Original Article

A Comparative Study on the Results of Estimating Children's Weights Based on Arm Circumference, Height, and Body Habitus against Estimated Weight Broselow on 2–24 Months Children in Isfahan

Abstract

Background: Resuscitation of children in different treatment wards is a challenge. Given that the pediatric drug dosing is based on weight and weighing is not practical in emergency situations, it is critical to employ a fast, easy, and reliable technique. Hence, this study attempted to evaluate the real weight children against Broselow estimation. **Materials and Methods:** This cross-sectional study involved 1500 children of 2–24 months referred to Isfahan urban and rural health centers in 2015. Children's estimated weights were measured based on the standard Broselow tape and real weights through a digital scale. The factors such as age, sex, height, arm circumference, head circumference, and living place of children were recorded. The collected data were analyzed through independent *t*-test, ANOVA, and linear regression using SPSS (version 20). **Results:** The weight difference of children through Broselow estimation was 0.019 kg, and the correlation coefficient was 0.893 ($P > 0.05$). The difference sorted by age ranges was significant only in >12 months ($P < 0.05$). It was estimated at error of 10% to be 68.9% correctly. The mean weight estimation error was significant sorted by weight, sex, habitus, and living place of children ($P < 0.001$). **Conclusion:** Although Broselow tape has been proved to be accurate it led to a significant error at different age ranges. Hence, the present study estimated the age, arm circumference, and height of Iranian children based on new formulas providing more successful tool through controlling the confounding factors in estimating the real weight.

Keywords: *Arm circumference, body habitus, children, estimated weight, height, weight*

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Introduction

Resuscitation of children is a fundamental challenge for physicians and nurses. Resuscitation management in children needs to skills and precision through a systematic approach to ensure the child's safety. The care of critically ill children requires attention to details and effort to determine the proper dosage of medication required by the child.[1] Therefore, accurate estimation of the child's weight is crucial in the emergency room for treatment and proper care. Calculation of doses, intravenous fluid intake, and electric shock depends on the child's weight. In critical situations, it is impossible to weigh injured children through accurate measurement tools. There is no possibility of measuring weight using precision instruments.[2] On the other hand, the child's weight can provide a basis to select the essential equipment such as end tracheal tube. It will not be easy to decide on the measurement equipment if the child's weight is not estimated correctly.[1]

In addition to the emergency hospital and children admissions, weight estimate holds true about prehospital emergency. That is because the recovery in stressful situations outside the hospital and prehospital emergency will be challenging for personnel. Poor weight estimation in children leads to increased errors in the application of medicines and equipment before children are transferred to the health center.[3]

Recently, there have been numerous errors in weight estimation using visual means by doctors or relatives, patient's age, and certain formulas. Growth charts are not suitable for emergency situations, since there is a significant difference in weights of children at the same age.[4]

In general, it is possible to estimate the weight of the child using demographic

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and anthropometric characteristics such as age, ethnic background, and height or body habitus.[5] In addition, the weight of the child is estimated by parents, doctors, and nurses. Studies have reported that estimated of child's weight by the medical care staff is poorly accurate and cannot be used as a method for estimating the weight and the basis for calculating the dosage.[4] The estimation of weight by parents especially the mother can be more accurately than the estimate by the medical staff, even though the unavailability of parents makes it impractical. Under recovery conditions with extreme stress, the child's parents may not be able to remember the exact weight of their child. Moreover, the parents in some cases may not provide the exact weight of the child.[6,7]

Previous studies proposed certain techniques to estimate the weight of the child and calculate the drug dosage through particular variables.[8] However, it is crucial for the medical staff to have high accuracy and easy to use tools at disposal.[9]

To solve these problems and increase the accuracy, speed, and decrease visual errors Lubitz *et al*. designed a tape in 1979 to rapidly estimate the weight based on height.[10] In addition to estimating the weight of children, the tape determined the drug dosage and other devices and medical equipment when it comes of resuscitation. Therefore, one of the common methods for estimating the weight of children in emergency situations is the estimation of weight based on body length.[11] In the 1990s, this tape was widely used in many countries.[12]

Previous studies in the United States, South Korea, China, India, and Hong Kong confirmed the accuracy of this tape.[1-3,8,13,14]

Nieman *et al*. have reported that the Broselow tool (BT) failed to estimate the weight of a third of patients.[1] Ramarajan *et al*. have indicated that it overestimated the weight of Indian children that were over 10 kg >10% of the time.[15] Another method of estimating the weight of a child is through age-based equations. Among age-based methods, Advanced Pediatric Life Support (APLS) equation ([age +4] × 2 for aged 1–9) has been widely used, along with Shann, Leffler, Nelson, and Best Guess formulas.[16-20]

Now, the application of this tape has been challenged in developing countries. In Iran, Mahmudzadeh used the Broselow tape to estimate weighs accurately. They concluded that the weight estimates that 69.5% of cases were different from accurate figures by 10%.[21] In their study, Akaberian *et al*. showed that BT is simple, fast, and accurate to estimate the weights of children in emergency situations in Bushehr compared to their parents or medical personnel.[22] The tape is still usable, but not confirmed in Iran and requires more studies. Therefore, this study attempted to evaluate the results of estimating the weight of children based on arm circumference, height, and body habitus against the results of Broselow's study on children 2–24 months of age in Isfahan.

Materials and Methods

This cross-sectional study conducted on 1500 children with the age of 2–24 months referred to urban and rural health centers of Isfahan during 2015.

The children were selected by multistage random cluster sampling, where the researcher first prepared a list of urban and rural health centers supported by No. 1 and 2 health centers of Isfahan University of Medical Sciences. Then, 10 urban and rural health centers were randomly selected. The quota sampling was used for selection according to age distribution, sex, and living location.

In this study, healthy Iranian children without severe disease or congenital anomalies within the age of 2–24 months living in Isfahan and their parents had expressed consent to participate in the study were included. The exclusion criteria were <3 kg weight or height <46 cm, risk of mental retardation, malnutrition, children with dehydration, edema, stunting, mutilation, impaired growth hormone, and lack of parental consent.

To record the required information, the sample collector was trained about how to work with the scales, how to calculate height and arm circumference and complete the corresponding checklist.

All demographic data including age (in months), sex, height, arm circumference, head circumference, weight, and location of children were recorded. The mid-upper arm circumference measurements in the middle arm's length were made by a meter and child's right arm (in a state of undress).

The height and weight of children in light clothing and without shoes while standing were measured with a digital scale standard stadiometer seca to be ±100 g with an accuracy of 1 mm made in Germany (for height) in a standing position while legs are conjoined, shoulders, hips, and head are in contact with the stadiometer. For children <1 year unable to stand, the measure was done in supine position.

Calibration of scales was done with weight control 50 g daily. To determine the child's body size and shape, standard percentile charts were used as advised by the World Health Organization. In the growth curves used for children younger than 2 years, the 0–5th percentile was very lean body, 25th percentile was small size, 50th percentile was average size, seventy-fifth percentile was large habitus and 95–100th percentile was fat habitus. Estimated weight of children by the standard Broselow tape was measured based on the distance between the head and heel in the lying on back position. Broselow tape is a paper tape with a length of 146.5 inches divided into 9 different colors. Each part shows a weight range with 2–4 kg different as well as a certain amount of medication and appropriate medical devices. Maximum weight in the tape is 36 kg.[23]

The difference percentage between Broselow tape and the real weight was calculated through the formula (100 × [estimated weight Broselow − real weight]/real weight) at error margin of ±10%.

Finally, the collected data were imported into SPSS (version 20; SPSS Inc., Chicago, IL, USA). Moreover, paired *t*-test and Pearson correlation coefficient were used to compare estimates of Broselow and real weights. The independent *t*-tests and ANOVA were used to compare the error margins of BT in terms of weight, sex, habitus, and living place. Moreover, linear regression was adopted to determine formulas for estimating the weight by controlling the confounders of age, height, and arm circumference. The statistical significance in all analyses was <0.05.

Results

This study involved 1500 children with the age range of 2–24 months, of whom 635 were <12 months and 865 were 12–24 months old, selected approximately equal to the urban and rural populations. The number of boys was 800 (53.3%) with the mean age of 13.02 ± 6.31 months. The average height of children was 75.35 ± 8.72 cm, the average arm circumference was 15.05 ± 1.92 cm, and the mean head circumference was 45.25 ± 3.01 cm. The mean weight of children was 9.41 ± 2.10 kg separated in pediatrics (<12 months) 7.55 ± 1.61 kg and 2–24 months at 10.78 ± 1.15. The lowest frequency was in very small habitus with 47 subjects (3.2%), and the highest frequency was in the average size of 649 subjects (43.3%). The obese habitus (large or very large size) was mostly in the age group of 2–24 months and the very small size was mainly founded in the infant group [Table 1].

The comparison of weight compared to the estimated weight by BT, which generally indicated very little difference between the two weights equal to 0.019 kg ($P > 0.05$). Furthermore, the correlation between real and estimated weights by BT was strongly significant and direct (correlation = 0.893, $P < 0.001$). It can be argued that the real weight and the estimated weight by BT were very close to each other. On the other hand, evaluation of Broselow estimated and real weights in children of (<12 month) and 2–24 months old showed that in the latter there is no significant difference between the two weights but in children aged <12 months Broselow weight was significantly less than the real weight estimates (mean different: −0.201, $P < 0.001$) [Table 2]. On the other hand, the mean percentage error of assessment by BT was 0.769% overall, −2.357% in ages <12 months and 1.335% at ages 2–24 months. The estimation error at 10% indicated that the weight estimation through Broselow in 1033 subjects (68.9%) led to error <10% [Table 2].

Table 1: Population characteristics of the children in each of the weight category and habitus score categories

Characteristics	Overall	<12 months (*n*=635)	12-24 months (*n*=865)	Habit score*				
				1	2	3	4	5
Sex (boy)	800 (53.3)	340 (53.5)	460 (53.2)	22 (45.8)	74 (38.5)	320 (49.3)	296 (60.9)	88 (70.4)
Age (month)	13.02±6.31	7.71±2.97	17.66±3.43	10.21±3.98	10.38±5.19	12.72±5.85	15.19±6.31	11.32±7.95
Weight (kg)	9.41±2.10	7.55±1.61	10.78±1.15	8.16±0.68	8.01±1.78	9.15±1.80	10.35±1.97	9.68±2.89
Height (cm)	75.35±8.72	67.53±7.56	81.08±3.47	78.37±5.46	73.19±8.51	75.30±8.12	77.20±8.41	70.53±11.26
Arm circumference (cm)	15.05±1.92	13.59±1.89	16.10±1.08	14.42±1.51	14.19±1.75	14.89±1.64	15.68±1.85	14.93±2.90
Head circumference (cm)	45.25±3.01	42.79±2.84	47.06±1.40	44.97±1.89	44.09±3.14	45.15±2.68	46.13±2.92	44.67±3.95
Habit score								
Very small size	47 (3.2)	33 (5.2)	15 (1.7)	-	-	-	-	-
Small size	192 (12.8)	114 (18)	78 (9)	-	-	-	-	-
Average size	649 (43.3)	284 (44.7)	365 (42.2)	-	-	-	-	-
Large size	486 (32.4)	139 (21.9)	347 (40.1)	-	-	-	-	-
Very large size	125 (8.3)	65 (10.2)	60 (6.9)	-	-	-	-	-
Residence								
City	897 (59.8)	383 (60.3)	514 (59.4)	123 (50.6)	151 (58.3)	223 (50.3)	274 (73.5)	126 (69.2)
Village	603 (40.2)	252 (39.7)	351 (40.6)	120 (49.4)	108 (41.7)	220 (49.7)	99 (26.5)	56 (30.8)

*Habitus of children, 1: Very small size, 2: Small size, 3: Average size, 4: Large size and 5: Very large size

Table 2: Mean different of estimated weight brose low from child's real weight

Variables	Overall	<12 months (*n*=635)	12-24 months (*n*=865)
Mean different (kg)* (95% CI)	+0.019 (−0.039-0.057)#	−0.201 (−0.276–−0.121)†	+0.102 (−0.010-0.222#)
Mean percentage error**	+0.769	−2.357	+1.335
Within 10%	1033 (68.9)	309 (48.7)	464 (53.6)

*Mean different = estimate weight−real weight, **Mean percentage error = 100 × (estimated weight−real weight)/real weight, #Significant level is upper than 0.05, †Significant level is <0.05. CI: Confidence interval

In addition, the mean percentage of estimated weight error by BT separately in two age groups <12 months and 12–24 months in Figure 1 revealed that the mean percent weight error in the infant subclass was higher than that in the 12–24 months.

The effects of variables such as sex, weight, body shape, and living locations of children turned out to be significant on the mean of weight error and percentage of weight estimation by BT. In general, Broselow estimation was more than real weight of girls and lower than real weight of boys (mean error: 0.31 ± 0.99 and −0.26 ± 0.84, $P < 0.001$). Moreover, in weights >10 kg, the habitus of very large and living locations of children, BT had higher weight estimation error than the real weights of children ($P < 0.001$) [Table 3].

Finally, given that the BT was generally desirable for weighing the Iranian Children with minimal error, the separate examination within different age ranges indicated that the tool is not desirable for estimating the weight of children under 1-year-old. Therefore, the following provides formulas to estimate the weight of children under 1-year-old and 1–2 years provided where the underlying variables such as gender, body habitus, and living place of children have been adjusted and estimated through independent variables such as age, height, weight, and arm circumference [Table 4].

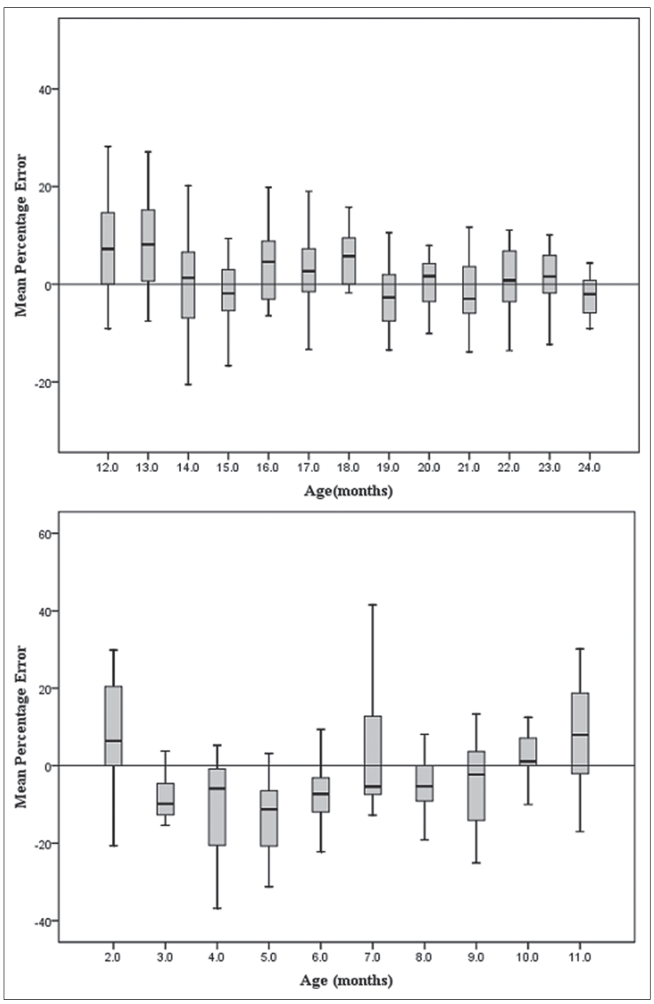

Figure 1: Mean Percentage error for weight estimated of real weight in infants (by months of age). Error bars indicate two standard deviation either of the mean % error, mean percentage error = 100× (estimated weight − real weight)/real weight

Discussion

Selecting the appropriate dose of medication and other medical equipment in emergency situations is difficult for doctors and nurses. Medical wards to determine the dose at resuscitation are needed to determine the child's weight, and weight measurement is not possible in emergency situations. Therefore, finding a simple and convenient way to weigh children is essential. Several reports have pointed out to the techniques used to estimate the weight of children based on height, age, arm circumference, etc.[4,8,10,24,25] According to research, BT is the best practice in emergency situations.[4,12] To this end, the current study compared estimation of children weight based on BT with real weight of children on 1,500 children at age range of 2–24 months, and it was shown that overall 649 children (43.3%) had normal average size, in turn, 611 children (40.7%) had large or very large size. According to the reports by the National Nutrition and Health centers in the past three decades, the prevalence of obesity among children has increased.[1] At the same time, childhood obesity has turned into one of global development problems and the World Health Organization has warned on the pandemic of obesity among children which leads to complex problems and chronic diseases for children.[26] In such conditions and given the range of height and weight of children, such tools as BT should be re-evaluated.[1]

According to our assessment, the mean of real weight differences compared to the mean of estimated weight by

Table 3: Factors affecting on mean percentage error

Factors	Mean percentage error	*P*	Mean error	*P*
Sex				
Girl	4.46±12.01	<0.001	0.31±0.99	<0.001
Boy	−2.47±8.98		−0.26±0.84	
Weight (kg)				
<10	2.55±13.18	<0.001	0.18±1.03	<0.001
>10	−1.45±7.01		−0.20±0.82	
Habit score				
1	8.44±19.11	<0.001	0.67±1.52	<0.001
2	9.62±12.27		0.71±0.88	
3	2.69±8.98		0.22±0.76	
4	−2.97±10.78		−0.32±0.72	
5	0.077±11.06		−1.14±1.07	
Residence				
City	0.93±11.32	<0.001	−0.17±0.99	<0.001
Village	3.29±10.15		0.27±0.85	

Table 4: The derives linear relationships and simplified equations on base age, height and arm circumference

Independent variable	R^2*	Linear relationships	Simplification
Age			
Infant (<12 months)	0.726	Mean weight (kg) = 0.461 × (age in months) + 3.069	(age in months+6)/2
12-24 months	0.688	Mean weight (kg) = 1.958 × (age in years) + 5.678	2 × (age in years+3)
Height			
Infant (<12 months)	0.928	Mean weight (kg) = 0.221 × (height in cm) − 9.351	(height in cm − 37)/4
12-24 months	0.905	Mean weight (kg) = 0.228 × (height in cm) − 10.623	(height in cm − 41)/4
Arm circumference			
Infant (<12 months)	0.659	Mean weight (kg) = 0.679 × (arm in cm) − 2.142	(arm in cm − 4)/2
12-24 months	0.586	Mean weight (kg) = 0.420 × (arm in cm) + 1.774	(height in cm + 3)/2

Use of regression linear with adjusted sex, residence, and habitus score of children.*R^2 is the percentage of the response variable variation that is explained by a linear model. Also R^2 obtained indicate that the model explains the variability of the response data around its mean very good

BT is generally very negligible, so that there is direct and significant relationship between average real weight and estimated weight. However, with controlling for age and categorizing children into two age groups into <12 months and 12–24 months, it was observed that BT accuracy in estimating the weight of children under 12 months is <12–24 months old children, so that weighs less than the real are estimated and it is associated with more errors. In this regard, the rapid growth of the child in different time periods and different nutritional status of children can be effective.[4]

In a study in Australia, it was shown that BT has ease of use in the emergency ward compared to the other methods (e.g., APLS, Best Gues), and it is more accurate.[27] Another study also showed that the BT was useful in estimating Indian children weigh younger than 6 years of age.[28]

However, some studies reported that the current BT incorrectly predicted the real weight in almost one-third of the US children.[4,29] Theron *et al*. also showed that the BT underestimated the weights of Pacific Island and Maori children younger than 10 years of age.[29]

Ramarajan *et al*. also indicated that use of this tape in children above 10 kg leads to overestimation of the weight.[15]

Estimated Broselow weight in the current study with ±10% error was 68.9%. It is comparable with findings by Akaberian *et al*. in Iran, which estimated weight within 10% error correctly in 72.5% of children.[22]

Also Hofer *et al*. study, which showed the BT weight to be within a 10% error in 65% of the enrolled children.[30]

Kun *et al*. also showed that weight was correctly estimated with BT within a 10% error in 69.5%of children in Hong Kong.[12] Krieser also reported the accuracy of BT estimation as 61%.[6]

In the present study, Broselow weight estimation's error percent was assessed based on factors such as gender, the child's weight, habitus, and the residence and it was shown that Broselow weight estimation in boys or in obese children is more precise with less error, although it estimated the weight less than the real weight. In addition, the weight of children living in rural areas was estimated with higher error more than their real weight, but the weight estimation accuracy by BT was higher in urban children.

The BT, created in 1986, is somewhat limited as it only applies to children who are between 46 and 145 cm in height and between 3 and 34 kg in weight. It also assumes a particular body habitus and may be less accurate with very thin or obese children. It has also been reported that the tape performs less well in some ethnic groups, notably Maori and Pacific Island people.[29]

Consistent with the current study, some studies also stated that in cases with obese children, weight estimation by BT was better than doctor's estimation.[4,12]

In the end, considering that such factors as children's age, gender, weight, shape, and location can be effective in weight estimation by BT, some formulas are provided in the current study to estimate the weight using age, height, and arm circumference with controlling these risk factors. These formulas can have some advantages over BT or other weight estimation formulas. First, these formulas are provided separately for children below 12 months (Infants) and 12–24 months old children. Also, since when calculating the weight by the age, the doctor may not be aware of the child's age, provided formulas can be used based on the weight or child's arm circumference. Second, confounding variables such as location, weight, gender and habitus of the child are controlled in use of these formulas. Thus, there is no need for separating obese or tall children in using these formulas. Because of controlling location, rural or urban situation of children given different diets cannot influence weight estimation.

Conclusion

According to findings of the current study, the estimation of weight by BT has a significant difference with real weight of Iranian children only in age range of <12 months. On the other hand, weight calculation by BT can be affected by such variables as gender, weight, age, habitus, and living location. Hence, we developed a simple formula to estimate body weight based on the age, length, and arm circumferences of Iranian infants and 12–24 months children. However, care should be taken when applying this formula to older children because of a large standard deviation of estimated weight.

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Conflicts of interest

There are no conflicts of interest.

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