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SENPE

Utilidad de las ecuaciones que consideran la función motora gruesa para estimar la talla en una población mexicana de niños y adolescentes con parálisis cerebral

Utility of equations that consider gross motor function to estimate height in a Mexican population of children and adolescents with cerebral palsy

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ABSTRACT

Introduction: height estimation is essential for the assessment of nutritional status. In children with cerebral palsy (CP), it is difficult to obtain this information reliably. The equations that consider gross motor function to estimate height have not been tested in the Mexican population.

Objective: to evaluate the usefulness of equations that consider gross motor function to estimate height in a Mexican population of children and adolescents with CP.

Methods: this was an analytical cross-sectional study of children and adolescents from two to 18 years of age with CP. Height, height-for-age index and BMI were estimated via the Stevenson and Ruiz-Brunner equations. The Mann-Whitney U-test, Spearman correlation and Bland-Altman concordance analysis were performed.

Results: the equations that consider gross motor function showed excellent correlations (height $r = 0.987$, $p < 0.001$; height-for-age index $r = 0.959$, $p < 0.001$; and BMI $r = 0.986$, $p < 0.001$). The mean difference for height was -2.92 ± 3.14 cm; for the height-for-age index, it was -2.67 ± 2.66 %; and for BMI, it was 0.75 ± 0.71 kg/m^2. The groups with levels 1-3 gross motor function showed wider limits of agreement than groups with levels 4-5 for the three anthropometric indicators.

Conclusion: the equations that consider the levels of gross motor function to estimate height are useful in a Mexican population with CP.

Keywords: Cerebral palsy. Height. Body mass index. Children. Adolescents.

RESUMEN

Introducción: la estimación de la talla es indispensable para la evaluación del estado nutricio. En niños con parálisis cerebral (PC), ésta presenta dificultades para obtenerse de manera confiable. Las ecuaciones que consideran la función motora gruesa para estimar la talla no han sido probadas en población mexicana.

Objetivo: evaluar la utilidad de las ecuaciones que consideran la función motora gruesa para estimar la talla en una población mexicana de niños y adolescentes con PC.

Métodos: estudio transversal analítico en niños y adolescentes de dos a 18 años de edad con PC. Se estimó la talla, el índice talla/edad y el IMC por medio de la ecuación de Stevenson y las de Ruiz-Brunner. Se realizó la prueba U de Mann-Whitney, la correlación de Spearman y el análisis de concordancia de Bland-Altman.

Resultados: las ecuaciones que consideran la función motora gruesa mostraron excelente correlación (talla r = 0,987, p < 0,001; índice talla/edad r = 0,959, p < 0,001 e IMC r = 0,986, p < 0,001). La diferencia de medias en la talla fue -2,92 ± 3,14 cm, en el índice talla/edad -2,67 ± 2,66 % y en el IMC 0,75 ± 0,71 kg/m^2. El grupo de los niveles 1-3 de la función motora gruesa mostró límites de concordancia más amplios que el grupo de los niveles 4-5 en los tres indicadores antropométricos.

Conclusiones: las ecuaciones que consideran los niveles de la función motora gruesa para estimar la talla son útiles en una población mexicana con PC.

Palabras clave: Parálisis cerebral. Talla. Índice de masa corporal. Niños. Adolescentes.

INTRODUCTION

Cerebral palsy (CP) is the leading cause of motor disability in childhood and has a significant impact on growth and physical development (1). According to Rosenbaum et al. (2), it is a group of alterations in the development of posture and movement, which limits activity and is attributed to a nonprogressive alteration that occurs in the development of the fetal or infant brain. In Mexico, approximately 7.7 million people live with some disability, and around 770 thousand have been diagnosed with CP (3). A study in northeastern Mexico reported an incidence of 4.4 cases per 1000 live births up to 18 months of age, which is higher than that reported in developed countries, where it has been estimated to be between two and three cases per 1000 live births (4). Height and/or length are key indicators of health and growth; its monitoring is essential for assessing and diagnosing adequate nutritional status and estimating anthropometric indices such as height-for-age and BMI (1,5). Children with CP have motor limitations, spasticity, skeletal deformities such as contractures, scoliosis, and a lack of cooperation, which makes it difficult to obtain accurate height measurements, especially in the most affected children (6). Studies such as those by Amezquita et al. (7) and Ruiz-Brunner et al. (8) have shown that motor limitations can influence children's muscular and bone development. Therefore, alternative measurements of body segments, such as tibia length, knee height and arm length, have been developed to allow for a more reliable height estimation (9-12). Chumlea et al. (12) developed equations to estimate height in children and adolescents with reduced mobility aged six to 18 years from body segment measurements such as knee height. Later, Stevenson et al. (9) developed equations from body segments such as tibia length, knee height and arm length in children with CP aged two to 12 years, concluding that knee height is the most consistent in this population. Gauld et al. (11) developed equations to estimate height from the ulna and tibia length in healthy Australian children aged five to 19 years of age. All these equations have been widely used in several studies (6,7,13-19). The equations proposed by Chumlea et al. (12), Gauld et al. (11) and those proposed by Stevenson et al. (9) do not consider the levels of gross motor function, which may introduce some bias in the measurement of height, especially in the most affected populations. Recently, Ruiz Brunner et al. (20) developed specific equations to estimate height using knee height in a population of children and adolescents with CP from two to 19 years of age from five cities in Argentina, considering the level of motor function according to the Gross Motor Function Classification System (GMFCS) and dividing the population into levels 1-3 and 4-5. The usefulness of these equations in the Mexican population with CP is unknown; therefore, the aim of this study is to evaluate the utility of equations that consider the levels of gross motor function to estimate height in children and adolescents with CP in the Mexican population.

MATERIAL AND METHODS

A cross-sectional analytical study was carried out in which 152 subjects (80 males and 72 females) with CP from two to 18 years of age, belonging to all levels of gross motor function and attending the Nuevo Hospital Civil de Guadalajara and the Centro de Rehabilitación e Inclusión Infantil Teletón (CRIT), were included. A pediatric neurologist confirmed the diagnosis of CP as well as the level of gross motor function of each subject. The subjects were classified into two groups according to gross motor function: 1-3 and 4-5. Subjects with confirmed metabolic, endocrine, or neurodegenerative diseases, those receiving medications that alter body composition (steroids or antiretrovirals), and those with CP of postnatal origin were not included. Subjects for whom no anthropometric measurements could be performed or whose data were incomplete were excluded. The sample size was obtained from a previous study (19), and 44 more subjects who attended the same centers from January to September 2024 were added, considering the same selection criteria.

Anthropometry

Weights were obtained with minimal clothing and a clean diaper. A SECA® scale (Model 700, Hamburg, Germany) with a precision of 50 g and a Tanita (BC-601F, Japan) with a precision of 10 g were used. To measure the weight of children who could not stand up, the child was first weighed in the arms of his or her father and then only the father, and finally, the difference in both weights was obtained (19). Two observers were standardized to estimate height. Height was measured using knee height with the technique and equation proposed by Stevenson et al. (9) as well as with the equations proposed by Ruiz-Brunner et al. (20). To perform this measurement, a segmometer (Rosscraft, Surrey, BC, Canada) was used, with the knee flexed at an angle of 90° in a straight line with the heel. Knee height was estimated from the proximal border of the patella to the lower border of the heel. The average of the two observer measurements was used for data analysis. The height-for-age index was calculated as a percentage of the median using the Waterlow equation. Brooks et al. (21) growth charts were used to estimate the height-for-age index and BMI.

Statistical analysis

The Mann-Whitney U-test and Spearman's correlation coefficient were used for quantitative data. The concordance of the estimated height with the equations proposed by Stevenson et al. (9) and the estimated height with the equations proposed by Ruiz-Brunner et al. (20) was analyzed via Bland‒Altman analysis, for which the mean differences in the estimated height using the two methods, the standard deviation of the differences and the limits of concordance (the mean differences ± 1.96 multiplied by the standard deviation) were calculated. SPSS version 25 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis.

Ethical considerations

The protocol did not put the study participants at risk and adhered to the guidelines of the Declaration of Helsinki and the principles of beneficence, nonmaleficence, justice, and decision-making autonomy. Informed and signed consent was requested from the parents or legal guardians of the child. The protocol was approved by the ethics committee of the Nuevo Hospital Civil de Guadalajara with No. 1344/14 for 108 subjects. For the extra 44 subjects, the protocol was approved by the same committee with number 66/HCJIM-JAL/2023 and by the CRIT with No. 01-23-10-2023.

RESULTS

Anthropometric variables

The median age was 97.1 (57.3-144.8) months, with no significant differences between males and females. Table I presents the anthropometric characteristics of the study population. Weight, height, and BMI were assessed using the Stevenson et al. (9) and Ruiz-Brunner et al. (20) equations and did not significantly differ according to sex or gross motor function levels. However, the height-for-age index expressed as a percentage of the median showed a significant difference in the total population between males and females with both methods (p = 0.016 and p = 0.025, respectively), which was greater in males. There were no significant differences in height, height-for-age index, or BMI between levels 1-3 and 4-5 in the general population using either equation.

Characteristics of CP subtypes and gross motor function levels

Table II presents the distributions of CP subtypes and gross motor function levels. The most common CP subtype was mixed cerebral palsy (57.2 %), followed by spastic CP (24.3 %). For gross motor function, levels 4 (15.2 %) and 5 (73.0 %) were the most common. No significant differences were observed in the CP subtype or gross motor function levels by sex. The group with levels 1-3 represented 11.8 %, whereas the group with levels 4-5 represented 88.2 % of the population.

Correlations of the anthropometric indicators estimated using both equations

Table III shows the correlation coefficients of height, height-for-age index and BMI estimated using the Stevenson et al. (9) and Ruiz-Brunner et al. (20) equations. Compared with the height-for-age index and BMI, height had the highest correlation coefficient for the total population and levels 1-3, whereas for levels 4-5, the height-for-age index had the highest correlation coefficient. When the correlation coefficients between both groups were compared, the group at levels 4-5 presented the highest correlation coefficient for height and the height-for-age index, whereas the group at levels 1-3 presented the highest correlation coefficient for BMI.

Concordance analysis in the total population

Figure 1 shows the concordance analysis between Stevenson et al. (9) and Ruiz-Brunner et al. (20) equations for estimating height, height-for-age index, and BMI from knee height in the entire population. The mean difference between the heights estimated with the Stevenson equation and the Ruiz-Brunner equations was -2.92 ± 3.14 cm, so there was a systematic underestimation error between -9.06 and 3.23 cm. The mean difference in the height-for-age index was -2.67 ± 2.66 %, with a range between -7.88 and 2.54 %. Finally, the mean difference in BMI was 0.75 ± 0.71 kg/m^2; hence, there was a systematic error of overestimation, with a range between -0.64 and 2.15 kg/m^2.

Concordance analysis according to levels of gross motor function

Figures 2 and 3 show the concordance analyses between the Stevenson et al. (9) and Ruiz-Brunner et al. (20) equations for estimating height, height-for-age index, and BMI from knee height at gross motor function levels 1-3 and 4-5. For levels 1-3 and 4-5, the mean differences in height were -4.42 ± 5.39 cm and -2.72 ± 2.67 cm, respectively. Both correspond to a systematic underestimation error. The ranges in height for levels 1-3 were between -14.98 cm and 6.15 cm, and those for levels 4-5 were between -7.94 cm and 2.51 cm. The mean differences in the height-for-age index were -4.09 ± 4.79 % and -2.48 ± 2.19 % for levels 1-3 and 4-5, respectively. Both correspond to a systematic error of underestimation. The ranges for this index were between -13.48 % and 5.30 % for levels 1-3, whereas for levels 4-5, they were between -6.77 % and 1.81 %. The mean differences in BMI were 0.98 ± 1.14 kg/m^2 and 0.72 ± 0.64 kg/m^2 for levels 1-3 and 4-5, respectively; hence, there was a systematic overestimation error. The ranges in BMI for levels 1-3 were between -1.25 cm and 3.21 kg/m^2, whereas for levels 4-5, they were between -0.52 kg/m^2 and 1.97 kg/m^2.

DISCUSSION

The present study is the first in Mexico to analyze the equations published by Ruiz-Brunner et al. (20) for estimating height, height-to-age index, and BMI in a population of Mexican children and adolescents with CP. Several studies have proposed equations to assess height in different populations based on body segments (9,11,12,22-24); however, very few have been based specifically on populations of children with CP. In the study by Bell et al. (25), the equation by Stevenson et al. (9) performed on a population of children with CP was shown to be the most accurate and had the lowest bias for estimating height in ambulatory children with CP with diplegia and hemiplegia, with an accuracy of 0.4 % and bias of -0.5 ± 6.1 cm, compared with the equation by Chumlea et al. (12), which was performed in a population with reduced mobility and showed a bias of 1.7 ± 5.0 cm, making it less precise (25). In the study by Haapala et al. (6), the equation by Stevenson et al. (9) showed a greater bias (-4.04 ± 5.36 cm) than did the equation by Gauld et al. (11) (-0.90 ± 6.73 cm) in the population of children with moderate to severe CP. This bias was lower in the population with mild CP with the Stevenson equation than with the Gauld equation (-0.68 ± 4.28 cm and 2.46 ± 5.08 cm, respectively). In our results, the height-for-age index was the only anthropometric indicator that showed a significant difference between males and females, regardless of the equation used, being greater in males. A possible explanation for this difference could be that the height-for-age index was expressed as a percentage of the median and that these data were higher in boys than in girls in the general population. The height-for-age index tended to be greater in girls than in boys in group 1-3; however, this difference was not statistically significant. Our results show a high, direct, and significant correlation for all the anthropometric indicators when they were estimated using the equations of Stevenson et al. (9) and Ruiz-Brunner et al. (20). The small variations in the analysis of the correlations by levels of gross motor function, such as the higher correlation coefficients for height and height-for-age index at levels 4-5, may be due to the difference in the sample size of each group since it was greater at levels 4-5. These findings indicate that the equations proposed by Ruiz-Brunner are suitable for estimating height, the height-for-age index, and BMI even in the most affected population.

The anthropometric indicator with the highest concordance and the lowest mean difference was BMI, which was estimated using the equations of Stevenson et al. (9) and Ruiz-Brunner et al. (20), both in the general population and at levels 1-3 and 4-5, indicating a better estimate of this index with the equations of Ruiz-Brunner et al. (20). Systematic bias refers to the difference in the estimate between the two comparison methods, which can lead to systematic over- or underestimation in the measurements. This finding reinforces the validity and study of these equations in clinical contexts where obtaining accurate estimates is essential. On the other hand, the limits of agreement for height and height-for-age index were wider, with those for height being wider in the general population (-9.06 cm to 3.23 cm) and in levels 1-3 of gross motor function (-14.98 cm to 6.15 cm). Similarly, when all anthropometric indicators were analyzed by gross motor function groups, the group that presented the widest range was the group with levels 1-3; this could be because the sample size in this group was smaller (n = 18) and because of the dispersion of the data compared with the group of levels 4-5 (n = 134).

Several key differences are identified between the equations proposed by Stevenson et al. (9) and Ruiz-Brunner et al. (20). First, the equations of Ruiz-Brunner et al. (20) incorporate the level of the gross motor function, dividing it into two equations: one for the first three levels and another for the last two. In contrast, the equation by Stevenson et al. (9) does not consider the levels of gross motor function. In addition, the equations by Ruiz-Brunner et al. (20) include age as a variable in their calculations, which does not occur with the equation by Stevenson et al. (9). However, both equations agree on the use of knee height as a body segment to estimate height in children with CP, and neither of them distinguishes between sexes as applying to both sexes; however, the correlation coefficient for estimating height was high (r = 0.987; p < 0.001). According to the results of the study by Ruiz-Brunner et al. (20), the limits in the concordance analysis for estimating height ranged from -14.0 cm for the lower range to 14.6 cm for the upper range when the height estimated by body segments was compared with the height estimated by knee height. In the present study, limits of -9.06 cm in the lower range and 3.23 cm in the upper range were obtained for the total population.

In the study by Amezquita et al. (7), height was compared using the knee height segment with the equations of Stevenson et al. (9) *vs.* height measured in the supine position, in which a very similar mean difference was reported to the mean found in our study (-2.96 cm and -2.92 cm, respectively). Similarly, the limits of agreement also differ: Amezquita et al. (7) document wider limits, from -9.1 cm to 5.3 cm, whereas in our analysis, the limits are narrower, between -9.06 cm and 3.23 cm.

The results reported by the study by Haapala et al. (6) indicate that the mean difference between the height estimated with the knee height formula of Stevenson et al. (9) and the height or length by segments was -1.77 ± 5.4 cm in the total population. This study revealed a greater mean difference in the most affected population (-4.04 ± 5.3 cm) (levels 4-5 of gross motor function) than in the least affected population (0.68 ± 4.3 cm); however, in our study, the mean difference in the most affected group (-2.72 ± 2.67 cm) was similar to that in the total population (-2.92 ± 3.14 cm), which could be due to the smaller number of subjects in the group with levels 1-3.

Our study not only sets a precedent at the national level but could also serve as a reference for future research using these equations in diverse samples of Mexican children and adolescents. Likewise, its application in clinical practice could improve the precision of anthropometric assessment and diagnosis, favoring a more precise nutritional intervention according to the needs of this population.

One of the strengths of this study is the large number of subjects with CP who formed our sample, which allowed comparisons between anthropometric indicators. Another strength is that this study used anthropometric indices such as height-for-age and BMI, which have not been analyzed in other studies. One of the weaknesses was that the group with levels 1-3 of the gross motor function was small compared with the group with levels 4-5, so the findings of this group should be interpreted with caution.

CONCLUSION

The equations proposed by Ruiz-Brunner et al. (20) allow a useful estimation of anthropometric indicators such as height, height-for-age index and BMI in the Mexican population of children and adolescents with CP. BMI was the anthropometric indicator with the smallest mean difference and a smaller limit of agreement than the other anthropometric indicators, both in the total population and at levels 1-3 and 4-5 of gross motor function. More studies with larger sample sizes are needed to allow more precise comparisons between levels 1-3 and 4-5 of gross motor function with different anthropometric indicators.

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Table I. Anthropometric characteristics of the total population and by sex. Data are presented as medians and interquartile ranges

Variable	**All** **n = 152**	**Male** **n = 80**	**Female** **n = 72**	***p****
Age (months)	97.1 (57.3-144.8)	88.5 (57.3-145.2)	98.4 (56.8-143.4)	0.998
Weight (kg)	15.2 (11.4-22.4)	15.5 (11.5-22.7)	15.0 (11.0-21.5)	0.409
Height[1] (cm)	109.2 (94.1-124.3)	109.9 (94.3-124.0)	108.5 (93.1-125.1)	0.637
Height[1] (cm)†	111.9 (95.1-141.8)	105.4 (94.8-137.0)	120.0 (94.3-142.2)	0.696
Height[1] (cm)‡	108.9 (93.9-122.8)	109.9 (94.3-124.0)	107.7 (92.5-122.5)	0.437
Height[2] (cm)	111.1 (98-126.3)	111.4 (98.5-126.3)	111.5 (98.0-127.4)	0.730
Height[2] (cm)†	114.4 (101.2-140.5)	110.6 (101.1-143.2)	119.7 (100.7-140.5)	0.762
Height[2] (cm)‡	110.6 (96.9-125.3)	111.5 (96.8-126.3)	110.1 (96.2-123.9)	0.491
HA[3] (%)	100.5 (93.6-108.1)	103.9 (94.7-111.6)	98.4 (92.5-105.9)	*0.016*
HA[3] (%)†	97.2 (91.6-106.0)	94.1 (91.2-104.9)	101.6 (91.7-107.7)	0.203
HA[3] (%)‡	100.7 (93.7-109.1)	101.9 (94.4-109.6)	100.0 (93.2-107.0)	0.435
HA[4] (%)	103.7 (97.8-109.7)	105.7 (99.3-111.6)	102.0 (97.1-107.3)	*0.025*
HA[4] (%)†	102.5 (98.7-106.0)	101.0 (99.4-105.9)	103.9 (95.7-107.8)	0.829
HA[4] (%)‡	103.9 (97.7-	104.9 (98.2-	102.9 (97.4–	0.53

	110.0)	110.2)	109.4)	4
BMI[5] (kg/m^2)	13.1 (11.7-14.8)	13.3 (12.1-15.1)	13.0 (11.4-14.7)	0.179
BMI[5] (kg/m^2)†	12.6 (11.6-16.5)	12.6 (11.6-16.1)	12.8 (11.4-17.4)	0.984
BMI[5] (kg/m^2)‡	13.2 (11.7-14.8)	13.3 (12.2-14.9)	13.0 (11.4-14.7)	0.145
BMI[6] (kg/m^2)	12.6 (10.9-14.2)	12.7 (11.2-14.3)	12.3 (10.7-14.1)	0.215
BMI[6] (kg/m^2)†	12.6 (10.5-14.8)	12.3 (10.1-14.2)	12.7 (10.0-16.5)	0.762
BMI[5] (kg/m^2)‡	12.6 (10.9-14.2)	12.8 (11.2-14.3)	11.9 (10.7-14.1)	0.144

[1]Height (Stevenson); [2]Height (Ruiz-Brunner); [3]Height-for-age index (Stevenson); [4]Height-for-age index (Ruiz-Brunner); [5]BMI (Stevenson); [6]BMI (Ruiz-Brunner). *Mann-Whitney U-test; †Levels 1-3 of gross motor function; ‡Levels 4-5 of gross motor function.

Table II. CP subtypes and levels of gross motor function in the study population

Variable	**All**	**Male**	**Female**
CP subtype, n (%)			
Spastic	37 (24.3)	18 (22.5)	19 (26.4)
Ataxic	6 (3.9)	2 (2.5)	4 (5.6)
Dyskinetic	2 (1.3)	2 (2.5)	-
Hypotonic	20 (13.2)	9 (11.3)	11 (15.3)
Mixed	87 (57.2)	49 (61.3)	38 (52.8)
GMFCS, n (%)			
1	6 (3.9)	4 (5.0)	2 (2.8)
2	7 (4.6)	2 (2.5)	5 (6.9)
3	5 (3.3)	2 (2.5)	3 (4.2)
4	23 (15.1)	10 (12.5)	13 (18.1)
5	111 (73.1)	62 (77.5)	49 (68.0)
Levels 1-3, n (%)	18 (11.8)	8 (10.0)	10 (13.9)
Levels 4-5, n (%)	134 (88.2)	80 (90.0)	62 (86.1)

GMFCS: gross motor function classification system.

Table III. Correlation coefficients of anthropometric indicators between Stevenson et al. and Ruiz-Brunner et al. equations in all the population (n = 152) and by GMFCS levels

Variable	*r*	R^2	*p**
All			
Height	0.987	0.974	< 0.001
HA	0.959	0.919	< 0.001
BMI	0.986	0.972	< 0.001
Levels 1-3 (n = 18)			
Height	0.983	0.966	< 0.001
HA	0.920	0.846	< 0.001
BMI	0.973	0.947	< 0.001
Levels 4-5 (n = 134)			
Height	0.988	0.976	< 0.001
HA	0.995	0.990	< 0.001
BMI	0.960	0.893	< 0.001

GMFCS: gross motor function classification system; HA: height-for-age index. *Spearman correlation coefficient.

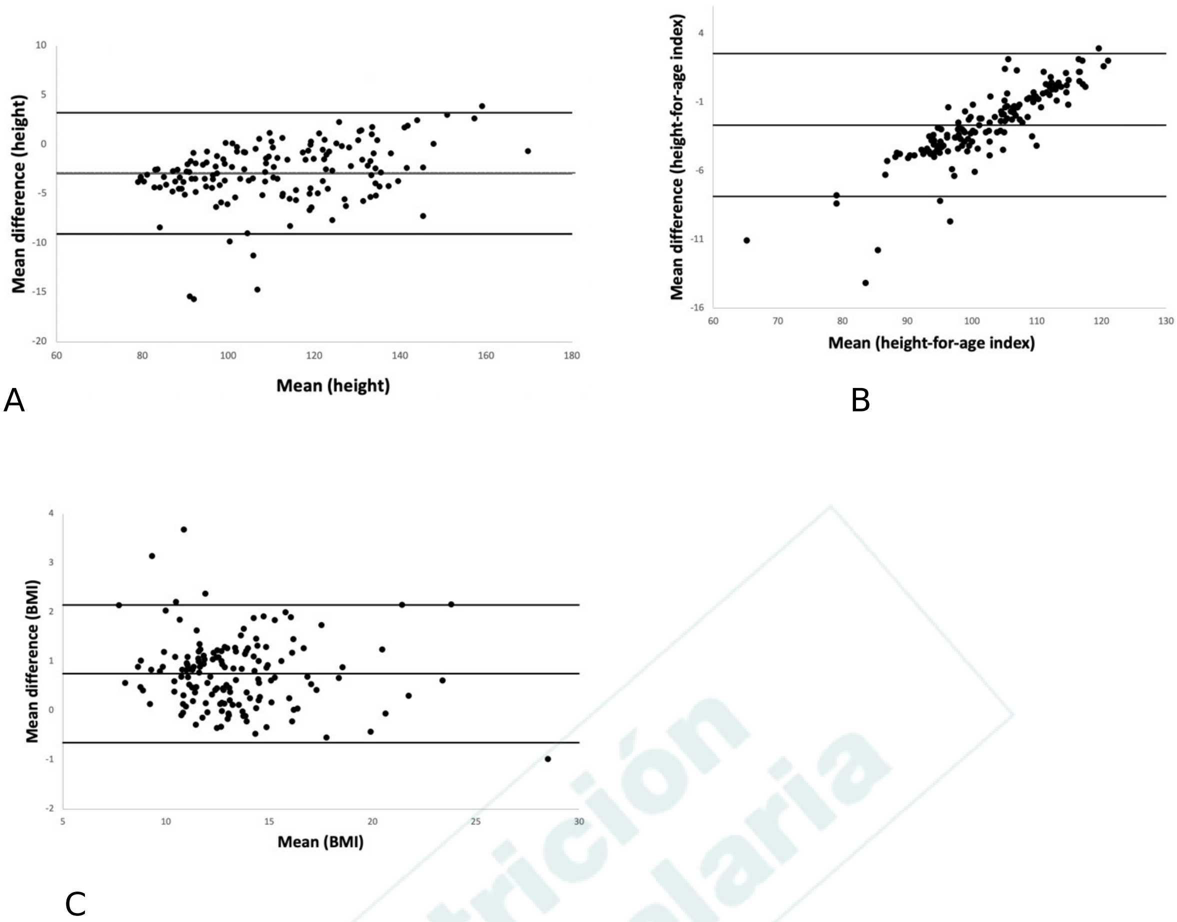
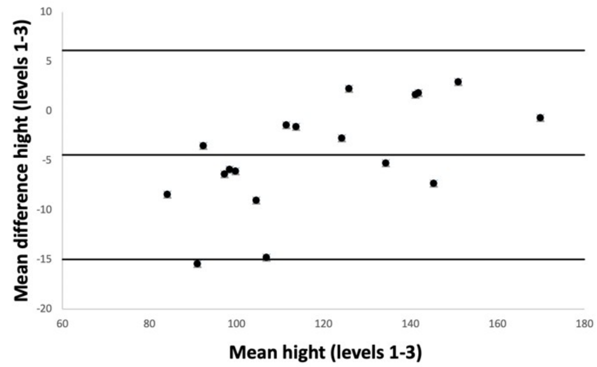
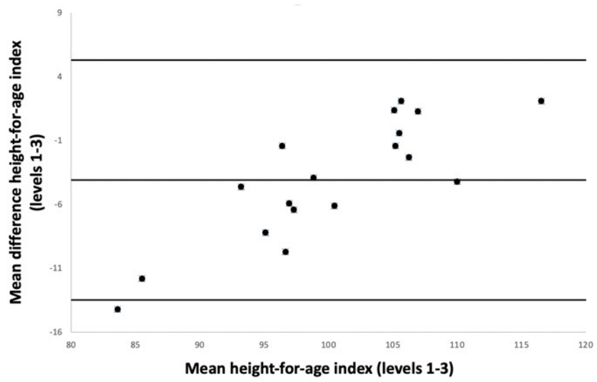


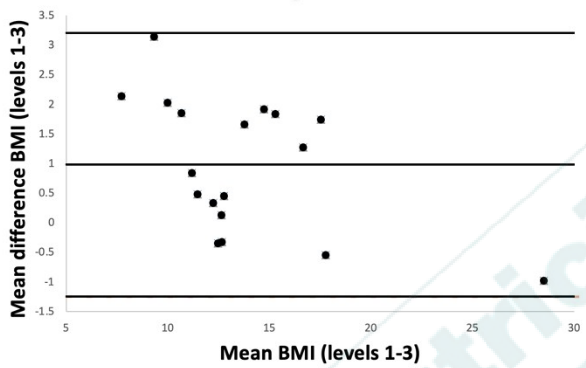
Figure 1. Concordance analysis between the Stevenson et al. (9) and Ruiz-Brunner et al. (20) equations to estimate height (A), height-for-age index (B), and BMI in the entire population (C).



A

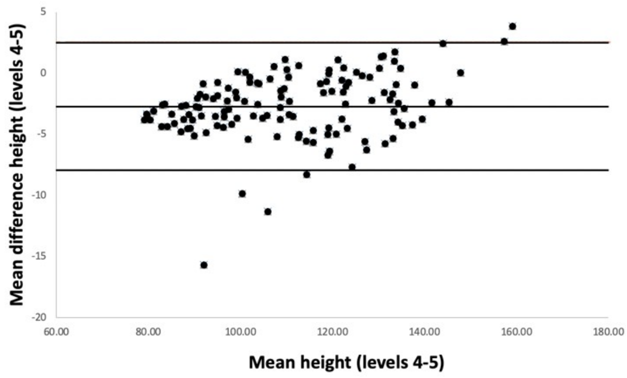


B

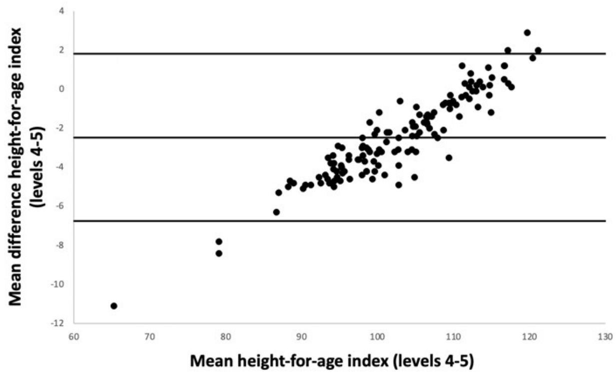


C

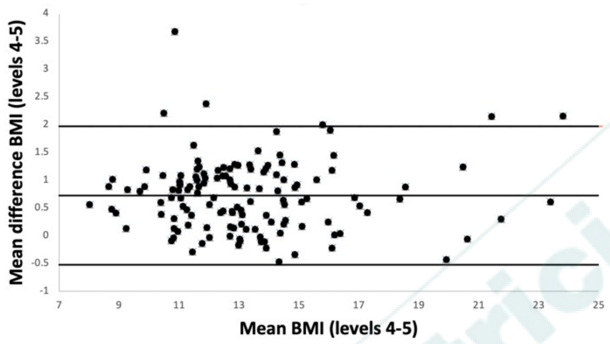
Figure 2. Concordance analysis between Stevenson et al. (9) and Ruiz-Brunner et al. (20) equations to estimate height (A), height-for-age index (B), and BMI at levels 1-3 of the GMFCS (C).



A



B



C

Figure 3. Concordance analysis between Stevenson et al. (9) and Ruiz-Brunner et al. (20) equations to estimate height (A), height-for-age index (B), and BMI at levels 4-5 of the GMFCS (C).