British Journal of Medicine & Medical Research
14(12): 1-10, 2016, Article no.BJMMR.25458
ISSN: 2231-0614, NLM ID: 101570965

SCIENCEDOMAIN ***international***
www.sciencedomain.org

Height and Body Mass Index Estimated by Alternative Measures in Children with Spastic Quadriplegic Cerebral Palsy and Moderate/Severe Malnutrition

Andrea A. García-Contreras[1], Edgar M. Vásquez-Garibay[1,2*], Enrique Romero-Velarde[1,2], Rogelio Troyo- Sanromán[1], Imelda E. Sandoval-Montes[1] and Daniel Illescas Zárate[1]

[1]Instituto de Nutrición Humana, Universidad de Guadalajara, Mexico.
[2]Hospital Civil de Guadalajara Dr. Juan I. Menchaca, Guadalajara, Mexico.

Authors' contributions

This work was carried out in collaboration between all authors. Author AAGC designed the study, wrote the protocol, made the field work and wrote the first draft of the manuscript. Author EMVG designed the study, made the analysis and interpretation of results and wrote the last draft of manuscript. Author ERV participated in the analysis and interpretation of results and contributed to the final draft of the manuscript. Author RTS made the statistical analysis and interpretation of results. Author DIZ participated in the field work. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJMMR/2016/25458
Editor(s):
(1) Toru Watanabe, Department of Pediatrics, Niigata City General Hospital, Japan.
Reviewers:
(1) Mra Aye, Melaka Manipal Medical College, Malaysia.
(2) C. Sunil Pal Singh, Kamineni academy of medical sciences & research Centre, India.
(3) Hank White, PT, Shriners Hospitals for Children, Lexington, KY, USA.
(4) Reidun Stenberg, Orebro University, University Health Care, Sweden.
Complete Peer review History: http://sciencedomain.org/review-history/14044

Original Research Article

Received 4th March 2016
Accepted 30th March 2016
Published 7th April 2016

ABSTRACT

Objective: To demonstrate that alternative measures are reliable predictors of height in children with spastic quadriplegic cerebral palsy (CP) and moderate/severe malnutrition and in healthy children.
Methods: In an intervention study, thirteen patients with CP (10 females and 3 males, with an average age of 9 y 11 m±2 y 3 m) with Gross Motor Function Classification System level V and moderate/severe malnutrition were included. They were compared with 57 healthy participants (31

**Corresponding author: E-mail: vasquez.garibay@gmail.com;*

females and 26 males with an average age of 8 y 7 m±10 m). Weight, height and alternative measures to height were obtained. ANOVA, Student's t test, the Mann-Whitney U test, the Wilcoxon test, and the Pearson correlation were used.

Results: Significant differences were observed in weight, height and alternative measures between children with CP and healthy children ($p < 0.001$). In healthy children, knee height (KH) and lower-leg length (LLL) were similar to standing height. The correlation coefficients between height and alternative measures as well as correlations between the heights estimated by alternative measures were higher in children with CP than in healthy children.

Conclusion: KH was the most appropriate measurement to estimate height in children with spastic quadriplegic CP and in healthy children. In the absence of a segmometer, height can be estimated by LLL in children with spastic quadriplegic CP and healthy children. The anthropometric indexes height/age and BMI were more appropriately obtained by the height estimated by KH or LLL.

Keywords: Cerebral palsy; alternative measurements to height; lower-leg length; upper-arm length; knee height.

1. INTRODUCTION

Accurate and appropriate estimation of weight, height and length in children with cerebral palsy (CP) is essential to assess their nutritional status and linear growth through indexes such as height/age (H/A), weight/age (W/A) and body mass index (BMI), both in percentiles or Z score, and from these results to calculate correctly their energy requirements [1]. Often, the height or length cannot be estimated correctly due to factors such as contractures, muscle weakness, spasticity, and scoliosis and bone deformities, lack of patient cooperation or involuntary movements [1,2]. Therefore, alternative measures, such as knee height (KH), lower-leg length (LLL) and upper-arm length (UAL) [3-5], have been extensively studied and shown to be reproducible and suitable for their clinical use in children with CP [1,5]. Knee height is relatively easy to measure and is the measurement that has the lowest standard error, and it is the most useful measurement when a segmometer is available [5]. According to Stevenson [5] and Hogan[1], this measurement suitably correlates with stature or length in children with CP ($r = 0.98$ and $r = 0.88$, respectively; $p < 0.05$).

These alternative measures of linear growth have been assessed in children with CP [1,6] and healthy children [7-9] with various equations. The equations proposed by Stevenson have been implemented and reproducible for children with CP in different countries [6]. It is recognized that growth patterns for healthy children are not suitable for assessing the nutritional status of children with CP because their fat-free mass, fat mass, weight and bone mass are usually decreased [5]. These equations, which were made for children with CP [5], were reproducible for children with hemiplegia, diplegia [10] and triplegia, but have been little studied in children with quadriplegia. It is known that among children with CP, those with spastic quadriplegia have the greatest involvement of linear growth [11]. There are growth charts for assessing upper-arm and lower-leg lengths for children 3-18 years [12]; however, these charts derive from healthy subjects, and it would be inappropriate to use them for children with spastic quadriplegic CP because the height of children with CP is, on average, -1 SD at the age of three years [13]. Therefore, due to the limited information available on the use of these equations in children with spastic quadriplegia, the purpose of this study was to show that these alternative measures allow a reliable estimation of height and body mass index in children with spastic quadriplegia and moderate/severe undernutrition and in healthy children.

2. METHODS

There were two included studies. The first study was an intervention study including 15 subjects (10 females and 5 males) with spastic quadriplegic CP, moderate or severe malnutrition, and non-ambulation with severe brain damage. The age ranged from 6 years 9 months to 12 years 8 months (9 y 11 m±2 y 3 m). Patients were recruited at the Infant Nutrition Unit of the Dr. Juan I. Menchaca Civil Hospital and were hospitalized for four weeks of nutritional recovery. They were fed enterally (nasogastric tube or gastrostomy: n = 8, n = 5, respectively) with a lactose-free infant formula (Nestlé ®) supplemented with corn syrup to increase the energy density from 0.67 to 0.80 kcal/mL. The formula was placed in a bag with a capacity of 500 mL (Pisa®) and connected to a feeding tube

(D-731 or 732, Mexico Desvar SA). It was administered by a continuous infusion pump (Braun®). During the first two weeks, energy intake was 112 kcal/kg/d (12 kcal/cm/d) and was 115-116 kcal/kg/d (14 to 16 kcal/cm/d) for the following two weeks [14]. Throughout the study period, the formula covered 100% of the fluid, energy, protein and other nutrient requirements, and no other foods were offered. Beginning on the sixth day, elemental iron was added at a dose of 3 mg/kg/d.

The sample size of children with CP was described in a previous publication [15] in which a confidence level of 95% was estimated and a power of 0.8 was determined according to the average and variance of a medium upper arm circumference (MUAC) study by Stallings et al. [16]. Patients were included if they had moderate or severe acute undernutrition according to the weight/height index (W/H) of the Waterlow classification [17] in addition to two or more of the following criteria: triceps skinfold (TSF), subscapular skinfold (SSF), MUAC and/or body mass index (BMI) below -2 SD [18]. All patients with CP had been confined to a wheelchair and were totally dependent on their parents or legal caregivers to meet their daily needs, belonged to group V of the Gross Motor Function Classification System [19] and were evaluated by a pediatric neurologist who was in charge of the development of children during the intervention study. Most of the children were receiving at least two of the following anticonvulsants: phenobarbital, valproic acid, phenytoin, lamotrigine, topiramate, carbamazepine and clonazepam.

Children who had hereditary disorders, heart disease, hypothyroidism, or any other condition not related to cerebral palsy as well as CP of a postnatal origin as well as subjects with comorbid diagnoses (Down syndrome, autism, degenerative disorders and kidney disease) were not included. Two cases were excluded: one because of inaccurate data and the other due to excessive secretions that prevented the adjustment of fluids and energy. Anthropometric measurements were performed at baseline and at 30 days of the study period.

Second study: In a cross sectional study, 57 healthy subjects (31 females and 26 males) were evaluated, and their age ranged from 7 to 10 years (similar to children with CP). The sample was obtained from two private elementary schools in the city of Guadalajara. Informed consent of the parents or legal caregivers of all children was obtained. The study was approved by the ethics committee of the Dr. Juan I. Menchaca Civil Hospital.

2.1 Anthropometry

Anthropometric measurements included weight, height (for children with CP, this was estimated by segmental length, and for healthy children by standing height), and alternative measures to height, including knee height, lower-leg length and upper-arm length. The weight of children with CP was taken with a minimum of clothes and a clean diaper. A SECA® scale (model 700, Hamburg, Germany) with a 50-g precision graduation was used. For the first weight, the child was weighed in the arms of his father or legal caregiver, then only the parent or legal person was weighed, and finally, the difference of the two weights was obtained [20]. In healthy children, the weight was obtained with a Tanita scale model UM061 (Tokyo, Japan) with the child standing without shoes or socks. The height in children with CP was estimated with the child in the supine position through segmental body length, for which three measurements were performed: the first from the crown to the junction of the femur with the ilium, the second from that junction to the upper border of the patella, and the third from the kneecap to the lower edge of the heel [21]. Measurements were performed with a steel tape. Knee height, lower-leg length and upper-arm length in both groups were performed according to the methods described [5]. Lower-leg length (LLL) was obtained with a tape (Seca 206, Hamburg, Germany); it was measured from the line of the inner knee joint to the lower border of the malleolus of the tibia at an angle of 90°, knee height (KH) and upper-arm length (UAL) were obtained with a segmometer (Rosscraft SRL, Buenos Aires, Argentina). KH measurement was performed with the knee flexed to 90° in a straight line with the heel. It was measured from the proximal end of the patella to the bottom of the heel; UAL was measured with the arm relaxed at the side of the trunk. It was measured from the lateral edge of the acromion to the radial head. To estimate the knee height and upper-arm length, a segmometer (Rosscraft SRL, Buenos Aires, Argentina) was used, and for lower-leg length, a metal tape measure was used. For healthy children, height was measured with a SECA stadiometer (model 214); this measurement was performed with the subject standing without shoes with heels together and toes slightly apart, back as straight as possible, and heels, buttocks, shoulders and head touching the vertical surface of the stadiometer. The head remained in the Frankfurt plane. The arms of the subject hung freely at his/her sides with palms facing the thighs. The observer requested that the individual inhale deeply as the mobile part descended to touch the subject's head. BMI and height for age indexes were converted to Z scores and were compared with the WHO reference pattern [22]. All measurements were performed by two observers previously standardized.

2.2 Statistical Analysis

Student's t test was used for independent samples, and the Mann Whitney U test was used for comparing the anthropometric variables of the CP group vs. the group of healthy children and for comparing the same data among healthy males and females. ANOVA was performed to compare the anthropometric indexes among the group of children with CP. We performed Student's t test for related data and the Wilcoxon test for comparisons among alternative measures of growth by groups. Wilcoxon test was also used for height comparisons with alternative measures in the group of healthy children by sex.

Pearson correlation coefficients between height and alternative measures in the group of children with CP and healthy children were estimated. SPSS version 20 (SPSS Inc., Chicago, IL, USA) was used for the statistical analyses.

2.3 Ethical Considerations

Adequate information was given to parents about the importance of this interventional study, and after informed consent was signed, authorization was given to include each child in the study. The study complied with the principles of the Declaration of Helsinki adopted by the 18th World Medical Assembly, Helsinki, 1964; amended by the 29th World Medical Assembly, 1975, the 35th World Medical Assembly, 1983, and the 41st World Medical Assembly, 1989. The protocol used was approved by the Bioethics Committee of Guadalajara's Civil Hospital with number 1028/10.

3. RESULTS

Thirteen children with CP and 57 healthy children were evaluated. The comparison of age, weight, standing height and height estimated by alternative measures did not differ between healthy girls and boys. The top part of Table 1 shows anthropometric data and alternative measures for children with CP at baseline, children with CP at 30 days and healthy children. Significant differences in weight, height and height estimated by alternative measures ($p < 0.001$) among children with CP (30 days) and healthy children were observed. The lower part of the table shows that in healthy children, there was a significant difference between standing height and height based on the UAL ($p < 0.001$), whereas the KH and LLL were similar to the standing height. It also highlights the significant differences between alternative measures obtained at baseline and 30 days in children with CP.

Table 2 shows (in two parts) the Pearson correlation coefficients. The top part shows that the correlation between height measured by segments (children with CP) or standing height (healthy children) and height estimated by alternative measures is better in children with CP at baseline and at 30 days than in healthy children. The lower part shows the correlations among the alternative measures in children with CP and among the alternative measures in healthy children. It was also observed that the correlations between the heights estimated by alternative measures were better in children with CP at baseline and at 30 days than in healthy children.

The top part of Table 3 shows the differences between the height obtained with the stadiometer and the height obtained by alternative measures in healthy boys and girls. In the lower part of the table, the differences between alternative measurements in healthy boys and girls are shown.

Table 4 shows the BMI (kg/m^2 and Z) and height/age index according to the height estimated by alternative measures in children with CP (at 30 days) and in healthy children (standing height). Significant differences in BMI obtained by different alternative measurements of height in children with CP were observed; significant differences were also observed by comparing the BMI estimated by each of the heights obtained with alternative measures in children with CP vs. the BMI obtained with standing height in healthy children ($p < 0.001$).

Table 1. Age, weight, height and height estimated by alternative measures in healthy children and children with CP Mean (SD)

Variable	Children with CP (baseline) n = 13	Children with CP (30 days)* n = 13	Healthy children N = 57	Children with CP (30 days) Vs. healthy children *p***
Age (years, months)	9.8 (2.2)	9.9 (2.3)	8.7 (0.8)	0.155
Weight (kg)	11.9 (2.3)	14.6 (2.6)	30.5 (5.7)	< 0.001
Height (cm) [+ #]	110.5 (12.3)	112.8 (13.2)	132.2 (6.9)	< 0.001
Height estimated by KH (cm)	105.3 (10.9)	105.9 (10.1)	132.2 (7.4)	< 0.001
Height estimated by LLL (cm)	107.0 (12.5)	107.9 (12)	131.3 (9.9)	< 0.001
Height estimated by UAL (cm)	113.3 (13.3)	114.0 (14.4)	136.5 (8.3)	< 0.001
Height estimated by (KH+LLL)/2 (cm)	106.2 (11.6)	106.9 (10.9)	131.74 (7.9)	< 0.001
Height estimated by (KH+LLL+UAL)/3 (cm)	108.5 (11.9)	109.3 (11.6)	133.3 (7.1)	< 0.001
Height[+ #] vs.	*p****	*p****	*p****	
Height by KH	0.003	0.005	1.000	
Height by LLL	0.096	0.016	0.609	
Height by UAL	0.021	0.233	<0.001	
Height by (KH + LLL)/2	0.021	0.012	0.399	
Height by (KH + LLL + UAL)/3	0.248	0.042	0.012	
Height by KH vs. Height by LLL	0.080	0.055	0.531	
Height by KH vs. Height by UAL	< 0.001	0.002	< 0.001	
Height by LLL vs. Height by UAL	0.005	0.048	< 0.001	
Height by KH vs. Height by (KH+LLL)/2	0.080	0.055	0.531	
Height by LLL vs. Height by (KH+LLL)/2	0.080	0.055	0.531	
Height by UAL vs. Height by (KH+LLL)/2	< 0.001	0.008	< 0.001	
Height by KH vs. Height by (KH+LLL+UAL)/3	< 0.001	< 0.001	0.007	
Height by LLL vs. Height by (KH+LLL+UAL)/3	0.105	0.216	0.006	
Height by UAL vs. Height by (KH+LLL+UAL)/3	< 0.001	0.008	< 0.001	
Height by (KH+LLL)/2 vs. Height by (KH+LLL+UAL)/3	< 0.001	0.008	< 0.001	

** After 30 days of nutritional recovery. ** Mann-Whitney. *** Wilcoxon. + Height by segmental length (children with CP) (n = 12); # Height by standing height (healthy children). KH: knee height; LLL: Lower-leg length; UAL: Upper-arm length. Weight in children with CP (baseline vs. 30 d), p < 0.001. Height in children with CP (baseline vs. 30 d), p = 0.003*

Table 2. Correlation between height and the height estimated by alternative measures in healthy children and children with CP

Indicator	Healthy children (n = 57) r*	Children with CP (n = 13)	
		Baseline r*	30 days r*
Height+ #/			
Height by KH	0.883	0.947	0.912
Height by LLL	0.668	0.880	0.874
Height by UAL	0.587	0.949	0.935
Height by (KH+LLL)/2	0.830	0.917	0.846
Height by (KH+LLL+UAL)/3	0.844	0.944	0.943
Height by KH/ Height by LLL	0.666	0.962	0.973
Height by KH/ Height by UAL	0.530	0.950	0.852
Height by LLL/ Height by UAL	0.430	0.887	0.829
Height by KH/ Height by (KH+LLL)/2	0.844	0.989	0.992
Height by KH/ Height by (KH+LLL+UAL)/3	0.863	0.992	0.973
Height by LLL/ Height by (KH+LLL)/2	0.937	0.992	0.994
Height by LLL/ Height by (KH+LLL+UAL)/3	0.863	0.971	0.965
Height by UAL/ Height by (KH+LLL)/2	0.517	0.925	0.845
Height by UAL/ Height by (KH+LLL+UAL)/3	0.772	0.969	0.942
Height by (KH+LLL)/2/ Height by (KH+LLL+UAL)/3	0.943	0.990	0.975

*KH: knee height; LLL: Lower-leg length; UAL: Upper-arm length. + Height by segmental length in children with CP (n = 12); # Standing height in healthy children. * Pearson. In all cases p < 0.001*

Table 3. Comparison between standing height and the height estimated by alternative measures in healthy boys and girls

Variable	Females N = 31 *p**	Males N = 26 *p**
Height # vs.		
Height by KH	0.339	0.263
Height by LLL	0.217	0.083
Height by UAL	0.002	0.002
Height by (KH+LLL)/2	0.617	0.148
Height by (KH+LLL+UAL)/3	0.061	0.269
Height by KH vs. Height by LLL	0.074	0.010
Height by KH vs. Height by UAL	0.004	0.008
Height by LLL vs. Height by UAL	0.158	< 0.001
Height by KH vs. Height by (KH+LLL)/2	0.074	0.010
Height by LLL vs. Height by (KH+LLL)/2	0.074	0.010
Height by UAL vs Height by (KH+LLL)/2	0.019	< 0.001
Height by KH vs Height by (KH+LLL+UAL)/3	0.005	0.775
Height by LLL vs. Height by (KH+LLL+UAL)/3	0.896	< 0.001
Height by UAL vs. Height by (KH+LLL+UAL)/3	0.019	< 0.001
Height by (KH+LLL)/2 vs. Height by (KH+LLL+UAL)/3	0.019	< 0.001

*KH: knee height; LLL: Lower-leg length; UAL: Upper-arm length. * Wilcoxon; # standing height*

Table 4. BMI and height/age in children with CP (n = 13, at 30 days *) and healthy children (n = 57) &. Mean (SD)

Index	CP Children Estimated height by KH	CP Children Estimated height by LLL	CP Children Estimated height by UAL	CP Children Estimated height by (KH + LLL)/2	CP Children Estimated height by (KH +LLL + UAL)/3	ANOVA Among estimated heights *p*	Healthy children	Estimated height in CP vs. height in healthy children *p +*
BMI (kg/m^2)	13.0 (1.3)	12.56 (1.58)	11.36 (1.38)	12.78 (1.45)	12.22 (1.19)	0.034	17.41 (2.35)	< 0.001
BMI (Z)	-1.62 (0.59)	-1.78 (0.80)	-2.34 (0.57)	-1.72 (0.67)	-1.95 (0.55)	0.049	0.78 (1.27)	< 0.001
Height/age (Z)	-5.04 (1.72)	-4.75 (1.75)	-3.74 (2.28)	-4.89 (1.72)	-4.50 (1.84)	0.428	0.29 (0.85)	< 0.001

** After 30 days of nutritional recovery. & WHO, 2007; KH: knee height; LLL: Lower-leg length; UAL: Upper-arm length; BMI: body mass index; + Student's T- test for each of the estimated CP heights vs. height in healthy children.*

Student's T-test: BMI (kg/m^2), BMI (Z), H/A (Z): KH vs. LLL, p = 0.053, 0.139, 0.063, respectively; KH vs. UAL, p = 0.003, 0.002, 0.002, respectively; KH vs. (KH + LLL)/2, p = 0.065, 0.127, 0.061, respectively; KH vs. (KH +LLL + UAL)/3, p = 0.001, < 0.001, 0.001, respectively; LLL vs. UAL, p = 0.029, 0.033, 0.016, respectively; LLL vs. (KH + LLL)/2, p =0.045, 0.195, 0.059, respectively; LLL vs. (KH + LLL + UAL)/3, p = 0.126, 0.133, 0.105, respectively; UAL vs. (KH + LLL)/2, p = 0.010, 0.011, 0.005, respectively; UAL vs. (KH + LLL + UAL)/3, p = 0.012, 0.012, 0.006, respectively

4. DISCUSSION

To our knowledge, this is the first study in Mexico that demonstrates the utility of Stevenson's equations to assess height in children with CP and healthy children. One sample consisted of children with CP, in particular, those with spastic quadriplegia and moderate or severe undernutrition. Our data are consistent with previous results on the usefulness of lower-leg length (LLL) [5] and knee height (KH) [1,5,6,23] as reliable alternative measures to estimate height in children with CP. The other sample consisted of healthy children, where the best alternative measurement of height was KH, as this and standing height were identical. There were significant differences in estimating the height by upper arm length (UAL) ($p < 0.001$) and by the average of the three alternative measures [(KH + LLL + UAL)/3] ($p = 0.012$). When comparing alternative measures to each other, in children with CP at baseline and at 30 days and in the group of healthy children, there were significant differences between the estimated heights by UAL vs. the estimated height by the other alternative measures. These differences were due to the height obtained with UAL, which was higher than that of the others. There was a significant difference in the height estimated by the average of the three alternative measures [(KH + LLL + UAL)/3] and the height estimated by each of the alternative measures (KH, LLL, UAL) in healthy children. It has been reported that the inter-observer measurement error is greater with UAL than with LLL (6 mm vs. 4.9 mm). This finding might indicate that the measurement of UAL is more difficult to accomplish in children with CP [4].

The equations of Stevenson et al. [5] were applied in 172 American children with different types of CP, 31% with diplegia or hemiplegia and 52% with non-ambulatory CP. The correlation coefficients obtained were very good between height (estimated at supine or standing position when the subject did not show contractures or scoliosis) and KH ($r = 0.98$), height and LLL ($r = 0.97$) and also between height and UAL ($r = 0.97$). Using Stevenson's equations, Amezquita et al [6] evaluated a population of Chilean children with CP and reported very good correlation coefficients between height (estimated in the supine or standing position) and LLL ($r = 0.975$) and between height and KH ($r = 0.981$).

A suitable index to assess linear growth in children with CP is the H/A index. In our study, we observed that the H/A index significantly differed when the height obtained by UAL was compared with the index obtained with the other alternative measures (LLL, KH). The H/A index obtained by the average of the estimated three alternative measures [(KH + LLL + UAL)/3)] showed significant differences when it was compared with each of the indexes obtained with the estimated height by alternative measures separately, except LLL. We therefore recommend that the H/A index could be correctly estimated in children with CP with the height obtained by the alternative measures KH, LLL or the average of these measures.

In healthy children, when height cannot be assessed by conventional methods (standing height), for example, in postsurgical or bedridden children or in children who have undergone trauma, the most reliable and useful alternative measurement to estimate height is KH, but LLL and [(KH + LLL)/2] are also useful. We discourage the use of UAL and [(KH + LLL + UAL)/3] to estimate the height and anthropometric indexes in children with CP and healthy children because it had the biggest differences and less correlation with the other alternative measures of height.

It is recommended that BMI be assessed carefully in children with CP because height squared can boost the index error [24,25]. In our study, we found that when estimating the BMI (Z and kg/m^2) with height by UAL, there were significant differences when comparing BMI with the BMI estimated by the other alternative measures. Because UAL is the measurement that overestimated height in most cases, we believe that this measurement is not suitable when estimating BMI. When BMI was obtained with the average of the three alternative measures [(KH + LLL + UAL)/3)], significant differences were observed when it was compared with the BMI estimated by KH, UAL and [(KH + LLL)/2)], so we recommend caution with its use. We believe that the alternative measures that more adequately estimate the BMI in children with CP are KH, LLL and [(KH + LLL)/2)].

5. CONCLUSION

In conclusion, this study demonstrated that the alternative measurement KH is the measurement of choice for estimating the height of children with CP with spastic quadriplegia; but, when a segmometer is not available, the alternative measurement of height LLL is a reliable measurement for these children. We would speculate from our results, that the measurement of height by UAL is no completely accurate, maybe related to the equations or different velocity of growth, due to different situation of mobility of the upper and lower extremities. Furthermore, it is interesting that apparently, height by UAL was less precise for CP children as well as for healthy children. In children without CP with another disease or who are in a situation of immobility due to the severity of their clinical status, alternative measures of height, such as KH or LLL, are useful measures for estimating height and therefore for estimating the indexes of height/age and BMI.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Hogan SE. Knee height as a predictor of recumbent length for individuals with mobility-impaired cerebral palsy. J Am Coll Nutr. 1999;18:201-205.
2. Culley WJ, Middleton TO. Caloric requirements of mentally retarded children with and without motor dysfunction. J Pediatr. 1969;75:380-4.
3. Cameron N. The methods of auxological anthropometry. In: Falkner F, Tanner JM. Hum Growth. A comprehensive treatise, eds. 2nd ed. Plenum Press. New York. 1986;3:3-46.
4. Spender W, Cronk E, Charney E, Stallings VA. Assessment of linear growth of children with cerebral palsy: Use of alternative measures to height of length. Dev Med Child Neurol. 1989;31:206-214.
5. Stevenson RD. Use of segmental measures to estimate stature in children with cerebral palsy. Arch Pediatr Adolesc Med. 1995;149:658-62.
6. Amezquita GMV, Hodgson BMI. Alternatives to estimate stature during nutritional assessment of children with cerebral palsy. Rev Chil Pediatr. 2014;85: 22-30.
7. Yousafzai AK, Filteau SM, Wirz SL, Cole TJ. Comparison of arms pan, arm length and tibia length as predictors of actual height of disabled and nondisabled children in Dharavi, Mumbai, India. Eur J Clin Nutr. 2003;57:1230-1234.
8. Chumlea WC, Guo SS, Steinbaugh ML. Prediction of stature from knee height for black and white adults and children with application to mobility-impaired or handicapped persons. J Am Diet Assoc. 1994;94:1385-8.
9. Gauld LM, Kappers J, Carlin JB, et al. Height prediction from ulna length. Dev Med Child Neurol. 2004;46:475-80.
10. Bell KL, Peter S, Davis W. Prediction of height from knee height in children with cerebral palsy and non-disabled children. Ann Hum Biol. 2006;33:493-499.
11. Tobis JS, Saturen P, Larios G, Posniak AO. Study of growth patterns in cerebral palsy. Arch Phys Med Rehabil. 1961;42: 475-81.
12. Snyder RG, Schneider LW, Owings CL. Infant, child and teenager anthropometry for product safety design. 1978;5:499-507.
13. Pryor HB, Thelander HE. Growth deviations in handicapped children. An anthropometric study. Clin Pediatr. 1967;6: 501-12.
14. Marchand V, Motil KJ. NASPGHAN Committee on Nutrition. Nutrition support for neurologically impaired children: A clinical report of the North American Society for pediatric gastroenterology, hepatology and nutrition. J Pediatr Gastroenterol Nutr. 2006;43:123-35.
15. García Contreras AA, Vásquez-Garibay EM, Romero-Velarde E, et al. Intensive nutritional support improves the nutritional status and body composition in severely malnourished children with cerebral palsy. Nutr Hosp. 2014;29:838-43.
16. Stallings VA. Nutritional status and growth of children with diplegic or hemiplegic cerebral palsy. Dev Med Child Neurol. 1993;35:997-1006.
17. Waterlow JC. Classification and definition of protein-calorie malnutrition. Brit Med J. 1972;3:566-9.
18. Frisancho AR. Anthropometric standard for the assessment of growth and nutritional status. Ann Arbor, MI: University of Michigan Press; 1990.
19. Palisano R, Rosenbaum P, Walter S, et al. Develoment and reliability of a system to classify gross motor function in children with cerebral palsy. Dev Med Child Neuro. 1997;39:214-23.
20. Arrowsmith F, Allen J, Gaskin K, et al. The effect of gastrostomy tube feeding on body protein and bone mineralization in children

with quadriplegic cerebral palsy. Dev Med Child Neurol. 2010;52:1043-7.

21. Norton K, Whittingham N, Carter L, et al. Measurements techniques in anthropometry. In: Norton K, Olds T, Editors, 1st edition. Anthropometrica: A text book of body measurements for sport and heath courses. Sidney: University of New South Wales. 1996;25-75.
22. WHO, Growth reference data for 5-19 years. 2007. Obtenido el 7 de Octubre de Disponible en; 2015. Available:http://www.who.int/growthref/en/
23. Araújo LA, Silva LR, Mendes FA. Digestive tract neural control and gastrointestinal disorders in cerebral palsy. J Pediatr. 2012;88:455-64.
24. Happala H, Peterson MD, Daunter A, et al. Agreement between actual height and estimated height using segmental limb lengths for individuals with cerebral palsy. Am J Phys Med Rehab. 2015;94:539-546.
25. Samson-Fang L, Bell KL. Assessment of growth and nutrition in children with cerebral palsy. Eur J Clin Nutr. 2013;67: S5-8.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/14044