ORIGINAL ARTICLE

Estimation of Height Using Body Weight and Segmental Measurements in Children with Cerebral Palsy

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Abstract

Objectives

The current study aimed to determine the proxy measurements for height in children with Cerebral Palsy (CP).

Materials & Methods

In a cross-sectional descriptive study, the length/height of Nigerian children with CP was studied over eighteen months using descriptive statistics. The study subjects comprised children aged 15 months to 17 years with CP. Height/length, weight, arm span, forearm length, mid-upper arm circumference, foot length, head circumference, hip circumference, leg length, and tibia length were measured to the nearest 0.1 cm using standard procedures. The relations between segmental measurements and weight with height were investigated using linear regression.

Results

A total of 31 children were studied. The correlation between height/length and other linear measurements has a significantly strong positive relationship. Regression analysis showed that when used singly, the weight and thigh length offered a high explanation for the height variability with little estimation error. On the other hand, weight had a lower mean difference between observed and predicted height (0.21 and -0.76, respectively), with thigh length overestimating the height.

Conclusion

Weight measurement may be the preferred proxy for height in children with CP.

Keywords: Segmental Length, Cerebral Palsy, Height Estimation, Anthropometry
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Introduction

Cerebral palsy (CP) describes a group of cerebral dysfunctions resulting from non-progressive (static) injuries to the developing human brain occurring before, during, or shortly after birth (1). It primarily affects motor function, but other brain functions may also be affected (2). several clinical types of CP exist in which the actual aetiologic causes are not known, but a higher preponderance is commoner in babies whose birth weight is less than 2500g, and in all, these babies account for about one-third of all babies who later have signs of CP (3).

Children with CP have feeding problems that limit caloric intake. This can eventually lead to protein energy malnutrition (PEM) (4 - 6). In other words, CP and other chronic health problems are often complicated by overt malnutrition and more subtle nutritional deficiencies (7 - 9). Therefore, the nutritional status of affected children should be thoroughly assessed.

The periodic measurement of height, head circumference, arm span, and weight are important parts of routine healthcare for children, and comparison of these measurements against reference standards or norms can serve as a screening tool for nutritional problems (8 – 12). The need for periodic anthropometric measurements extends to children and adolescents with CP (2, 8, 10). However, difficulties exist in obtaining accurate measurements of height in children and adolescents with CP because of the structural deformities arising from muscle wasting and contractures in the limbs commonly seen in them (11 - 13). Therefore, proxy measurements for height are needed to assess growth and nutritional status in children with CP.

This study was carried out to determine the relationship between segmental length and actual height, as well as between length and weight among children with CP attending the Paediatric Neurology Clinic of Olabisi Onabanjo University Teaching Hospital (OOUTH), Sagamu, Nigeria. Expectedly, information derived from the current study would enhance the overall care of children with CP. It should provide a simple growth assessment tool for children with CP that will help clinicians provide timely interventions. Unsurprisingly, the data generated provide an assessment tool to monitor the growth and nutritional status of children and adolescents with CP in our practice area.

Materials & Methods

The study site was the Pediatric Neurology Clinic of Olabisi Onabanjo University Teaching Hospital, Sagamu (OOUTH), a semi-urban tertiary health center in Ogun State, Western Nigeria. It is a major referral center serving Ogun State, a gateway into Nigeria, and a few adjoining states such as Lagos and Ondo. The Pediatric Neurology Clinic of OOUTH runs once a week on Mondays with a total of 15 -25 children and adolescents aged 17 years and below with neurological disorders seen every week.

The study was a cross-sectional descriptive one involving children with CP. Subjects were recruited consecutively until the desired sample size was attained. This lasted from 1st July 2015 to 31st of December 2016. Ethical approval for the study was obtained from the Health Research Ethics Committee of OOUTH, Sagamu. The parents/caregivers of the subjects for the study were fully briefed on the research protocol in a language they understood, after which written informed consent was obtained. Confidentiality was maintained throughout the study and after that by assigning the study identification number.

The principal investigator performed a detailed neurological examination on all the studied subjects. CP was diagnosed based on two key findings: evidence of non-progressive damage to the developing brain and the presence of a resulting impairment of the motor (neuromuscular) control system of the body and the latter usually accompanied by a physiological impairment and functional disability (14, 15). None of the patients had any other chronic systemic illness (cardiac, renal), chromosomal disorder, or history regarding using medications (e.g., steroids) known to affect growth.

The inclusion criteria included confirmation of CP by clinical diagnosis and children with mild-moderate spastic CP without severe contracture that will limit the movement of their limbs. The exclusion criteria included children with severe spastic CP with severe contracture that the limb cannot be sufficiently stretched for measurement and children with other causes of bony deformities. (e.g., congenital talipes equinovarus, trauma, and burns), children with co-morbidities like cervical cord lesions (e.g., tethered cord), and children on long-term use of steroids and other drugs known to affect growth.

The sample size was calculated using the formulae for correlation coefficient (16) stated below:

$N = [(Z1\text{-}\alpha/2 + Z1\text{-}\beta) / C(r)2]2 + 3$

Based on the level of Type I error set at 0.05, level of Type II error set at 0.2, Standard normal deviate of type I error/alpha ($Z1\text{-}\alpha/2 = 1.96$), Standard normal deviate of type II error/beta ($Z1\text{-}\beta = 1.28$), correlation coefficient between height and arm span set at 0.96 based on a similar study conducted in India (17), the minimum sample size calculated was 18.

The study recruited children of both sexes aged between one and 17 years who were diagnosed with CP at the Pediatric Neurology Clinic of OOUTH, Sagamu. Consecutive subjects with CP who came for routine follow-up clinic and has satisfied the study criteria were recruited.

The anthropometric measurements included weight, body length or height, forearm length, leg length, and arm span, measured following the standard procedure. As earlier reported (17-21). Only the principal investigator, with the assistance of a hospital aide, carried out all measurements to eliminate inter-observer variability. The weight was measured using a calibrated weighing scale (Seca®). The measured weight was recorded to the nearest one decimal place (0.1 kg). Height was measured using a Stadiometer (Seca®). Recumbent length was measured in children who could not stand using the length board. Height/length measurements were recorded to the nearest 0.1 cm. The flexible inelastic measuring tape was used to measure forearm length, leg length, and arm span. The various linear measurements were taken two times, with the mean recorded and used for analysis.

Data were recorded in a data entry proforma and subsequently double-entered into SPSS 19 for analyses. Measures of statistical location like mean and standard deviation were calculated for continuous variables. Means were compared using Student's t-test or analysis of variance, while proportions were compared using chi-square tests or Fisher exact test as appropriate. Inter-relationships among segmental lengths, weight, and height were investigated using linear regression. Comparison of regression equations was made using standard error of the estimate (SEE), measuring the accuracy of predictions or errors attached to a prediction (22). Heights predicted from segmental measurements and weight were compared to actual measured heights using paired Student's t-tests. P-values less than 0.05 were regarded as statistically significant.

Results

Age and gender distribution of study subjects

Fifty-three children attended the routine follow-up during the study period; however, only 31 patients could have linear measurement using the standard method and were subsequently analyzed statistically. The remaining 22 patients were not included in the analysis because of their severe spasticity, making linear measurement using the standard method impossible. The age and gender distribution of the subjects are shown in Table 1. The mean (standard deviation) age of the study subjects was 6.07 (4.34) years, ranging from 15 months to 17 years. Ten (32.3%) of the study subjects were females. Almost half of the study subjects were younger than five years of age.

Mean values of the linear measurement

The results of mean values of weight, height/length, and segmental length among study subjects are shown in Table 2. The mean values of all measurements were highest among the subjects younger than five years. The patterns observed between the subjects aged 5-10 years and those older than ten years were markedly different. The mean values for height/length, leg length, and thigh length further decreased through the age range studied, whereas a steady rise was observed between subjects 5-10 years and subjects older than ten years for the mean values of weight, OFC, hip circumference, foot length, arm length, and forearm length. However, the observed difference was only statistically significant for Mid-Upper Arm Circumference ($p = 0.037$).

Correlation coefficients between length/height and alternative linear measures

The correlation between length/height and other linear measurements are shown in Table 3. A significant relationship existed between height/length and other liner measurements irrespective of age ($p < 0.05$). The hip circumference was observed to have a weak relationship with height.

Following age stratification, the relationship between height/length and other liner measurements remained good except for hip circumference in all age categories, leg length for subjects aged 5-10 years, as well as for OFC and MUAC among subjects older than ten years. However, none of the linear measurements have a statistically significant correlation coefficient among subjects older than ten years. The mid-upper arm circumference was the only linear measurement with a significant correlation coefficient across all the age categories. Age has a poor relationship with length and height across all age categories and irrespective of age group.

Regression equations for height prediction among study subjects

The regression equation presented in Table 4 shows how various alternative measurements predicted length/height among study subjects. Weight and thigh length were associated with a higher coefficient of determination (0.808, 0.798 respectively) and lower standard error (13.366, 13.055, respectively) than other linear measurements.

Comparison between height values measured and height obtained by predicted equations of the current study

The analysis comparing the measured height with the heights predicted from the regression equations derived from the current study using weight and segmental measurements as independent variables are shown in Table 5. Irrespective of the measurement included in the models derived, the overall mean predicted heights of study subjects were significantly different from the mean measured length/heights. Of the derived models, forearm and foot lengths had the lowest variations between actual and predicted height, with a mean difference of 0.11 and 0.13, respectively.

Table 1. Age and gender distribution of study subjects.

Age Group	Male	Female	All
1 – 5 years	9 (52.9)	6 (54.5)	15 (53.5)
>5 – 10 years	5 (29.4)	3 (27.3)	8 (28.6)
>10 years	3 (17.7)	2 (18.2)	5 (17.9)
All	17	11	28

$\chi = 0.015$ $p = 0.993$

Table 2. Mean values of the linear measurement.

Variable	1 – 5 years	>5 – 10 years	>10 years	All	p-value
Weight (Kg)	19.68 (13.96)	11.39 (5.67)	11.94 (3.68)	15.52 (11.08)	0.309
Length/Height (cm)	100.42 (33.41)	82.81 (15.86)	77.18 (35.74)	91.62 (29.95)	0.229
Occipito-Frontal Circumference (cm)	46.43 (4.29)	43.60 (5.69)	45.64 (2.67)	45.58 (4.60)	0.895
Leg Length (cm)	26.93 (9.72)	23.00 (6.78)	20.58 (4.96)	23.77 (8.08)	0.219
Hip Circumference (cm)	48.21 (13.63)	38.90 (10.02)	41.64 (10.20)	43.64 (12.74)	0.659
Foot Length (cm)	15.25 (4.97)	12.78 (2.42)	14.20 (2.88)	14.23 (3.98)	0.814
Mid-Upper Arm Circumference (cm)	17.35 (4.09)	14.40 (2.83)	15.68 (1.59)	16.16 (3.43)	0.559
Arm Length (cm)	18.61 (5.96)	16.60 (4.14)	18.94 (4.47)	18.01 (5.05)	0.744
Thigh Length (cm)	27.29 (10.14)	22.80 (6.14)	21.90 (4.84)	24.76 (8.31)	0.304
Forearm Length (cm)	17.52 (6.55)	15.30 (2.75)	15.58 (2.30)	16.38 (4.40)	0.454

Table 3. Correlation coefficients between height and alternative linear measures.

Variable	1 – 5 years r (p-value)	>5 – 10 years r (p-value)	>10 years r (p-value)	All r (p-value)
Weight (Kg)	0.969 (<0.0001)	0.968 (<0.0001)	0.747 (0.253)	0.893 (<0.0001)
Occipito-Frontal Circumference (cm)	0.893 (<0.0001)	0.818 (0.013)	0.219 (0.781)	0.698 (<0.0001)
Leg Length (cm)	0.730 (0.007)	-0.241 (0.565)	0.663 (0.337)	0.697 (<0.0001)
Hip Circumference (cm)	0.621 (0.031)	-0.158 (0.709)	0.343 (0.657)	0.521 (0.011)
Foot Length (cm)	0.975 (<0.0001)	0.865 (0.006)	0.622 (0.378)	0.883 (<0.0001)
Mid-Upper Arm Circumference (cm)	0.891 (<0.0001)	0.627 (0.096)	0.145 (0.855)	0.759 (<0.0001)
Arm Length (cm)	0.930 (<0.0001)	0.961 (<0.0001)	0.511 (0.489)	0.811 (<0.0001)
Thigh Length (cm)	0.926 (<0.0001)	0.915 (0.001)	0.889 (0.111)	0.899 (<0.0001)
Forearm Length (cm)	0.867 (<0.0001)	0.684 (0.062)	0.804 (0.196)	0.817 (<0.0001)

Table 4. Regression of height and alternative linear measures.

Independent Variables	Equation	R2	SEE (cm)
Age (years)	103.5 – 2.0 Age	0.088	29.283
Weight (Kg)	56.6 + 2.3 Wt	0.798	13.776
Occipito-Frontal Circumference (cm)	4.7 OFC – 122.3	0.487	21.965
Leg Length (cm)	34.2 + 2.4 LL	0.485	21.997
Hip Circumference (cm)	42.0 + 1.2 HC	0.272	26.168
Foot Length (cm)	2.9 + 6.3 FoL	0.780	14.387
Mid-Upper Arm Circumference (cm)	6.3 MUAC – 9.3	0.577	19.951
Arm Length (cm)	10.4 + 4.6 AL	0.658	17.929
Thigh Length (cm)	14.4 + 3.2 TL	0.808	13.444
Forearm Length (cm)	6.6 + 5.2 FL	0.667	17.690

Wt = weight OFC = Occipito-Frontal Circumference LL = Leg Length

HC = Hip Circumference FoL = Foot Length MUAC = Mid-Upper Arm Circumference

AL = Arm Length TL = Thigh Length FL = Forearm Length

Table 5. Comparison of measured height with predicted heights.

Segmental Measurements	Predicted Height (cm) Mean (SD)	Measured Height (cm) Mean (SD)	p-value
Age (years)	91.41 (9.01)	91.62 (29.95)	0.973
Weight (Kg)	91.36 (26.58)	91.62 (29.95)	0.928
Occipito-Frontal Circumference (cm)	93.23 (21.06)	91.62 (29.95)	0.723
Leg Length (cm)	90.85 (20.58)	91.62 (29.95)	0.866
Hip Circumference (cm)	93.19 (16.09)	91.62 (29.95)	0.770
Foot Length (cm)	91.18 (26.32)	91.62 (29.95)	0.883
Mid-Upper Arm Circumference (cm)	91.75 (22.77)	91.62 (29.95)	0.975
Arm Length (cm)	92.54 (24.57)	91.62 (29.95)	0.803
Thigh Length (cm)	92.38 (27.18)	91.62 (29.95)	0.783
Forearm Length (cm)	91.25 (24.35)	91.62 (29.95)	0.919

Discussion

Height is an essential part of nutritional assessment and growth monitoring (13). In turn, monitoring enables early detection of growth faltering to pre-empt subsequent malnutrition in children. In essence, it allows the clinician to promptly halt the progression of underlying malnutrition and illnesses (23, 24). However, some circumstances, including CP, make it difficult to measure height accurately because of limb deformities arising from tone abnormalities and contractures. Hence, the study's main objective is determining a proxy for height measurement among children with CP.

The mean weight of the CP participants was 16.14 ± 10.74kg. This was higher than the findings Adamu et al. (25) reported in a study conducted in Northern Nigeria among 150 children with CP aged two to twelve years whose the mean weight was 13.00 ± 5.20kg. Notably, the subjects in the index study were older than those in the Northern Nigeria study, which may explain the higher mean weight in the present study.

Besides, observingly, the mean height of the CP participants was 94.97 ± 29.52cm. This was lower than the findings Adamu et al. (25) reported among 150 children with CP aged two to twelve years in Northern Nigeria where the mean height was 97.20 ± 17.10cm. One would have thought that the current study, which has an older age group, should have higher mean values since height is a linear measurement that increases physiologically in the same direction with age. This observation may be due to the disparity in the severity of illness among the study subjects, which is incomparable. The current study, which recruited older children who would have had the disease for a longer period, will have their height more adversely affected.

Similarly, the mean value for MUAC in the current study (16.72 ± 4.10) was higher than that reported among children with CP at Lagos

University Teaching Hospital by Adekoje et al. (26). The observed difference might be due to associated deficits that adversely affect food intake in children with CP, not easy to compare across the study. Chronic gastrointestinal problems such as uncoordinated swallowing, gastroesophageal reflux, and constipation are common conditions that may influence nutritional status among children with CP (27).

In the present study, the mean values of the weight and linear measurements were highest among children under five years compared to older children. These findings are not unexpected as CP is a chronic disease associated with feeding difficulty, poor nutrition, and altered energy requirement (28-30) with potential adverse effects on growth. Older children's weight and linear measurements would be more adversely affected because they have had the disease for a longer period, as demonstrated, albeit inconsistently, in the current study.

The present study showed general agreements in a hierarchy of degrees of correlation between height and surrogate measures. However, differences exist in the absolute strengths of observed relationships. The correlation coefficient was strong for all the linear measurements as independent variables for height, with thigh length, weight, foot length, and forearm length having very high correlation coefficients. Therefore, the implication for clinical practice is that weight, thigh length, weight, foot length, or forearm length is the best surrogate for height in circumstances where the height cannot be measured for practical reasons.

The current study and that by Yousafzai (17) found that moderately high correlations existed between measures of leg length and height of 0.74 and 0.72. On the contrary, previous authors (19, 31, 32, 33) have reported very high figures above 0.90. Similar variations also apply to the relationship between forearm length and height. In comparison, the correlation coefficient of 0.81 herein reported for CP subjects compares favorably with 0.86 and 0.82 reported by Canda et al. for males and females, respectively (34). However, it is somewhat lower than the 0.94 reported by Neyestani et al. (33) among boys in Teheran. Again, variations in degrees of correlation are expected in biological experiments and may be enhanced by differences in race and age of subjects. Similarly, in absolute terms, the current study found a 79% correlation between arm length and height. Earlier researchers have reported high figures in the range of 93% to 99% (19, 31, 35 – 38). With a regression coefficient of determination (R2) of 0.803, the implication is that 80.3% of the variability in height was explained by weight. Using thigh length did not change the coefficient of determination appreciably. Similarly, the standard error of the estimate of 13.366 and 13.055 for weight and thigh length, respectively, was comparable. In children with contractures or severe spasticity of the upper limbs, an advantage could be taken of the relative ease of measuring either weight or thigh length, considering the high strength of the relationship with height.

Having established the strengths of individual linear measurements as a proxy for height, the study attempted to predict height using linear measurement models. The mean difference between actual body height and body height estimation result according to all tested alternative measurements based on the regression analysis formula, shows a closer value to the actual body height. Therefore, it is attractive to recommend using the weight or thigh length measurement derived formula with the lowest standard error of the estimate as a proxy for length or height.

In conclusion, weight and thigh length are reliable and valid proxies for height in children with CP aged one year up to 17 years. This study recommends that either weight or thigh length be measured in the routine anthropometry of children with CP whose height cannot be measured by standard techniques.

The small sample size was acknowledged as a limitation to the generalizability of the findings. A multicenter study with a large sample with a similar methodology established in the present study may be needed to determine the accuracy of the derived proxy for estimating body length/height among children with CP.

Acknowledgment

None

Authors' Contribution

The study was conceived by ASO. Data was collected by all authors. ASO analysed the data and wrote the initial draft of the manuscript. All authors reviewed and approved the final manuscript for submission

Conflicts of interest

None

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