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ORIGINAL ARTICLE

Validation of pediatric height estimation formulae in suburban communities in South-east Nigeria: a cross-sectional study

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Keywords

Children • Height • Estimation • Accuracy

Summary

Background. *Height measurement is one of the common essential anthropometric measurements in clinical pediatrics. The most accurate method of determining a child's height is to measure the height. However, in emergency situations and some resource limited settings, obtaining the actual height of a child may not be feasible hence the need to estimate. The most common age-based formulae for height estimation in children is the Nelson-Wheech formula, 6n + 77 where n = age in years. The accuracy of this height estimation formulae has not been assessed in a developing setting like ours with high prevalence of malnutrition. This study therefore sought to evaluate the accuracy of the height estimation formula in children in communities across Enugu southeast Nigeria.*

Method. *Children 2-12 years old who met the inclusion criteria were enrolled over 12 months from three of the 17 Local Government Area of Enugu State. Height was measured using a standard stadiometer and estimated height was calculated 6n + 77. Data collected was analyzed using SPSS.*

Result. *Of the 4046 children enrolled, majority (86.1%) were of normal height. The formula underestimated height of children in the two, 3, 4, 5, 6, 7, 9 and 10 years old categories by a factor of 1.2%-10.0% while overestimating height in 8-year old children by 5.1%, 11-year old by 0.2% and 12-year by 2.9%. Overall, the estimated height using the formula was within ± 10% agreement of the actual height of surveyed children in 77.0% of children surveyed.*

Conclusion. *The 6n + 77 formula is a reasonable but not entirely accurate for height estimation for children in our setting.*

Introduction

Accurate measurement of height is important for assessment of growth, development and nutritional status. Not only is measurement of height necessary for tracking growth and development in children, it is as well important for determining body surface area for pharmacological dosing. Additionally, height is essential in the calculation of body mass index (BMI), one of the most widely used screening tools to monitor nutritional status and obesity. Knowledge of a patient's height is vital for daily practice in the intensive care unit, for either assessment of renal function [1], calculating cardiac function indices or tidal volume setting [2]. In some circumstances, actual measurements of weight or height may not be feasible and estimates becomes imperative. The most accurate method of determining a child's height is to measure the height with an appropriate height measuring tool. However, in some settings, measuring the actual height may not be possible as a result of the child's clinical status and/or unavailability of a height measurement tool. The most used formulae in our setting for height estimation in children aged 2-12 years is *6n + 77* where n = age in years [3]. This so called ''Nelson-Wheech formula'' has little literature as to how it was derived but has universal usage. The accuracy of height estimates derived from this formula has not been validated in a developing setting like ours where an estimated 2 million children suffer from severe acute malnutrition [4]. This study therefore sought to assess the accuracy of the height estimation formula in children in communities in Enugu southeast Nigeria.

Materials and methods

Study area

This study was conducted in Enugu state in south east Nigeria located on latitude 6° 27´N and longitude 7° 30´E [5]. The economy of Enugu state is dependent mainly on national oil revenue and commerce. Enugu state is made up of 17 local government areas and majority of the inhabitants are of Igbo ethnicity with Christianity being the dominant religion. The minimum monthly income like the national average is ₦18,000 (110 US$). Literacy rate is 66%, higher than the national literacy rate of 45%, and there are 955 males per 1,000 females [6]. The fertility rate and neonatal mortality rate is similar to the national mean of 4.5 births per woman and 40 per 1,000 live births respectively [6].

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Study design, subject and sampling technique

This is a community based cross-sectional descriptive and analytical study conducted over 12 months among children aged 2 to12 years recruited from pre-school and primary schools in three of the 17 Local Government Area of Enugu State. Prior to the commencement of the study, the study protocol was explained to the parents and caregivers during the parents-teachers association meeting.

Multi-stage sampling method was used to select study participants (Fig. 1). In the first stage, convenient sampling method was used to select 3 LGAs based on proximity to the researchers. In the second stage, one community was selected from each LGA using simple random sampling. In the third stage, two schools (i.e. one private and public school) were selected from each community using simple random selection process. Each selected school had children in pre-school (2-5 years) and primary school (6-12 years). The number of children enrolled from each school was based on pupil's population in each school. With proportionate allocation method, the sample size of each school was proportionate to the population of the school. Strata sample sizes are determined by the following equation: $_{Nh} = (Nh / N)* n$; where Nh is the sample size of each school h, Nh is the population size for school h, N is the total population size of the schools to be studied and n is total sample size. The children enrolled were selected randomly using a computer-generated table of random numbers. Following this, the selected children were given a take-home questionnaire for their parents to complete as well as a consent form to be signed and/or thumb printed. They were instructed to return the questionnaires the next day which was the day for the study. Respondents who were seven years of age and above who returned a well completed questionnaire with an endorsed consent form from their caregivers were given the assent form before enrollment. The anthropometric data of all the selected participants were taken.

Based on malnutrition rate 39.4% [7], a three percent margin of error and an anticipated non-response rate of 10% the minimum number of children needed to make a valid assessment of height estimation was 1122 for each community giving a total minimum sample size of 3366. The choice of this prevalence of malnutrition was because it was the closest locally available published cross-sectional survey among primary school children that assessed both under- and overnutrition and reported the total prevalence of malnutrition.

Inclusion criteria

In this study were included both pre-school age and primary school age individuals:

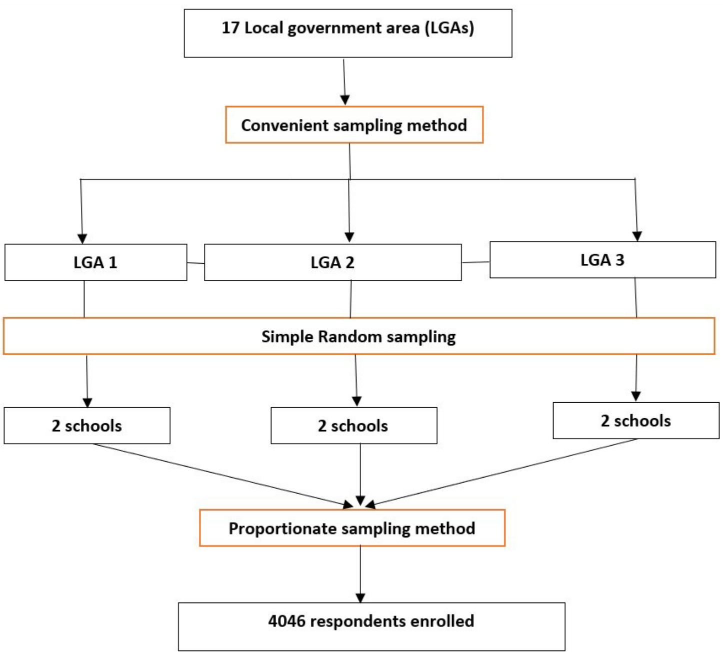
1. Children between the ages of 2 and 12 years.
2. Children who had lived in the study area for at least 12 months and completed the three terms of the preceding academic year in the present school.
3. Children whose parents and/or caregivers gave consent and completed the accompanying questionnaire and/or aged seven years and above who gave assent.

Measure

Height measurements

Height was measured to the nearest 0.1 cm using a stadiometer [SECA213, Hamburg August 2014] by trained research assistants. This stadiometer has a measuring range of 20-205 cm with a precision of up to 0.1 cm. The participants stood with the weight evenly distributed on both feet, heels together and the head positioned so that the line of vision was at right angles to the body. The correct position for the head is in the Frankfort plane [8] i.e. low-

Fig. 1. Summary of sampling technique in recruitment of study respondents.



er margins of the orbits and the upper margins of the ear canals lay in the same horizontal plane. The hands hung freely by the sides. The head, back, buttocks and heels were positioned vertically so that the buttocks and heels were in contact with the vertical board to obtain a consistent measure. The subjects were asked to inhale deeply and stretch to their fullest height. The measurements were taken to the nearest 0.1 cm. A repeat measurement was taken by a second reader after asking the subject to step off and step back onto the stadiometer while observing all the previous steps. Where the two measurements disagreed by equal to or more than 0.5 cm, a third measurement was taken. The subjects measured height was the mean of the two observations or the mean of the two closest measurements if a third is taken [9]. The estimated weight was also calculated using the Nelson-Wheech formula, *6n+77* where n is the age at the child's last birthday.

Socio-demographic characteristics

i) Age of respondent: in years at last birthday was assessed and grouped into eleven categories from 2-12 years *ii) Socioeconomic status:* defined as the wealth index of the household was derived using maternal and paternal highest educational attainment and occupation based on Oyedeji classification [10]. This was then categorized as lower, middle, and upper class; *iii) Stunting* was calculated using Height-for-age Z score using WHO Anthro-Plus software Values which were compared to the recommended 2007 WHO growth charts. Based on the z-score, respondents were re-categorized as severely stunted, stunted, normal and tall.

Data collection and statistical analysis

Data collected were inputted into the relevant sections of the questionnaire and subsequently transferred into a Microsoft Excel Sheet. Statistical analysis was performed using SPSS (version 21; SPSS Inc., Chicago, IL USA) software To compare the heights estimated using formula and actual height, the absolute error (estimated height minus measured height) were calculated and the mean percentage error [100 x (estimated height minus measured height)/measured height]. A Bland-Altman plot was displayed to graphically present the bias and 95% limits of agreement. The percentage differences (errors) between estimated and measured heights were plotted on the y-axis while the averages of the two were on the x-axis. The green lines represented the line of agreement (LOA) while the red lines represent the limits of agreement (confidence interval) showing the degree of reliability.

Results

Characteristics of children enrolled

Four thousand and forty-six children (4046) were enrolled for this study. The male to female ratio was 0.94 and almost half (46.0%) were from the families of low socio-economic status. Majority of the enrolled children (86.1%) had normal height for age while approximately 1-in-10 were tall for age. Ninety-two of the 4046 (2.3%) surveyed children were stunted with 6/92 (6.5%) of these being severely stunted (Tab. I).

Mean difference and Mean Percentage Error (MPE) of formula for height estimation

Tables II and III show the mean difference and MPE (or measurement bias) of the height estimation formula. It was noted that the formula underestimated height of children in the 2-7 and 9-10 years old categories by a factor of 3.0%, 4.4%, 7.2%, 5.6%, 10.0%, 7.8%, 4.8%

Tab. I. Summary statistics of children enrolled in study.

Study parameter	Variables	Frequency (n)	Percentage (%)
Age of respondents[†1]	2 years	104	2.6
(N = 4046)	3 years	86	2.1
	4 years	69	1.7
	5 years	57	1.6
	6 years	366	9.0
	7 years	508	12.6
	8 years	636	15.7
	9 years	681	16.8
	10 years	685	16.9
	11 years	482	11.9
	12 years	373	9.2
Gender	Male	1971	48.7
(N = 4046)	Female	2075	51.3
Socio-economic class	High	1053	26.0
(N = 4046)	Middle	1133	28.0
	Low	1860	46.0
HFA z-score category[†2]	Severe stunting	6	0.6
(N = 4035)	Stunted	86	2.1
	Normal	3923	86.1
	Tall	448	11.1

[†1] Age at last birthday, [†2] Height for age

Tab. II. Difference in height between the mean formulae estimation and actual measurement in each age category.

Variables	Formulae estimation		Actual height	Difference	Confidence Interval
Age category	N	Mean	Mean ± SD†	Mean ± SD†	(Lower, upper)
2 years	104	89.0	92.3 ± 8.3	-3.2 ± 8.3	-4.9, -1.9
3 years	86	95.0	99.7 ± 6.4	-4.7 ± 6.4	-6.2, -3.4
4 years	69	101.0	109.2 ± 6.6	-8.2 ± 6.6	-9.7, -6.7
5 years	57	107.0	113.8 ± 6.8	-6.8 ± 6.8	-8.5, -4.9
6 years	366	113.0	126.2 ± 9.4	-13.2 ± 9.4	-14.3, -12.2
7 years	508	119.0	131.7 ± 53.7	-12.7 ± 53.7	-18.2, -9.8
8 years	636	125.0	133.9 ± 10.9	-8.9 ± 10.9	-9.8, -8.2
9 years	681	131.0	137.7 ± 8.5	-6.7 ± 8.5	-7.4, -6.1
10 years	685	137.0	140.7 ± 9.8	-3.8 ± 10.8	-4.7, -3.0
11 years	482	143.0	143.9 ± 17.7	-0.9 ± 17.7	-2.8, 0.4
12 years	373	149.0	145.5 ± 9.7	3.4 ± 9.7	2.5, 4.4
Overall	4046	128.3	134.5 ± 24.4	-5.9 ± 29.1	-7.0, -5.6

† Standard deviation

Tab. III. Mean Percentage Error (MPE) or BIAS for formulae estimated heights.

Age variable	Mean Percentage	Confidence interval of MPE (%)		
	Error (%) †	Standard deviation	Lower	Upper
2 years	-3.0	7.2	- 20.9	-17.1
3 years	-4.4	6.1	- 16.4	7.6
4 years	-7.2	5.6	-18.2	3.8
5 years	-5.6	5.8	-17.0	5.8
6 years	-10.0	6.4	-22.5	2.5
7 years	-7.8	7.0	- 21.5	5.9
8 years	5.1	28.7	- 61.4	51.2
9 years	-4.8	5.9	-16.4	6.8
10 years	-1.2	33.5	- 66.9	64.5
11 years	0.2	8.0	- 15.9	15.5
12 years	2.9	7.1	- 16.8	11.0
Overall	-2.1	115.1	- 227.7	223.5

† Positive and negative values of MEP indicate over- and under-estimation of height respectively.

and 1.2% respectively while overestimating height in 8-year old children by 5.1%, 11-year old by 0.2% and 12-year by 2.9%. Figure 2 shows the Bland Altman plot of the estimated heights using the formula.

Accuracy of formula for height estimation

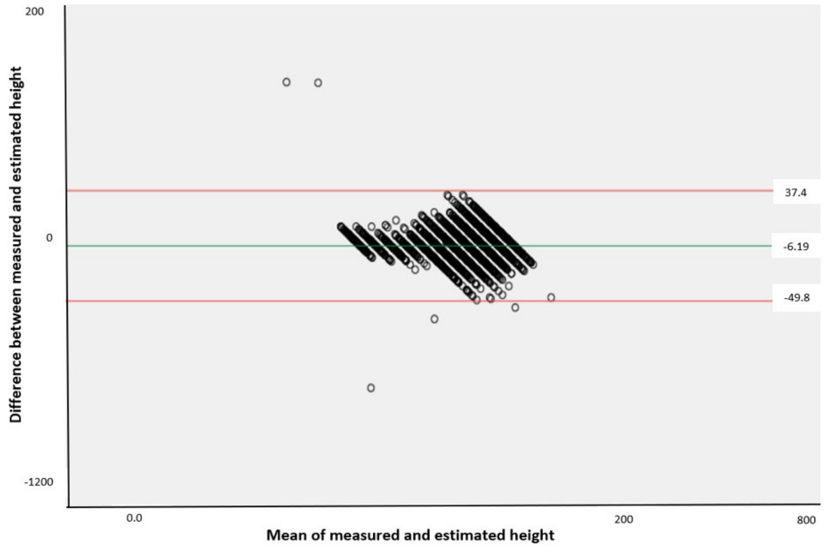
Overall, the estimated height using the formula was within ± 10% and ± 20% agreement of the actual height of surveyed children by 77.0% and 97.9% respectively. Table IV shows the degree of agreement stratified by age categories. The accuracy of the formula in estimating actual height within 10% interval of actual height was greatest in children that were two year old (85.6%), 9-years (83.0%), 10-years (87.3%) 11-years (86.3) and 12-years (83.9%) but worst in 6-years old children where its accuracy was slightly above 50%. The estimated height was fairly accurate and in agreement within 20% of the actual heights for all age categories (Tab. IV).

Discussion

Height measurement is one of the common essential anthropometric measurements for calculation of body mass index and body surface area [11]. These parameters are useful in adjusting drug dosage [12]. The knowledge of the accurate height of a child is an invaluable tool in pediatric practice hence the need to determine the accuracy of the common formula used in height estimation especially in emergency situations when the actual height of the child may be difficult to determine.

Our study showed that the formula estimated heights underestimated height in children surveyed. It was further noted that the underestimation of height progressively worsened as age increased from 2 to 6 years. Eke et al. [13], also documented similar results of an underestimation of the heights of children with the formula in 370 children in Enugu, Nigeria. Beyond 6 years, the formula calculated height followed no clear pattern of estimation error compared to the actual height. While the authors cannot give a concrete explanation for this finding, we believe that the effect of genetics and sex hormones in older children that results in non-linear growth curves may make prediction or estimation of height be more difficult using formula alone. This is unlike in younger age where growth curve is linear, and nutrition is the main determinant [14]. This reasoning is buttressed by a study conducted in 20 countries, including 180,520 paired measurements of heights in ages 1-19 years which showed that the relative genetic

Fig. 2. Bland-Altman plot of mean difference and average of measured and estimated height (Graph scaled to size for adequate formatting; Standard Deviation =22).



Tab. IV. Agreement within 10 and 20% actual height of Formulae Estimated Height.

Age	Estimated Height AGREEMENT with Actual Height		
(years)	N	Within ± 10%	Within ± 20%
2	104	89 (85.6)	103 (99.0)
3	86	66 (76.7)	86 (100.0)
4	69	43 (63.2)	68 (100.0)
5	57	43 (75.4)	57 (100.0)
6	366	194 (53.0)	335 (91.5)
7	508	351 (69.1)	494 (92.7)
8	636	437 (68.7)	621 (97.6)
9	681	565 (83.0)	679 (99.7)
10	685	598 (87.3)	683 (99.7)
11	482	416 (86.3)	472 (97.9)
12	373	313 (83.9)	363 (97.3)
Overall	4046	3115 (77.0)	3961 (97.9)

contribution increased with age and was greatest in adolescence [15].

Additionally, our study showed based on the Bland Altman plot that the estimated height was well clustered around the line of agreement and vast majority of the under and overestimated height were well within the limits of agreement. Overall, the estimated height using the formula was 77% of cases within ± 10% of actual height and in 97.9% measures within ± 20% agreement of the actual height of surveyed children. This suggests that the formula though not entirely accurate for children in our setting, is a reasonable clinical tool for height estimation especially in children less than 6 years in scenarios where conventional height measurement is either unavailable or impossible. We therefore recommend further study that would explore derivation of formula that is better suited for height estimation in children from developing setting like ours.

Limitations

Due to logistic and proximity to researchers, convenience sampling method was used in the selection of the study locations. This may have resulted in sampling and recruitment bias. However, the authors aimed to improve the validity and reliability of the data by employing multi-stage sampling technique and using the same research assistants and measurements tools across the 3 communities surveyed.

Conclusions

We conclude that the *6n + 77* formula is a reasonable but not totally accurate for height estimation for children in our setting. We recommend further study to assist in the devising of a height estimation formula that is better suited for children in developing settings like ours.

Ethics approval and consent to participate

Ethical approval was obtained from the Ethics and Research Committee of the University of Nigeria Teaching Hospital. Informed consent was obtained from the parents of the children. The retrieved information was transferred into a private computer and pass worded. Data was anonymized, and questionnaires had no names. Participation in the study was entirely voluntary, and no financial inducement whatsoever was involved. Participants were informed that voluntary withdrawal at any stage of interaction was guaranteed for them without any adverse effect.

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Conflict of interest statement

The authors declare no conflict of interest.

Authors' contributions

KKI, OOI and ONI conceptualized the study. IKK and ODIC developed and wrote the methodology. ODIC did the statistical data analysis of study and wrote the result section of the work. OOI, UCA and OHN wrote the discussion of the study. All authors contributed in writing and reviewed the final draft of the manuscript.

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