional variables should be considered for more accurate predictions.

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