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Validation of the Nelson Formula for Estimating the Height of Children in Ogbomoso, Nigeria

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Abstract:- When direct height measurement using a stadiometer or infantometer is problematic or impossible, an age-based formula is needed, but the commonly used Nelson formula has not been adequately validated for use in Nigeria. This study investigated the Nelson height formula in healthy children.

In a cross-sectional study, we recruited 1361healthy children aged 2 to 12 years using a multi-stage random sampling technique. Heights of the children was measured according to the World Health Organisation standard and estimated using the Nelson formula. We compared the two methods of height determination using the Bland-Altman analysis approach with clinically acceptable limit set at 5 cm a priori. Linear regression analysis was also used to examine the relationship between height and age at p = 0.05.

There were 708 (52.0%) males and 653 (48.0%) females, mean age 7.13.0 years. Male and female mean heights at ages 2 to 12 did not differ statistically .On the average, the Nelson formula was 1.3 cm higher than the actual stadiometer height, with 95% limits of agreement ranging from 13.2 to 15.8.The linear regression model that depicts the relationship between height and age as: $\mathbf{Height\ (cm) = 5.2\ x\ age\ (years) + 81.6}\ cm.$
A reasonable agreement between heights calculated using the Nelson formula and height measurements using a stadiometer, but systematic and random biases could be more than plus or minus 5 cm, which is outside acceptable clinical limits. A modified Nelson formula is proposed.

I. INTRODUCTION

The measurement of children’s heights is an essential part of child health practices, whether in the emergency department, admission ward, or consultation clinic settings. A number of diagnostic and treatment decisions are based on height and/or its derivatives, especially when body surface area or body mass index is required[1,2]. Some of these include assessment of nutritional status, determination of equipment size, use of treatment nomograms, estimation of required fluid therapy, drug dosing, and evaluation of diagnostic criteria such as the glomerular filtration rate (GFR).[1-6] Height measurement is also an important component of routine growth monitoring in child welfare clinics and is required for many preventative child health interventions.[7]

The best way to measure a child's height is to use a stadiometer, but this may not always be possible in situations like when a child has an urgent illness, needs to be resuscitated right away, or has restrictions on his or her movements. In some of these cases, using a stadiometer or infantometer to determine the actual height or length may be time-wasting or further compromise child survival, especially during cardio-respiratory support.[8] Anecdotal observations suggest that, in practice, healthcare providers in many community-based care centres, field work, clinics, and hospitals in Nigeria use the age-based Nelson formula for quick estimation of children’s height whenever they face difficulty with height measurement. The Nelson formula is "6n+77," where n is the age in year(s).[9] However, it may not be possible to generalise the Nelson formula, which was based on data from the United States of America, to children in other countries.[8,10] Similarly, the validity of previous formulae that used ulna bone length, hand length, and mid-parental height has been shown to vary across different populations. Therefore, there is the need to evaluate its accuracy in estimating height of children in other settings, especially African population.[1,11,12]

There are, at least, three reasons why height estimation using an age-based formula may be an alternative when actual height measurement is challenging. First, children show some degree of discomfort and sometimes become agitated during the measurement of height and weight.[13]

Second, accurate length or height measurement requires two to three people in the face of inadequate staffing, and this adds to the challenge of the already scarce height measurement equipment in resource-limited areas. Third, due to the agitation those children get during the measurements of height, there are higher chances of errors. This compromises the precision of measurement.

Ideally, normative reference values for anthropometry are population-specific because of the significant variations that exist across geographical boundaries.[14] The exclusion of children in developing countries from the reference population used to derive the Nelson formula for height,

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especially Africans, does not support the appropriateness of its use in those countries. Eke and colleagues[8] in Eastern Nigeria compared the age-based Nelson formula for both height and weight in children and found that the age-based Nelson formula for estimating height underestimates the actual values among a cohort of children presenting in clinics.

In many clinic settings, the opportunity to measure height only arises once, and the health personnel need to decide whether the one-time measured height is within the 3rd and 95th percentile lines. In such situations, the use of the Nelson formula to estimate the expected height for an age becomes necessary as an alternative to using the growth chart at the time of measurement. Therefore, it is expedient to test the accuracy and validity of estimated height obtained using the Nelson formula in the Nigerian context. This study was, therefore, carried out to investigate the accuracy of the Nelson formula for height estimation in children and to develop a new simplified formula specifically for Nigerian children if the Nelson formula shows considerable inaccuracy.

II. METHODS

- ***Study Design and Area*:** This cross-sectional study included children aged 2 to 12 years old from Ogbomoso North Local Government Area (OGBNLGA), Oyo State in Southwest of Nigeria. The OGBNLGA is one of the 33 Local Government Areas in Oyo State, with a land area of 187.36km2 and a projected population of 279,400 in 2016 based on the 2006 census. This study was carried out in crèches, day-care centres, nurseries, and primary schools. There are 88 registered private and public nursery/primary schools (27 public and 61 private) and 20 registered crèche/day-care centres.

- ***Study Population*:** Recent population projections show that children aged 2 to 12 years make up around 9% of the estimated population of OGBNLGA. Although data on the actual school attendance rate for OGBNLGA is limited, the general school attendance rate for Oyo State was projected to be 68.0% in the most recent National Demographic Health Survey (NDHS), 2018. As a result, the school population chosen for this study is expected to yield a representative sample of more than 65% of the study population. Children from OGBNLGA who appeared to be healthy, with no history of chronic illnesses or frequent hospitalisation, were considered eligible to participate in the study. Individuals in the study area were barred from participating if the child displayed obvious signs of chronic illness such as tuberculosis, chronic renal diseases, sickle cell anaemia, or skeletal deformities known to affect height, or if caregivers or parents refused to give consent, or if the child refused to give assent.

- ***Sample Size Calculation and Sampling*:** Assuming an expected mean difference of 5.9 cm between the heights estimated using the Nelson formula and the actual height obtained from using stadiometer, and standard deviation of 29.15 as reported in the study by Iloh and colleagues [15], we estimated a minimum of 416 as the required sample size. This estimate was obtained using the Bland-Altman plot menu Sample Size in the MedCalc Software (MedCalc Software Ltd, Belgium) alpha of 0.05 and 90% power. However, considering the clustering nature of the sample population a design effect factor of 3.0 was used to multiply the calculated minimum sample size and this gives a total of 1248 as the required minimum sample size[16].

We utilised a two-stage sampling technique to randomly select 7 out of 27 public nursery and primary schools, 15 out of 61 private nursery and primary schools, and 5 out of 20 registered crèche/day care centres at the first stage. At the second stage, eligible participants were randomly selected from sampling frames generated using the schools' and centres' official registers stratified by gender. The number of participants who were chosen for each school or centre was based on the size of the school population (children).

- ***Data Collection Procedure*:** The selected schools were visited twice. The initial visit was for the purpose of selecting students and distributing information brochures and consent forms to the students' parents/caregivers. Parents/caregivers are expected to complete the consent form after reading and comprehending the information booklet. The second visit included questionnaire completion and anthropometric measurements of children whose parents or caregivers had consented. To collect information from parents and students, a validated, structured, interviewer-administered questionnaire was used. Each child's age was confirmed using school/hospital data and/or birth certificates. Date of birth, age, sex, degree of educational attainment, and occupation of the parents, as well as family size and birth order of the pupils, are all collected.

The investigator and two trained assistants took height measurements in accordance with World Health Organization (WHO) standards[17]. Each child's height and weight were measured twice by two different individuals, and the average was used to determine the correct measurement. Height was measured for participants over the age of 2 using a calibrated wooden measuring board with a sliding head piece. Each child was asked to stand barefoot on the measuring board, with his back and heel contacting the instrument, his arms at his sides, his heels close together, and his gaze straight ahead. The perpendicular headpiece was then snugly lowered to the vertex of the child's skull. Infantometer was used to measure the length of children under the age of two. Using the eye level with the headboard, the length was measured to the nearest 0.1 cm.

The weights were measured using a battery powered digital scale (Seca, Inc, Columbia, MD, USA), and the corresponding digital infant scale was used for the infants and children that could not stand. Though this equipment is self-calibrating, known weights were used to check its correctness every day, and the investigator ensured the reading was set at zero before each use. The children, wearing light clothing and barefoot, were asked to stand at the centre of the platform with their hands to the sides and the weight was recorded to the nearest 0.1 kg. A general physical examination was carried out in a ‘cubicle’ or a room in each school.

- ***Data analysis:*** Frequencies, means, and medians were used to report demographic data. The Shapiro-Wilk test and histograms were used to determine whether the data was normal. The amount of agreement between heights estimated using the Nelson formula and actual values acquired with the stadiometer was the primary outcome. The paired t-test was used to see if there were any significant differences between the estimated and real heights. The level of agreement between the estimated and real heights was graphically evaluated using the Bland-Altman statistical analysis tool[18]. By evaluating the mean difference between two measures and establishing bounds of agreement using the mean and standard deviation of the difference between the two measurements, the Bland-Altman test can quantify the agreement between two measurements[19]. Our aim is to see if the two methods agree well enough that they can be used interchangeably. The difference between the estimated and actual heights for each research participant was displayed on the y-axis, and the mean of the estimated and actual heights was put on the x-axis. On the plot, the mean difference is represented by a horizontal dash line. Lack of bias is indicated by a tiny mean difference with a horizontal line close to y = 0. The dark grey area on the map represents the 95 percent bounds of agreement, which are defined as the mean difference of 1.96 SD of the discrepancies in the estimated and actual heights. A priori, we set the clinically acceptable level of agreement at 2.0 cm. The authors believed that a difference of 2 cm would not materially impact clinical management, necessitating the use of height measures. To determine the association between sex, age, and actual height, multivariable regression was used. All data analyses were carried out using Stata 17.0 (Stata Corp LLC, Texas, USA) and level of significance set at p = 0.05

- ***Ethical Consideration:*** The study's participation was entirely voluntary and based on informed consent. The information collected was given a serial number rather than a name to preserve participant privacy. Only the researchers were aware of the identity, which was kept private. The study was largely risk-free, as it only required anthropometric measurements and the completion of a form. There was no collection of blood or bodily fluid samples. The Ethics Committee of the LAUTECH Teaching Hospital (LTH), Ogbomoso, gave their approval. The Oyo State Ministry of Education, the Local and Zonal Inspectors of Education for OGBNLGA, and the Headmasters/Headmistresses of the selected schools, as well as the Proprietors of the selected day-care centres, all gave their approval. Before the measurements were conducted, parents or caregivers gave written informed consent, and older individuals gave verbal consent and agreement.

III. RESULTS

A. *Characteristics of study participants*

The study participants comprised 708 (52.0%) males and 653 (48.0%) females.Their ages ranged from 2 to 12 years (median = 7.0 years) and there was no significant difference between the mean ages of male (7.09±3.0 years) and female (7.12±3.0 years), p=0.888. Table I shows that the distributions of all participants by school type, religious belief, tribe, parents' marital status, number of mother's children, and position among mother's children were not significantly different between males and females.

B. *Comparisons Heights by Stadiometer and Estimated Heights by Formula*

The mean heights by stadiometer and the respective 95% confidence intervals of the participants by age and sex were as shown in Figure 1. Notably, the mean heights of the participants increased as the age increases, and the 95% confidence intervals are relatively narrow. However, there were no statistically significant differences between mean heights of male and female participants at each age of 2 to 12 years.

Tables II and III show the mean height and the mean of the differences between heights estimated by formula and actual measurement, as well as the 95 percent confidence ranges for the differences. Male participants' heights calculated by the Nelson formula were significantly lower than actual measures at 4 years (p = 0.001), 6 years (p = 0.048), and 7 years, but higher at 9 years (p = 0.001), 10 years (p = 0.001), 11 years (p = 0.002), and 12 years (p = 0.001) (Table I). The mean heights calculated using the formula were significantly lower than actual measurements only in female participants aged 4 years (p = 0.016), but greater in 2 years (p 0.041), 9 years (p = 0.006), 10 years (p = 0.002), 11 years (p 0.001), and 12 years (p 0.001), respectively as shown in Table III.

In addition, Figure 1 shows the pattern of the mean of the height differences calculated by the Nelson formula and actual measures among male (blue coloured bars) and female (red coloured bars) participants. Figure 1 illustrates that from the ages of 3 to 7, the heights estimated by the Nelson formula were lower than the actual measurements, while after the age of 8, the pattern was inverted, with the heights estimated by the Nelson formula being higher than the actual measurements.

C. *Agreement between Heights Obtained by Nelson Formula and by Stadiometer*

The Bland-Altman plots (Figure 2A and 2B) of heights of all participants shows that the Nelson formula demonstrated an average bias of 1.3 cm higher than the actual height measured on the stadiometer, with the 95% limits of agreement ranging from −13.2 to 15.8. Notably, Figure 2A also showed that the difference between heights estimated using Nelson formula and those measured on stadiometer tend to get larger as the average height increases. Further regression analysis, using these differences as the dependent variable and the average heights as the independent variable, showed that there is significant proportional bias as the average height increases [F(1, 1359) = 24.17, p <0.001; R-squared = 0.02].

However, segregating by biological sex, the Bland-Altman plot shows that the Nelson formula had an average bias of 1.2 cm higher than the actual height measured on the stadiometer, with 95% limits of agreement ranging from -13.2 to 15.7 in male participants, as shown in Figure 2C. Also, figure 2D shows that the average bias of the Nelson formula was 1.4 cm higher than the actual height measured on the stadiometer, with 95% limits of agreement ranging from −13.1 to 15.8. The Bland-Altman plots also showed that 4.7% and 4.8% of the differences between the estimated height by the Nelson formula and the actual height measured on the stadiometer were outside the limits of agreement in male and female participants, respectively.

D. Relationship between Heights Obtained by Nelson Formula and by Stadiometer

The statistical estimates of four regression models generated to examine the relationships among height, age, and sex are shown in Table III. Model I established that age could significantly predict participants' height, F (2, 1358) = 3444.92, p <0.0001. However, sex does not predict height because its coefficient of regression (β = -0.1) was not significantly different from zero (p = 0.728). Age and sex can explain 84.7% of the variability in participants' height. Model II, generated by the exclusion of sex from model I, demonstrated that a statistically significant relationship exists between height and age, F (1, 1359) = 6991.87, and that age could explain 83.7% (R-squared = 0.837; p <0.001). A linear regression equation that depicts the relationship between height and age can be written as: $\text{Height (cm)} = 5.2 \text{ x age (years)} + 81.6\ cm$. The likelihood-ratio test to compare models I and II showed that the two were not significantly different in the performance (p = 0.727).

Characteristics	All participants (N = 1361)		Male (N = 708)		Female (N = 653)		P*
	N	%	n	%	N	%	
Type of school							
Private	867	63.7	459	52.9	408	47.1	0.368
Public	494	36.3	249	50.4	244	49.6	
Religious beliefs							
Islam	434	31.9	224	31.6	210	32.2	0.740
Christianity	924	67.9	483	62.8	441	67.5	
Traditional	3	0.2	1	0.1	2	0.3	
Tribes							
Yoruba	1309	96.2	682	96.3	627	96	0.442
Ibo	11	1.6	5	0.8	16	1.2	
Hausa	36	2.6	15	2.1	21	3.2	
Parents marital status							
Single parent	30	2.2	14	2.0	16	2.5	0.684
Married living with spouse	1272	93.5	663	93.6	609	93.5	
Widowed/Divorced/separated	59	4.3	31	4.4	28	4.3	
Number of mother's children							
1 – 4	1083	79.6	577	80.8	511	78.3	0.884
>4	278	20.4	136	19.2	142	21.7	
Position among mother's children							
First	403	29.6	211	29.8	193	29.4	0.246
2nd to 4th	850	62.5	441	62.3	409	62.5	
Beyond 4th	108	7.9	56	7.9	52	8.0	

Table 1: Characteristics of study participants by gender

n – Number of participants % - Percentage of column total
*P-values obtained by comparing male and female using Chi square test

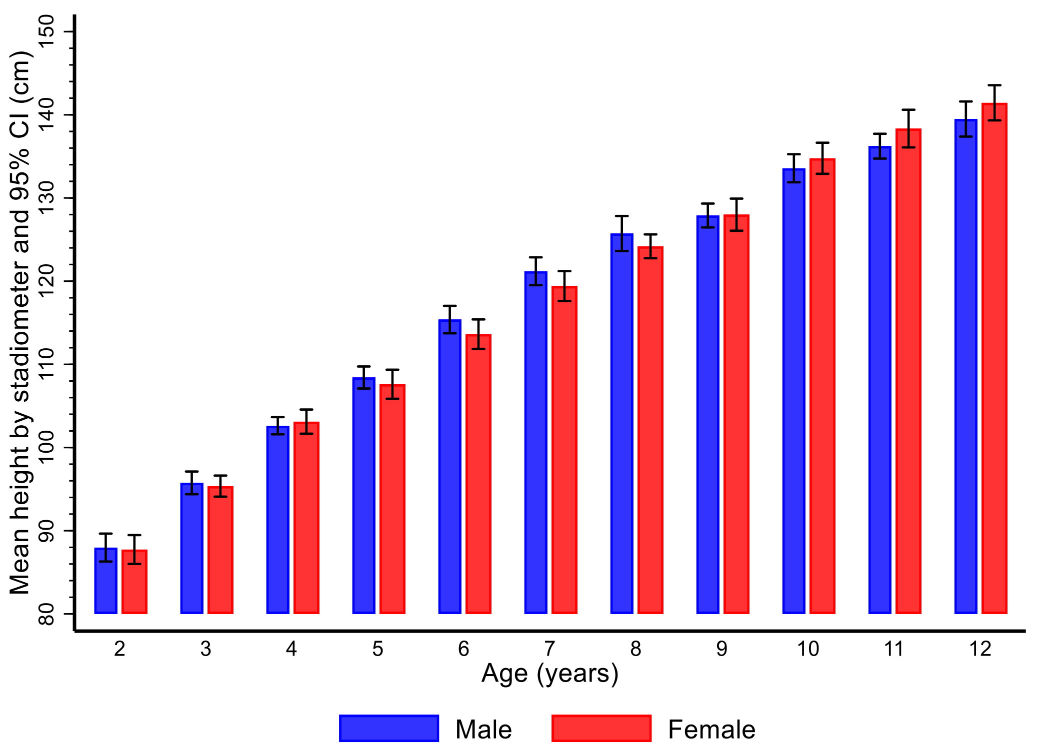

Fig. 1: Mean Height by Stadiometer and 95% Confidence Interval for Male and Female Children

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Age	Male Participants						Female Participants					
(years)	N	*Formula	+Stadiometer	Diff	95% CI	p	n	*Formula	+Stadiometer	Diff	95% CI	P
2	48	89.0	88.2	0.8	87.1, 89.3	0.137	51	89.0	88.0	1.1	87.0, 89.0	0.041
3	64	95	95.1	-0.1	94.1, 96.1	0.887	49	95.0	95.2	-0.2	94.2, 96.2	0.657
4	64	101	102.3	-1.3	101.6, 103.1	0.001	60	101.0	102.1	-1.1	101.2, 103.0	0.016
5	63	107	107.7	-0.7	106.7, 108.6	0.160	67	107.0	107.2	-0.2	106.2, 108,1	0.682
6	70	113	114.0	-1.0	113.0, 115.0	0.048	53	113.0	113.0	0.1	111.8, 114.0	0.847
7	74	119	120.1	-1.1	119.3, 121.0	0.011	67	119.0	119.0	0.1	118.0, 119.9	0.878
8	62	125	125.8	-1.8	124.7, 126.9	0.139	62	125.0	124.1	0.9	123.2, 125.1	0.071
9	71	131	129.5	1.6	128.6, 130.3	0.001	62	131.0	129.6	1.4	128.6, 130.6	0.006
10	75	137	134.98	2.0	134.1, 135.9	<0.001	79	137.0	135.4	1.6	134.5, 136.4	0.002
11	64	143	139.5	1.6	138.8, 140.1	0.002	44	143.0	140.6	2.4	139.5, 141.7	<0.001
12	53	149	145.3	3.7	214.5, 146.1	<0.001	59	149.0	145.7	3.7	144.5, 146.1	<0.001

Table 2: Age- and sex-specific differences between heights calculated by formula and measured by stadiometer

Diff – mean difference *Heights calculated by formula +Heights measured by stadiometer

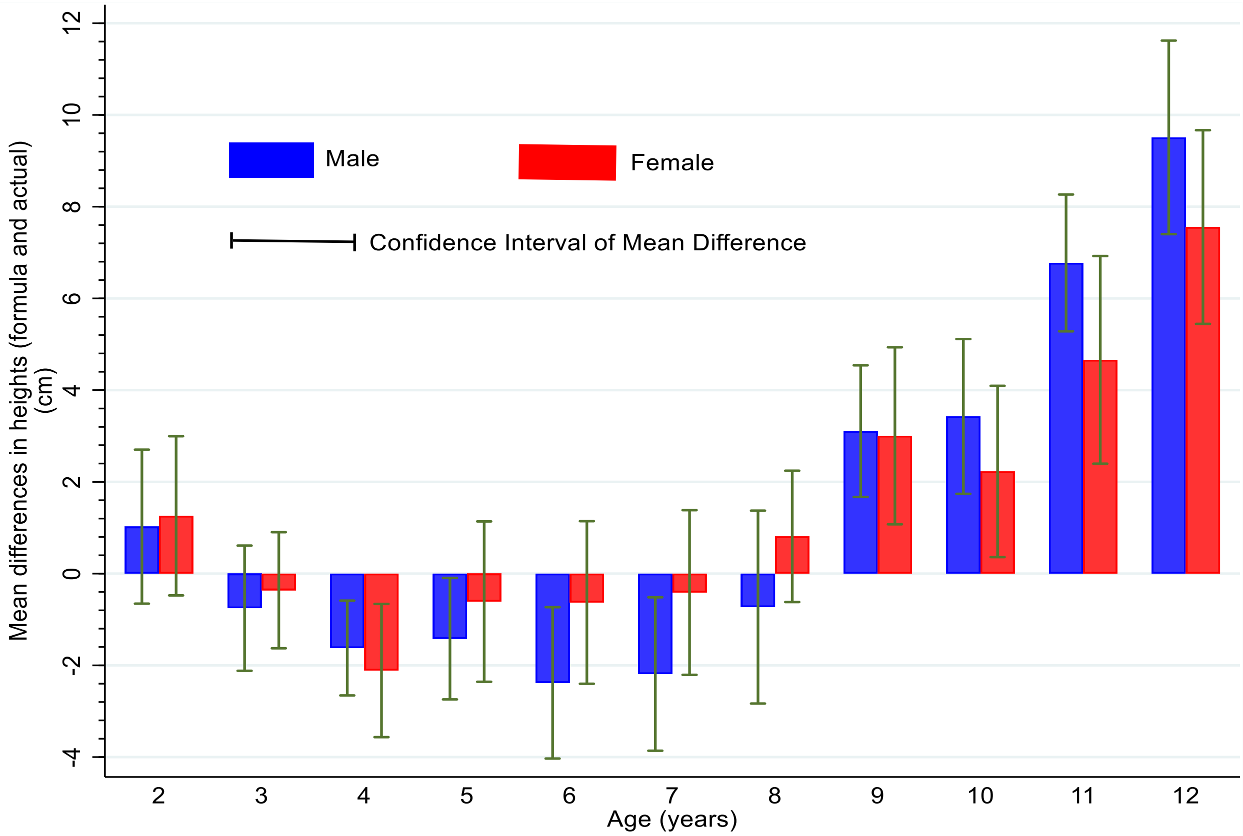

Fig. 2: Pattern of the mean differences and standard deviations by age

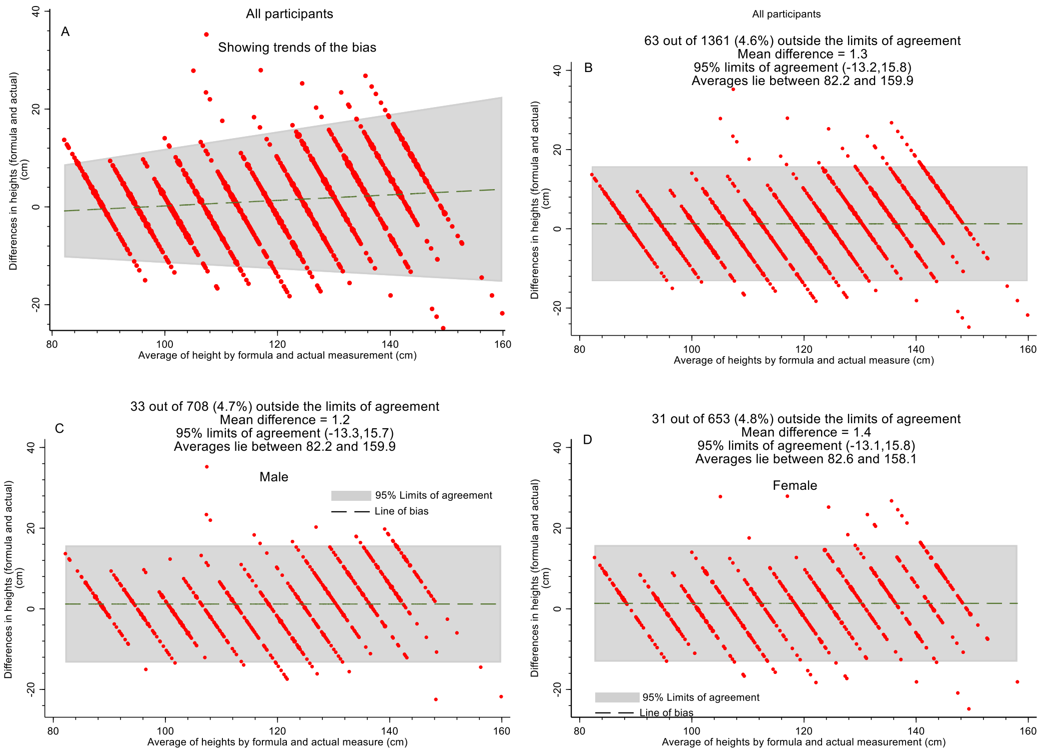

Fig. 3: Bland-Altman plots of the heights obtained using Nelson formula and stadiometer.

Note: The dashed black lines represent the observed mean agreement between the methods, and the grey solid areas represent the 95% limits of agreement

Model	Variables	β	95% CI	p	Model Test Statistics			
					F	df.	P	R-squared
I	Age (years)	5.2	5.1, 5.3	<0.001	3444.92	2, 1358	<0.001	0.847
	Sex	-0.1	-0.9, 0.6	0.728				
	Constant	81.6	80.2, 83.0	<0.001				
II	Age (years)	5.2	5.1, 5.3	<0.001	6991.87	1, 1359	<0.001	0.837
	Constant	81.4	80.5, 82.3	<0.001				

Table 3: Regression Models of Relationships among Actual Heights, Age and Sex

Models I and II– All participants II – Male participants III – Male participants
BIC for Model I = 9154.6, BIC for Model II = 9152.728; LR chi^2 (1) = 0.12; p = 0.727

IV. DISCUSSION

This study found a high level of agreement between heights calculated using the Nelson formula and actual heights measured using a standard stadiometer in all age groups, in both male and female children aged 2 to 12 years. The limits of agreement, which indicate the interval within which 95% of the disparities between the estimates from Nelson formula and stadiometer readings lie when repeated even 95 times, are quite large. Accurate and reliable means of height estimation in children is vital. For instance, measurement of stature (standing height),[20,21] is a prerequisite for determination of body surface area, glomerular filtration rate and body mass index and the use of treatment nomograms like the blood pressure nomograms.[3,22] More importantly, accurate height is required for growth monitory and immediate nutritional assessment of children;[7,23] these important uses of height in clinical practices underscore the need to evaluate the methods by which height estimation is performed in order to ensure the desired high precision. In many clinic settings, opportunity only arises to measure height once and the health personnel needs to decide whether the one-time measured height is within the 3rd and 95th percentile lines. In such situations, the use of Nelson formula to estimate the expected height for age becomes necessary as an alternative to using the growth chart at the time of measurement. Therefore, it is expedient to test the accuracy and validity of estimated height obtained using the Nelson formula in the Nigeria context.

Monitoring a child`s height, weight and development is a routine part of child health care in many countries including Nigeria. In a typical scenario, the health care worker plots heights and weights on a reference diagram and assesses whether the growth pattern of the child deviates from that of the reference population. If so, thorough examination of the child might be needed. Height measurement is, therefore, an important step in identification of diseases and conditions like chronic malnutrition, failure to thrive, precocious puberty, short stature, Turner syndrome, growth hormone deficiency, coeliac disease and many more. Child health workers including paediatricians need to monitor linear growth using height for the purpose of early detection of abnormality and monitoring of response to treatment and/or nutritional rehabilitation. The need-to-know expected height for age in child health practice and the frequency with which paediatricians and other health workers do it underscore the need to get it done accurately and as quickly as possible.

The current investigation discovered a minimal mean discrepancy between estimated and real heights. This conclusion implies that the predicted heights in the study population were close to the heights measured by stadiometer. Unlike an earlier study by Eke and colleagues,[8] the overall mean difference between estimated and real heights in this sample suggests a small overall overestimation of height by the algorithm. Eke and colleagues[24] discovered that formula approaches for calculating heights in children of various ages under-estimate their real values.[8] The observed disparity may be explained in part by the fact that the sample size in the study by Eke and colleagues[24] is smaller than the sample size in the current investigation. Furthermore, the likelihood that the numerous clinical diagnoses on patients' height, particularly chronic illnesses, had a negative impact on the participants' heights in that study cannot be ruled out. Another probable explanation for the study's substantially bigger mean discrepancy between actual and estimated heights could be the inclusion of newborns in the sample population. The Nelson formula proposes 75 cm as the average length of one-year-old children, and height at this age is not supposed to be calculated using the formula[9].

While Eke and colleagues[24] found underestimating of height in all age groups when the Nelson formula was used, the current investigation found noteworthy changes in the disparities between estimated and real heights across the ages. The Nelson formula appears to have somewhat underestimated heights in children aged 3 to 7 years, while overestimating heights in children aged 8 to 12 years. The negative disparity between estimated and actual heights seen at ages 3 to 7 years showed that the Nelson formula was likely to underestimate the participants' heights. While the positive disparity between estimated and actual heights seen at ages 8 to 12 years indicated that the Nelson formula was likely to overestimate the participants' heights. The discovery of a substantial direct positive relationship using linear regression analysis between the discrepancies in heights estimated by Nelson and the actual measurement by stadiometer showed the variation of estimation biases as average height increased. This observation may be explained by the common findings of higher prevalence of stunting among children as age increases, as demonstrated by other authors in their various studies on the prevalence of stunting in school children, such as Adenuga et al[25], Fetuga et al,[26] and Senbanjo et al,[27] in the South West of Nigeria.

Another interesting finding in this study is that the height of both male and female participants increases with age. This observation is consistent with the findings of Eke et al.[8] However, in contrast to another Eke and colleague's[8] finding, which indicated a uniformly higher mean height in male participants, this study revealed that the mean height for both genders was similar across all ages from 2 to 12 years. An earlier study in a similar population found that the prevalence of stunting among children aged 5 to 19 years showed no significant difference in height-for-age of male and female participants[27]. Nevertheless, in that study,[27] the z score values for height-for-age were compared between male and female instead of the actual heights used in the current study. In disparity to the lack of gender differences identified in this study, Eke and colleagues[8] reported consistently higher mean heights in males than females, although no explanation was provided. However, it is well known that female children are taller and heavier than their male counterparts during early puberty, as discovered by this study, due to the pre-pubertal growth spurt occurring earlier in girls than males[28,29]. Similar findings have been reported in two more studies from Nigeria's southeast[30] and north central regions[31].

In the present study, though there appeared to be a reasonable agreement between the heights estimated using Nelson formula and those determined by stadiometer, we observed that the 95% limits of agreement were larger than the acceptable 5% limits set a priori. The 95% agreement, according to Krouwer (2002)[21], integrate both systematic (bias) and random error (precision) and provide a useful measure for assessing the likely variances between individual findings measured by Nelson formula and stadiometer. The huge interval of the limits of agreement found in this study population suggests that the overall error in measuring height using the Nelson formula is unsatisfactory above the 5 cm margin error stated during the study's design stage. A formula for estimation of height which validity is not satisfactorily proven in a particular population cannot produce reliable height estimates, hence, the need for modification of Nelson formula for use in Nigerian children population.

To correct for the bias identified with Nelson formula in this study, we propose an adjustment to the Nelson formula, by simplifying the equation derived by the models tested in our regression analysis as follows: $\text{Height (cm)} = 5 \text{ x age (years)} + 87\ cm$. Within the limit of the internal and external validity of our findings, we believe that this equation will sufficiently explain an estimated 84% of the variation in height among the study population. The benefit of the formula described here is that it provides a simple and alternate way of determining height in clinical situations where actual measurements are not immediately feasible. Clinicians can also use the equation to decide if a child's height is normal by comparing the measurement from a stadiometer with the new equation's estimated value.

Nonetheless, a few points lend credence to the merit of this research. First, the study population could be adjudged to be representative of children aged 2–12 years in Ogbomosho North Local Government Area because the estimated sample size was met. The probability sampling method employed with stratification by age and types of schools reduces selection bias as much as possible. The study was not only powered at 80% but the participants' selection was spread across the geopolitical wards. Other merits of this study are the fact that there was no record of refusal of parents to give consent for the participation of eligible children. Secondly, the measurement of heights and lengths was carried out by two independent trained personnel for each participant. The average value of the two height measurements was meant to guarantee accuracy as much as possible. This limits systematic bias.

However, the non-inclusion of out-of-school children and infants that were not in crèches or day-care centres limit extrapolation of the study findings to all children in Ogbomosho. It remains unknown whether inclusion of such categories of children would remarkably alter the outcomes of the study. Secondly, genetic variations were not investigated in this study. This makes it impossible to rule out the effect of heritable gene on the similarity or otherwise of the estimated heights compared with the directly measured heights.

V. CONCLUSION

This study showed a reasonable agreement between heights estimated using the Nelson formula and real height measurement using a stadiometer; however the width of both systematic and random biases could be more or less than 5 cm, which is outside the range of acceptable clinical limits. As a result, to improve its accuracy, a novel modified Nelson formula is proposed. However, more research is needed to determine the applicability of the modified Nelson formula in bigger and child populations in other parts of Nigeria.

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