

Evaluation of a rapid weight estimation tool for pediatric emergencies

Evaluación de una herramienta de estimación rápida de peso para urgencias pediátricas

Tito Andrés Ortega Toro^a, Javier Sierra Abaunza^{a,b}, Jorge H. Botero Garcés^c,
Vanessa Margarita Lasso^a, Liliana C. Sarria^a

^aEspecialista en Pediatría, Universidad de Antioquia. Medellín, Colombia.

^bDepartamento de Pediatría, Universidad de Antioquia. Medellín, Colombia.

^cGrupo de Parasitología, Facultad de Medicina, Corporación de Patologías Tropicales, Universidad de Antioquia. Medellín, Colombia.

Received: October 01, 2021; Approved: August 8, 2022

What do we know about the subject matter of this study?

Rapid weight estimation for pediatric emergencies can be performed with several methods, including the Broselow Tape. This tape was developed with data from U.S. children and its accuracy varies according to the weight range of the child.

What does this study contribute to what is already known?

This study evaluates the performance of the Colombian Pediatric Tape (CPT) compared with the Broselow Tape. In addition, the weight range in which both tapes make the best weight estimation in Colombian children is identified.

Abstract

Weight measurement is essential in the treatment of pediatric patients in emergencies, however, in cases of patient instability or limited resources, weight estimation becomes a plausible alternative. There are rapid estimation methods, although with performance discrepancies in different populations. **Objective:** To compare the performance of the “Colombian Pediatric Tape” (CPT) and Broselow Tape (BT) in weight estimation in children. **Patients and Method:** Descriptive cross-sectional study and concordance analysis. Sample of 42,232 children from the 2010 National Survey of the Nutritional Situation of Colombia. For the performance evaluation, the prediction of zones and weight of each tool and their concordance using the Kappa coefficient and the Bland-Altman index were considered. **Results:** Cohen’s Kappa index for the BT with respect to the color area agreement was 0.57 and for the CPT it was 0.65. The Bland-Altman index for CPT of the actual weight and the estimated weight showed a mean difference of 0.005 Kg (CI95; -4.1 to +4.1), and for the BT was 0.13 Kg (CI95; -5.2 to 5.5). The percentage difference analysis of concordance between the two tools showed a statistically significant overall difference in favor of the CPT, 66% Vs 70% ($p = 0.00001$). **Conclusions:** In Colombian children, the BT overestimates or underestimates the weight by up to 21% with respect to the real value, while CPT can be used with better performance to estimate the weight.

Keywords:

Broselow Tape;
Body Weight;
Body Height;
Forecasting;
Pediatrics;
Colombian Pediatric Tape;
Pediatric Emergency Medicine.

Introduction

Adequate care of the pediatric emergency population is a challenge for medical personnel¹, mainly because most methods for selecting the appropriate size of the equipment and correct doses of medications are based on the patient's weight. However, an accurate measurement is often not possible due to the condition of the patients, resorting to weight estimates in up to 98% of the cases^{2,3}. These estimates, if inadequate, put the health and life of patients at risk.

In pediatrics, inadequate administration of medications is the most frequent error in medical care, which has been associated with the need to make individualized calculations based on the weight of each patient^{4,5}, with prescription errors being three times more frequent in children than in adults under similar conditions⁶. Another factor contributing to the increase in errors (up to 25%) is the need to perform quick calculations in a stressful environment, such as pediatric emergency and urgent care settings, where cognitive stress increases^{7,8}.

Given this reality, it is evident the benefit of tools that can reduce or eliminate the need to make estimates or calculations, which consequently, reduces the percentage of errors made. As stated by Luten⁸, aids for the reduction of cognitive stress during resuscitation, regardless of their form of presentation, whether physical or electronic, should meet certain requirements such as eliminating the need to perform calculations during the critical time, facilitating the recognition of errors, and finally easing the transformation of complex activities (non-automatic) into activities of less complexity (automatic).

Several estimation methods have been published, including estimation by parents, nurses, or physicians. One of the most widely used methods is the age-specific calculation such as the Luscombe and Owens formula⁹. However, the low accuracy of these formulas has been reported and therefore they are not an effective measure to reduce the risk of errors¹⁰.

Length-based tapes have also been described, with the Broselow Tape (BT) as the most widely accepted. This tape relates length to weight categories on a colored tape. Using data from the U.S. Census and the National Center for Health Statistics, the tape was developed by John Broselow and Robert Luten in 1986 and subsequently validated in 1987^{11,12}, showing better agreement compared with estimation by medical personnel¹³ and mathematical formulas¹⁴. In addition to weight estimation, BT provides information about drug dosage and the size of equipment to be used in resuscitation¹⁵, thus reducing the cognitive load in a stressful situation and contributing to the reduction of potential medical errors secondary to miscalculations,

which has become BT a common tool in resuscitation¹⁶ and has been recommended by the advanced pediatric resuscitation guidelines of the American Heart Association and the European Resuscitation Council^{17,18}.

However, studies in different populations around the world have reported differences in its performance, with accuracy varying between 33 and 91% (proportion of estimated weights within 10% of actual weight)². One reason for this variation could be that the most updated BT version uses exclusively North American population data from the National Health and Nutrition Examination Survey (NHANES 2007) and that similarly to the age-based formulas, the BT tends to underestimate weight in children from industrialized countries where overweight has increased and overestimate weight in children from regions where undernutrition is more common¹⁹. These variations could lead to inappropriate use of resuscitation equipment and medication errors. At the time of this study, no studies that reported the accuracy of this tool in the Colombian population were found.

The objective of this study is to determine the concordance of two weight estimation tools (BT and CPT) and the actual weight measured in a sample of children and to compare their performance.

Patients and Method

Descriptive cross-sectional study and performance comparison between two weight prediction tools.

The sample was obtained from the National Survey of Nutritional Status of Colombia (ENSIN 2010), a population-based study of national coverage with urban and rural representativeness, carried out between 2008 and 2010, in the 32 departments of Colombia. Colombian children aged between 1 month and 12 years of both sexes were included.

The exclusion criteria were children with incomplete data, length less than 47 cm or larger than 143.6 cm, weight higher than 40 kg, poor health status, edema, and childhood obesity. These criteria were chosen considering the greater variability and dispersion of the data with extreme anthropometric values and, in the specific case of obesity, the inclusion of this data could lead to overestimating the actual weight of the patients, which could lead to errors in the calculation of medications and equipment in patients without this pathology.

The anthropometric data were obtained from the ENSIN 2010 database; the original collection of these data was done by standardization with determination of precision and accuracy after staff training in taking anthropometric measurements and the use of standardized and calibrated equipment. For weight measure-

ment, a digital scale was used (SECA® 872), with 200 kg capacity and 50 gr accuracy (for weights from 0 to 50 kg). For measuring length, a portable wooden measuring rod was used (Diseños Flores S.R. Ltda.), with 2 m of maximum capacity and 1 mm accuracy, and 3 wooden measuring rods (Weight and Measure LLC, formerly Shorr Productions), with 1.97 m of maximum capacity and 1 mm accuracy.

From an initial sample of 53,632 children and after applying the exclusion criteria, a final sample of 42,232 individuals was reached. The use of the ENSIN 2010 database for the development of this research was requested and authorized by the repository of the Ministry of Health and Social Protection of Colombia.

Development of the new tape

Using the SPSS Statistics Version 24 software and based on the selected sample, the length variable of the database was transformed from a continuous variable to a discrete variable, and the arithmetic mean of the corresponding weight for each length was calculated (e.g., for patients with lengths of 47, 48, and 49 cm, the corresponding weight was 3 kg). With this information, 9 intervals (colored zones) were created where with the length of each patient, the weight can be predicted more quickly in the context of emergencies when the patient cannot be easily moved or in remote regions of scarce resources. The intervals of the predicted zones and weights were optimized considering the linear regressions provided by the Bland-Altman method (Figure 1).

For the information on the CPT, such as recommended drug doses, device size, and normal values of physiological variables and algorithms, the 2020 pediatric resuscitation guidelines published by the AHA were used as a reference¹⁸.

For the selection of the information, we considered other tools published worldwide and the results of a survey applied to 70 health professionals (pediatricians, pediatric residents, and physicians), from different levels of care in Colombia, about the information they considered relevant in the context of pediatric emergencies, adding on the B side of the tape information about the management of status epilepticus and the doses of the most widely used antidotes in the country.

Weight estimation by BT and CPT

It is recommended to use the BT to extend the tape along the child's body from the beginning of the head to the heels. The color of the tape that is at the level of the child's heels will provide its approximate weight in kilograms and its color zone, being the same procedure in the case of the CPT.

In this case, the predicted weight and color zone

were estimated with the length recorded in the database, extrapolating this value to the described intervals of color and weight for BT. The same procedure was performed to estimate the weight and corresponding color zone for CPT with the new intervals.

Identification and control of errors and biases

Children from the 32 departments of Colombia with urban and rural representation and of different ethnic groups were analyzed. The anthropometric data came from standardized and verified measurements performed with high-precision equipment. Inconsistent and incomplete data were excluded, as well as data from children with edema whose measured weight does not reflect their actual weight, obese children, and in poor health status. Resampling was performed several times, obtaining the same parameters as those observed with the complete database.

Variables

The main variables evaluated in this study were estimated weight by tapes and color zones assigned by length and by weight for both tapes.

The following were considered as dependent variables: the estimated weight with BT and the color assigned in BT based on the estimated weight and the estimated weight with CPT and the color assigned in CPT based on the estimated weight. The independent variables considered were length and actual weight (measured).

The presence of edema, extreme anthropometric data, and poor health status was considered potential confounding variables and was therefore excluded from the study.

Definition of variables

Actual weight: weight in kilograms measured and recorded in the ENSIN 2010 database.

Length: length in centimeters measured and recorded in the ENSIN 2010 database.

Estimated weight by BT: weight in kilograms estimated by length using BT.

Estimated weight by CPT: weight in kilograms estimated by length using the CPT.

BT color zone assigned by length: corresponding color area in the BT estimated by length.

CPT color zone assigned by length: corresponding color area in the CPT estimated by length.

BT color zone assigned by weight: corresponding color area in the BT estimated by the actual weight.

CPT color zone assigned by weight: corresponding color area on the CPT estimated by the actual weight.

Statistical analysis

For sociodemographic variables such as sex, age,

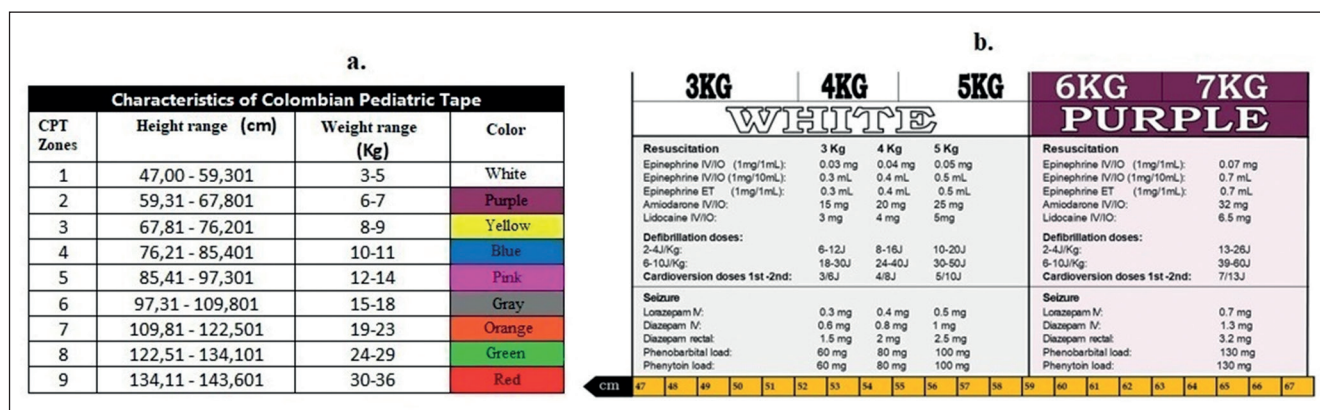


Figure 1. Characteristics of Colombian Pediatric Tape (CPT). **A.** Color zones, height ranges, estimated weight and assigned color. **B.** Side 1 of the tape.

origin, and ethnicity, the absolute frequency and relative frequency (proportion and percentage) were determined, creating frequency tables. In addition, summary statistics (descriptive statistics) were performed, and the normal distribution of the data was verified using the Shapiro-Wilk test. When the data were normally distributed, they were reported as mean with its respective standard deviation and as median and its respective interquartile range (quartile 3-Q3 minus quartile 1-Q1) when the distribution obtained was not normal. Categorical variables were summarized as proportions.

The concordance between the BT color zone assigned by the actual weight and the zone estimated by length was estimated by the Kappa coefficient, and the same analysis was performed for the CPT. The interpretation of the kappa coefficient was performed by correlating its value with a qualitative scale that includes six levels of concordance strength which are: none (0 - 0.2), minimal (0.21 - 0.39), weak (0.40 - 0.59), moderate (0.6 - 0.79), strong (0.8-0.9), and almost perfect (> 0.9) (20). On the other hand, the concordance between BT estimated weight and actual measured weight and the concordance between CPT estimated weight and actual measured weight were evaluated by the Bland-Altman method.

For all statistical tests, a significance of 95% was considered, that is, a type I error (α) equal to 5%, therefore, a value $p < 0.05$ was considered statistically significant.

All the data obtained were analyzed with SPSS® version 24, MedCalc version 15.8, and Epidat version 3.1.

Ethical considerations

The study complied with the principles of the 2005 Universal Declaration on Bioethics and Human Rights

and the Declaration of Helsinki of the WMA-Strength, 2013. Informed consent was not required since the information came from the ENSIN 2010 survey database, whose protocol indicates that informed consent was obtained from participants before data collection.

The research and its protocol were evaluated and approved by the Bioethics Committee of the Medical Research Institute of the University of Antioquia.

Results

A total of 42,232 children were evaluated. Table 1 shows the distribution of sociodemographic variables. The distribution by sex and age groups of the participants was similar. In addition, there was a representation of all ethnic and minority groups, which in descending order are mainly: Indigenous, Afro-Colombian, and Raizal archipelago. The most representative group with 31,347 children (74.2%) does not belong to any legally recognized ethnic group, which is called *mestizos*. Regarding the region and area of origin, information was obtained from all departments of Colombia, where 39.1% and 60.9% were from rural and urban areas, respectively.

The concordance assessment between the BT color assigned based on weight estimated by length and the color reassigned in the same based on actual weight was performed with the Cohen's Kappa index, showing an index of 0.578 (CI95: 0.573 to 0.583), while the same analysis for the CPT showed an index of 0.65 (CI95: 0.645 to 0.655), indicating a weak and moderate concordance strength, respectively (Table 2).

The same concordance analysis was also performed for the CPT but considering subgroups of the different sociodemographic variables, observing an index with

considerable concordance strength and homogeneous values for the different variables (Supplementary Table 1).

The analysis of percentages of concordance between the color assigned by each tape, based on the estimated weight by length and the color reassigned in the same based on the actual weight showed 70% concordance for the CPT and 66% for the BT with a $p < 0.001$. The same analysis by individual zones showed statistically significant differences in the CPT for zones 2, 3, 4, 5, 6, and 8; for zones 1 and 7, no difference was found and for zone 9 the statistically significant difference was observed in the BT (Table 3).

The Bland-Altman analysis of the actual measured weight versus the estimated weight with the CPT showed a mean difference in kilograms of 0.005 (CI95:

-4.1 to +4.1), while for the BT, it showed 0.13 (CI95: -5.3 to 5.5), (Figure 2). As for the mean percentage difference, this was -0.3% for BT (CI95: -21 to 21%) and -0.1% for CPT (CI95: -18 to 17%).

Discussion

In resuscitation scenarios, when time optimization is essential or when tools are not available in low-resource settings (e.g., no scales or cribs or beds with scales included), it is a challenge to determine the exact weight and thus the dose of drugs, cardioversion, or defibrillation, and size of medical equipment to be used. This makes methods for rapid and inexpensive weight estimation a real alternative and widely used^{15,16}. One of these methods is BT, however, studies have reported imprecision in weight estimation using it depending on the geographic region of its application, as in the study by Milne, W. et al with 6,361 children where BT showed a mean difference of 7.1%²¹, while Askaryar and Shankar in India, reported that BT overestimates weight by 5-15% depending on the color zone in their cohort of 1,185 children aged 1 month to 12 years²². In addition, Khouli M described a difference in the measured weight and that estimated in BT by more than 10% in a sample of 815 Mexican children¹¹. Greater differences have also been reported using BT, with a mean difference of 1.62 kilos²¹. Finally, in the meta-analysis and systematic review by Wells M, a suboptimal estimation of BT was observed, with greater overestimation of weight in low- and middle-income countries²³.

In this study, the CPT outperformed the BT in terms of accuracy in weight estimation with a mean difference of 5 and 130 grams, respectively. In addition, the BT presented a variation of up to -5.2 to +5.5 kg compared with the CPT where 95% of the differences were a smaller variation between -4.1 to 4.1 kg. This difference was greater in heavier children, as shown by the Bland-Altman analysis since the dispersion becomes greater above 25 kg (Figure 2). The concordance measured by Cohen's Kappa index for BT was 0.57, which is classified as weak, compared with 0.65 for CPT, considered moderate. As reported by McHugh ML, a Kappa index < 0.6 indicates inadequate concor-

Table 1. Sociodemographic characteristics of the sample

Sociodemographic variables	n	(%)
Gender		
Boys	21982	(52.1)
Girls	20250	(47.9)
Ethnic group		
Indigenous	5894	(14)
Romani	11	(0.0)
Raizal	323	(0.8)
Palenquero	15	(0.0)
Afro-Colombian	4642	(11.0)
Non-Ethnic Population	31347	(74.2)
Age		
1 month to 2 years	9943	(23.5)
2 years to 6 years	14439	(34.2)
7 years to 12 years	17850	(42.3)
Residence area		
Urban zone	25721	(60.9)
Rural zone	16511	(39.1)
Region of origin		
Atlantic	10114	(23.9)
Oriental	6161	(14.6)
Central	8937	(21.2)
Pacific	5596	(13.3)
Bogotá	2013	(4.8)
National Territories	9411	(22.3)

Table 2. Concordance between color zones assigned by estimated weight and by measured weight

Tape	Kappa coefficient	Standard error	Confidence interval (95%)
BT	0.578	0.003	0.573 - 0.583
CPT	0.65	0.003	0.645 - 0.655

BT: Broselow Tape; CPT: Colombian Pediatric Tape.

dance so little confidence should be placed in such results, as is the case with the BT Kappa²⁰. These differences in BT regarding concordance and weight estimation may lead to under- or overdosing, or to the inadequate selection of the size of resuscitation equipment such as laryngoscope blades or endotracheal tubes, all this entailing greater risk for patients or representing more valuable time in resuscitation^{4,6,8}.

When analyzing the difference in percentages of agreement of the color zones for the two tapes according to the estimated weight and the actual weight, a statistically significant overall difference was found in the CPT (70% vs 66%; $p < 0.001$), with an overall estimation difference of 4% in the CPT and, in the individual analysis by zones, it was found the CPT was superior to the BT in six of them and only in one was inferior (oldest age), considering that other studies have already mentioned the decrease in accuracy of the tape as weight or age increases²⁴⁻²⁶.

The strength of the CPT lies in the fact that it was developed based on anthropometric data from a representative sample of the Colombian population and therefore the estimates obtained from it provide greater reliability in its calculation. Another advantage is that, when comparing the concordance percentages according to different sociodemographic variables with the overall concordance, these were similar, which makes it useful in different scenarios in the country. In addition to weight estimation, the CPT provides information about drug doses and the size of the equipment used in resuscitation in our native language, thus, it can reduce the cognitive load in a stressful situation and contribute to the reduction of potential medical errors secondary to erroneous calculations, which benefits the Colombian population.

One of the limitations of this study is its cross-sectional design based on secondary sources, even though

Table 3. Concordance between measured and estimated weight for BT and CPT

Color zones	Percentages of concordance		p
	BT	CPT	
1	80.2%	79.4%	0.77
2	67.1%	73.9%	< 0.001
3	64.8%	70.7%	< 0.001
4	64.8%	70.7%	< 0.001
5	69.6%	74.0%	< 0.001
6	70.0%	72.0%	< 0.001
7	72.5%	73.7%	0.0879
8	56.0%	70.5%	< 0.001
9	88.0%	70.8%	< 0.001
Overall Comparison	66.0%	70.0%	< 0.001

BT: Broselow Tape; CPT: Colombian Pediatric Tape.

it is a representative sample of Colombian children that is similar to the process used to develop the BT for the United States. In addition, both tools use data collected in 2007 for the BT and 2010 for the CPT, which could be a limitation due to the trend of increasing child overweight in some countries and undernutrition in other regions¹⁹. However, the two tapes are the most updated in each country of origin.

Conclusions

In this study, with a representative sample of Colombian children, it was found that BT can over- or underestimate weight by 21% and that its concordance

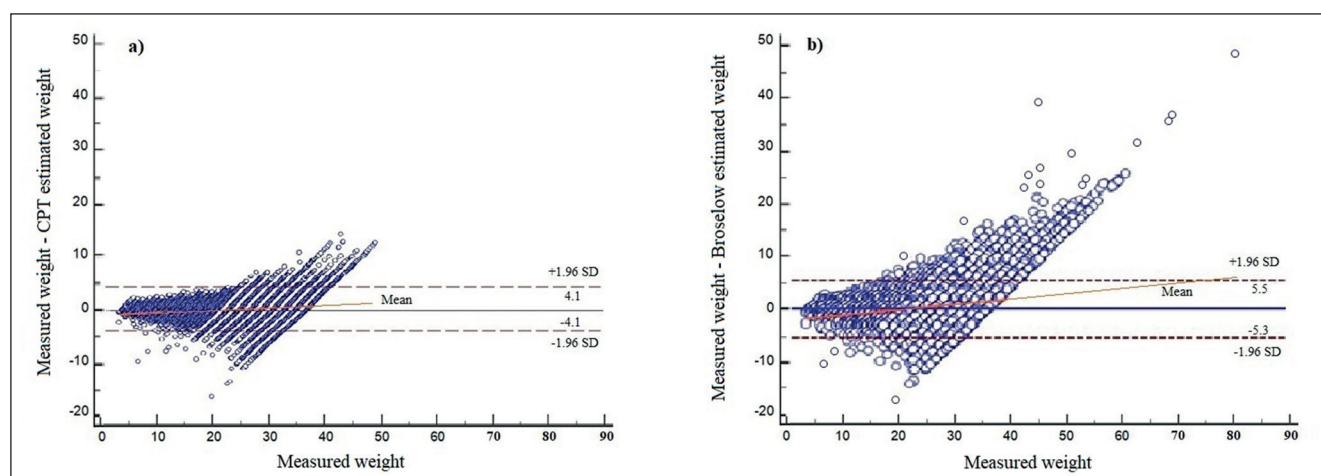


Figure 2. Bland-Altman analysis of actual (measured) versus estimated weight. **a)** Estimated by the Pediatric Colombian Tape. **b)** Estimated by the Broselow tape.

is inadequate. The CPT is a tool that can be used with better performance than BT to estimate the weight of Colombian children in different scenarios.

It is expected that CPT, as a medical tool, will be useful in different scenarios and remote regions of Colombia, where it will ultimately have a favorable impact on Colombian children. It is suggested that, in the future, the performance of CPT in pediatric emergency scenarios be evaluated and validated and that it could be validated with an updated data sample in order to reduce the risk of errors derived from nutritional changes in the Colombian population.

Ethical Responsibilities

Human Beings and animals protection: Disclosure the authors state that the procedures were followed according to the Declaration of Helsinki and the World Medical Association regarding human experimentation developed for the medical community.

Data confidentiality: The authors state that they have followed the protocols of their Center and Local regulations on the publication of patient data.

Rights to privacy and informed consent: The authors state that the information has been obtained anonymously from previous data, therefore, Research Ethics Committee, in its discretion, has exempted from obtaining an informed consent, which is recorded in the respective form.

Conflicts of Interest

Authors declare no conflict of interest regarding the present study.

Financial Disclosure

Authors state that no economic support has been associated with the present study.

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