Original Research Article

Accuracy of Broselow Tape in Weight Assessment Among Pediatric Population Presenting to Emergency Department of a Low-Income Setting.

Abstract:

Background

Near precise weight assessment among sick pediatric patients remains a dilemma and conventionally accepted weight assessment methods, in busy ED might be inaccurate or unreliable. Children have different weights at different ages, and accurate/precise weight measurement is of utmost importance for weight-related dose calculation of drugs/fluids, equipment sizes, an accurate dose of electrical currents during cardiac shock, etc.

Several weight estimation methods are available and are dependent on the child's age, length, or both. However, length or length-and-age-based methods may have greater accuracy than merely age-based, still precise weight measurement while children are recumbent (length) has its own challenges.

Aim

We aim to determine the accuracy and reliability of BT by comparing it with actual weight and advanced pediatric life support formula (APLS) among the pediatric population presenting to the emergency department.

Study design.

A single-center, cross-sectional study prospective study design.

Place and duration of study.

This study was conducted at pediatric emergency of a urban tertiary care hospital after ethics committee approval and written consent from parents/caregivers during July 2021- June 22.

Methods

Pediatric patients aged 1 month to 12 years, weight 3-36 kg, and height 46.5-142.5 cm on BT were included. Actual weight was measured on a standard weighing machine. We use Broselow pediatric emergency tape (2017 edition), APLS formula was also used to measure the estimated weight by using the age provided by parents.

Descriptive analysis, mean and standard deviation were calculated, frequencies and percentages were calculated for categorical variables. Cronbach's alpha and Passing-Bablok regression analysis was applied to assess the reliability and identify systematic biases between actual body weights with estimated BT. Bland–Altman analysis was also performed to measure the precision, accuracy, and bias.

Results

250 children were included with equal gender distribution and were divided in to three categories as per the weight estimation by BT in to <10 kg (n=58, 23.2%), 10-18 kg (n=151, 60.4%) and >18 kg (n=41, 16.4%). The mean age was 5.26 (±2.37) years, majority of children were below 5 years of age (n=144, 58%).

Positive agreement between BT weight with actual weight and other formulas in weight category of <10 kg, however as weight increases from 10 kg, onward results are not significant.

Passing and Bablok Regression analysis showed a positive correlation between the estimated and actual (AW) body weight (r=0.9280, p<0.001) and accuracy (r^2=0.929), and the accuracy of BT weight decreases with the increasing weight of children.

Similarly, 95% agreement limit and mean biased was 0.465 to 1.113 and 0.789±2.602 between BT and APLS, BT with AW was -0.50 to -0.28 and -0.39±0.885. Comparing and correlating weight assessment of APLS formula vs LF and TF didn't show significance with a p-value of 0.041 and 0.034 respectively.

Bland-Altman plot between BT measurement with AW demonstrates a bias equal to 1.096 kg with a limit of 0.870 to 1.815 (Figure *1*). This figure shows that many observation points fall inside the Limit of agreement (LOA) in weights between 10-16 kg, indicating statistically significant agreement for children with an actual weight of the children (P<0.001*).

Conclusion

BT is an accurate method of weight assessment when compared with other available methods of weight estimation. Accuracy of BT may be adversely affected when age exceeds 95 months and weight >26 kg. Hence BT may be safely used in the younger pediatric population. Health care professionals may consider this information while using BT to estimate weight for pediatric resuscitation, however, the potential for improvement is still there.

Keywords: Pakistan Children, Nutritional Deficiencies, Anthropometric Measurements, and Broselow Tape

Introduction

The weight of children differs with age, hence the precise weight assessment particularly among the critically ill children remains a dilemma especially when they are unable to maintain their posture (sit or stand independently). Conventionally accepted weight assessment methods either via mechanical or electronic scales in busy emergency settings might be inaccurate, hence the precise weight measurement is of utmost importance in paediatric emergencies for weight-related dose calculation of drugs, fluids, equipment sizes, electrical currents calculation during defibrillation, etc.[1]

When the ED physicians are unable to get the accurate weight of a child, the option to calculated the near precise weight by using various age-based formulas such as Advanced Pediatric Life Support (APLS), Leffler and Theron formula, are the next possible options, however these may be incorrect and time-consuming,[2] even parental weight recall, recent weight data or visual estimation of weight lack accuracy and consistency in different situations and populations.[3] Inappropriate estimation of patient weight leading to incorrect drug dosing, one of the most frequently reported medical errors.[4] Hence, we need a precise or near accurate weight, to avoid delay or wrong dosages calculation that may compromise the quality of patient's care and pose them at risk of harm.

Broselow pediatric emergency tape (BT) is a length-based resuscitation tape that has been widely used in a pediatric emergency (PEM) to estimate the patient's weight. This color-coded tape is also embedded with pre-calculated medication doses and equipment sizes which helps in avoiding possible errors in patient management. Studies have shown that BT provides an accurate estimation of body weight based on a measured body height.[4.5] However some studies showed that BT is known to both over and underestimate weights among high and low-middle income countries, especially if malnourished. [6, 7]

Around 14% of our children are stunted with height and weight falling between 10-25 centile.[8] National Nutritional Survey (NNS) from Pakistan estimates children under five years of age, 14% are found wasted and 43% stunted, this proves wasting, stunting, and malnutrition are endemic in Pakistani children.[9] Multiple local epidemiological surveys focused on pediatric growth parameters, which may help us in formulating and designing our standards measurements protocol as per our anthropometric parameters, however, no local study identified the accuracy and precision of BT in our pediatric population. Therefore, in this study, we aim to determine the accuracy and reliability of BT by comparing it with actual weight and advanced pediatric life support formula (APLS) among the pediatric population presenting to the emergency department of our hospital.

Methods

Data collection

This was a single-center, cross-sectional study, conducted in the Pediatric Emergency of a level III, tertiary care teaching hospital, post hospital ethic review committee. Data was collected from July 2021-June 22, after written consent from parents/caregivers. The flow process of patient triage to management was followed as per the hospital guideline.

All pediatric patients aged 1 month to 12 years, weight 3-36 kg, and height 46.5-142.5 cm on BT were included. Actual weight was measured on a standard weighing machine. Patients with lower limb amputation, dwarfism, severe dehydration, volume overload, growth hormone deficiency, severe joint contractures or arthrogryposis, and chronic medical conditions that would lead to a reduction of their weight or height were excluded from the study.

Demographic data were collected from guardians using a pre-designed questionnaire. Anthropometric measurements were obtained by a data collection team that comprised of triage nurses and assessing residents who were trained for BT measurements. Actual weight (AW) was measured to the nearest of 0.1 kg in infants wearing a dry diaper on an electronic scale (SEC A, Germany), calibrated daily using a Troemner® weight. The weight of older children was taken on the standard weighing machine after removing shoes and heavy clothes. We use BT tape (2017 edition), available in our pediatric emergency to record the estimated weight measured in the supine position from head to heel. APLS formula was also used to measure the estimated weight by using the age provided by parents or caregivers.

APLS formula: weight in (kg): infant 0–12 months = (0.5 × age in months) + 4; children aged 1–5 years = 2 × age (years) + 8; 6–12 years = 3 × age (years) + 7.

Sample size calculation.

The following were employed to calculate the sample size to determine a minimum of 10% difference between any two-weight estimation methods in the proportion of children estimated within 10% of their body weight, i.e. (the difference between AW and BT with an aggregate). The level of significance difference will be 0.05, with the power of the test being taken at 0.9 as the sample size was recruited 220 children during the stud period. Assuming population proportion for the standard normal deviate was 50% for the sample calculation for the target population. With a 95% confidence interval and margin of error was 6.5% and 10% non-respondent will be increased so finally, at least 250 patients were recruited during the study period.

Statistical analysis

Data were entered and analyzed using SPSS version-21 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp) [10] and R-Software version 4.0.3. Descriptive analysis was done and mean, and standard deviation was calculated for normally distributed continuous variables whereas frequencies and percentages were calculated for categorical variables. Shapiro-Wilk test was applied to check the hypothesis of the normality assumption. Spearman rank correlation was applied to investigate the link between actual body weight and estimated body weight. Cronbach's alpha and Passing-Bablog regression analysis was applied to assess the reliability and identify systematic biases between actual body weights with estimated BTW. Bland–Altman analysis was also performed to measure the precision, accuracy, and bias. Mean percentage error (MPE = [Estimated weight-sum of actual weight/actual weight] × 100) limits of agreement (LOA) was used to assess deviation and accuracy. The weight estimate is between 10% and 20% of the actual weight (PW10 and PW20) to evaluate the accuracy of BT and the updated APLS formula. Finally, all analyses were done at a 95% confidence interval by taking a 5% level of significance at two sides.

Results

A total of 250 children were included after parental consent with equal gender distribution. They were divided in to three categories according to the weight estimation by Broselow tape in to <10 kg (n=58, 23.2%), 10-18 kg (n=151, 60.4%) and >18 kg (n=41, 16.4%). The mean age was 5.26 (±2.37) years, mostly below 5 years of age (n=144, 58%). Agreement of each color zone of BT with actual weight and other formulas is shown in **Table I,** an agreement between the mean weight of BT with AW and other formulas in the weight category of <10 kg, as weight increases from 10 kg, onward results are not significant.

Interestingly BT weight assessment correlates well with APLS, TF, and LF A good correlation is identified between actual weight measured and Broselow tape estimates which demonstrate biases and precision of BTM, this also shows that BTM overestimates the actual weight **Table I.**

Table II showed the reliability and relationship between AW measurement with BT and found to be perfect 0.994 (0.990 - 0.995) with the relationship 0.989** and likewise among all demographics measurements as well.

Table III showed the bias, accuracy, and accuracy measurements with Broselow tape and APLS equations for weight estimation. This table also includes Mean Percentage Error (MPE), it was lowest at <10 kg (2.9%) and gradually increased at 10-18 kg (3.5%) and >18 kg (3.08%) group in BTM. Similarly, Weight estimation bias compared to APLS equations in the first and last weight groups are comparable, except among 10-18 kg Group, where bias was more in the APLS formula.

The predicted weight in PW10 is <10 kg group with both BT and BT with APLS formula (22.8% and 21%) and weighing 10-18 kg was (56.4% to 72.7%) It is the lowest in the group weighing over 18 kg (20.7% and 6.3%). Furthermore, the predicted weight in PW20 is <10kg group with both Broselow tape and Broselow was (25.3% and 24.3%) and weighing 10-18 kg was (54.6% to 65.4%) It is the lowest in the group weighing over 18 kg (20.1% and 10.3%, respectively) **Table III.**

Passing and Bablok Regression analysis showed a perfect high positive correlation between the estimated and actual body weight ($r=0.9280$, $p<0.001$) and accuracy ($r^2=0.929$). There is crowding of data points below the weight of 10 kg and starts to disperse as the weight increases. This indicates that the accuracy of broselow tape weight decreases with the increasing weight of children. **Figure I.**

Bland-Altman plot for Theron formula and BT, presented in **Figure-II,** showed 95% limits of agreement was 0.870 to 1.815 and mean biased with standard error (SE) was 1.096±1.815. Similarly, 95% agreement limit and mean biased was 0.465 to 1.113 and 0.789±2.602 between BT and APLS BT with AW was -0.50 to -0.28 and -0.39±0.885, BT with LF was -2 to -0.72 and -2±0.685, BT with age was found moderate agreement with 95% CI was 1 to 2.04 and 1.52±0.786. Interestingly comparing and correlating weight assessment of APLS formula vs LF and TF didn't show significance with a p-value of 0.041 and 0.034 respectively.

Bland-Altman plot between BT measurements with AW demonstrates a bias equal to 1.096 kg with a limit of 0.870 to 1.815 **Figure II.** This figure shows that many observation points fall inside the limit of agreement (LOA) in weights between 10-16 kg, indicating statistically significant agreement for children with an actual weight of the children (P<0.001*).

Discussion.

Weighing the critically ill child who rushed to the pediatric emergency resuscitation room for immediate management is a difficult task, hence different methods or formulas were designed as per age or length, however, the simplicity, accuracy, and precision are main concern. This study identified that BT methods of estimating weight correlate well with the actual weight measured, however, they have substantial outliers.

This has been shown that age-based calculation of weight estimation may also underestimate the actual weight and the error increases with age, however, data on the accuracy of length-weight measurements is also contradictory, this may be superior as documented in certain data.[10] however, Ken Milne et al. reported this as non-accurate and tend to underestimate the actual weight. [11] Canadian study identified BT which tended to underestimate the weight among rural children. [12, 13] A study conducted on simulated patients to estimate pediatric patient weight measured 43% correctly and showed a disparity in the prevalence of overweight and obesity. [14] However, few developed societies demonstrate more accuracy of BT in estimating actual weight. [15].

BT, an effective tool for rapid weight assessment based on linear height (length)-weight correlation. Developed countries use BTM widely based on its simplicity and accuracy, however, seems to be accurate and precise only in children weighing <10 kg when tested among children from low-to-middle income countries with limited data. [15] Though another study demonstrates that BT weight assessment was accurate when weight <15 kg or age <36 months, however, if weight or age increased from 26 kg or 95 months simultaneously BM assessment of weight become inaccurate, as was observed in this study. Studies from a pediatric population of LIC found similar data [16, 17] of the inaccuracy of weight assessment when age or weight increases.

Comparing BT with different weight formulas like Leffler, we observed both with similar results and are not statistically superior. While Theron seems more statistically similar to BT weight measurement, however, APLS and Leffler didn't correlate well with each other in assessing weight. Findings are consistent with past studies which demonstrate underestimation of measured weight by BT in older children and those weighing >20 kg.[18] BT weight assessment correlates with APLS, LF, and TF formulas however result by So T Y et.al., identified BTM and LF performed better than TF in underweight subjects.[19]
These results may not be generalized to the general population because of the smaller size population and single-center hospital-based study, hence need community-based multicenter study with larger population data especially from a malnourished population of developing countries for accuracy and precision of results so that it may be generalized for LIC countries.

Conclusion.

BT is an accurate method of weight assessment when compared with other available methods of weight estimation. Accuracy of BT may be adversely affected when age exceeded 95 months and weight was more than 26 kg. Hence BT may be safely used in the younger pediatric population of the third world. Health care professionals should consider this information when using the BT to estimate weight for pediatric resuscitation, however, the potential for improvement is still there.

Limitation.

BT measurement was virtually conducted by a single observer hence the chance of error was still there. Moreover, BT assessment was limited to children between 6-59 months, weight between 02-25 kg, and length/height between 49-137.5 cm. secondarily the data size was limited and a single-center hospital-based study.

Consent

This study was approved from the IRB of the institution.

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Table I: Comparison of actual weight with Broselow tape and other formulas estimates

Study	Weight Group

variables	<10 Kg, n=58 (23%)	10-18 Kg, n=151 (60%)	>18 Kg, n=41 (16%)	Total
	Mean ± SD (min - max)	Mean ± SD (min - max)	Mean ± SD (min - max)	Mean ± SD (min - max)
Age in (months)	2.48 ± 0.98 (1 - 5)	5.32 ± 1.33 (3 - 9)	8.98 ± 1.29 (7 - 12)	5.26 ± 2.37 (1 - 12)
Broselow Tape Measurement	7.62 ± 2.31 (2 - 10)	14.82 ± 2.64 (10 - 20)	23.29 ± 4.06 (18 - 35)	14.54 ± 5.65 (2 - 35)
Body Mass Index	14.24 ± 1.78 (11.7 - 17.2)	15.3 ± 1.91 (8.7 - 27.8)	15.14 ± 1.62 (13.4 - 21.4)	15.23 ± 1.85 (8.7 - 27.8)
Leffler Formula	7.96 ± 2.68 (4 - 14.8)	16.36 ± 2.93 (9 - 25)	23.85 ± 2.52 (20 - 30)	15.64 ± 5.74 (4 - 30)
Advance pediatric Life	7.78 ± 2.22 (4 - 12.8)	14.98 ± 3.77 (9 - 28.7)	27.28 ± 4.33 (18 - 37)	15.33 ± 7.04 (4 - 37)
Theron Formula	8.69 ± 2.52 (4.3 - 14.4)	15.31 ± 3.05 (8.3 - 23.6)	22.14 ± 3.83 (5.3 - 29)	14.89 ± 5.21 (4.3 - 29)

Table II: Reliability and correlation between actual weight with Broselow tape

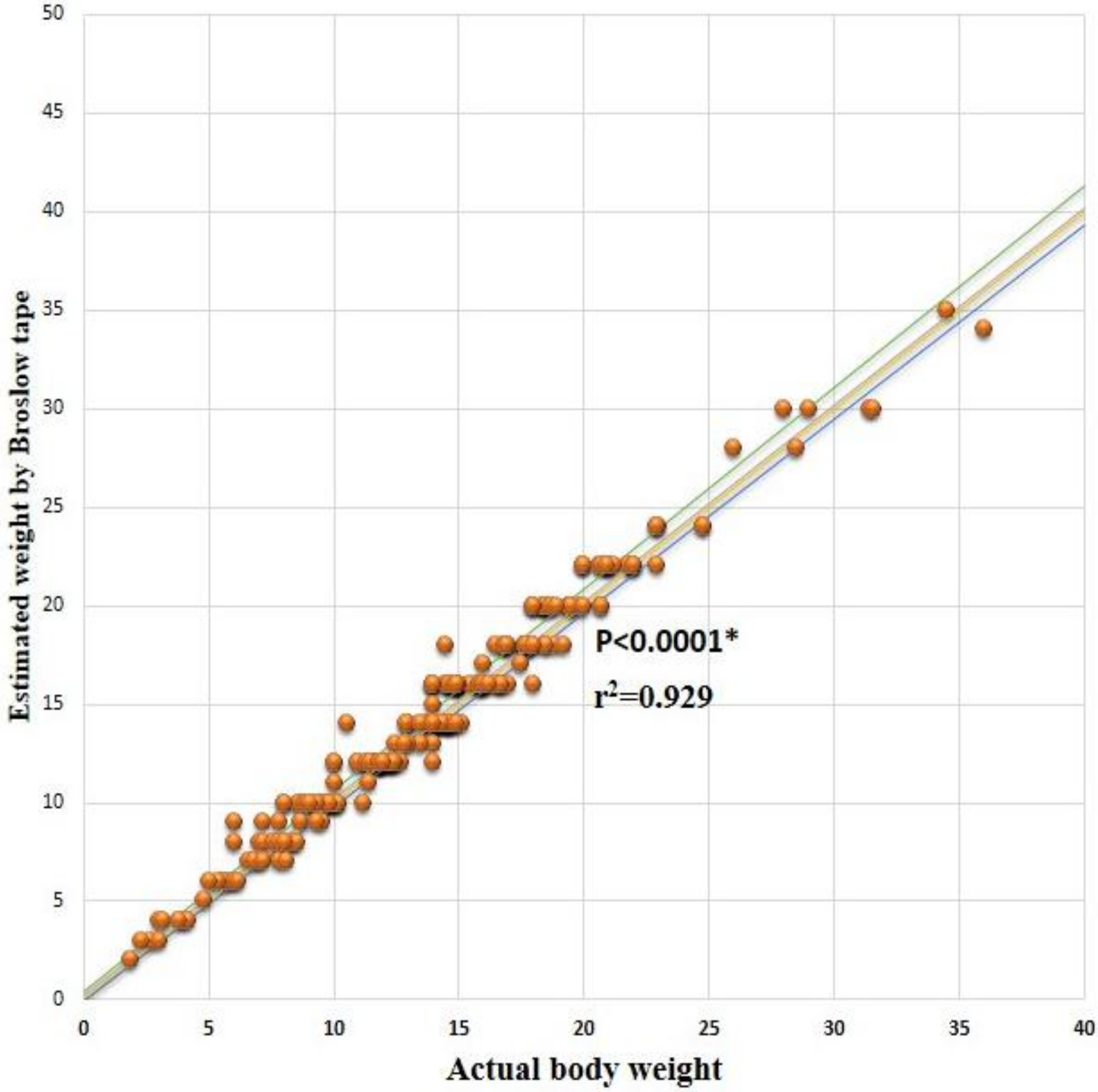
Variable	Correlations	Cronbach Alpha (Reliability) [95% C.I]
Actual weight and Broselow tape measurement (overall)	0.989**	0.994 [0.990 - 0.995]
Actual weight and Broselow tape by gender		
Male	0.985**	0.985 [0.978 - 0.989]
Female	0.990**	0.990 [0.986 - 0.993]
Actual weight and Broselow tape Measurement by weight groups		
<10 kg	0.947**	0.972 [0.953 - 0.984]
10 - 18 Kg	0.942**	0.968 [0.956 - 0.977]
>18 Kg	0.970**	0.984 [0.970 - 0.991]

Table III: Bias, accuracy, and accurate measurements with Broselow tape and APLS equations for weight estimation

Weight Group	**Broselow tape**	**APLS**
Group I (<10 Kg)		
MPE ± SD (maximum–minimum)	2.9 ± 6.22 (-11.11 -25.93)	-14.58 ± 30.76 (-136.84 - 27.78)
PW10, n (%)	55 (22.8%)	30 (21%)
PW20, n (%)	63 (25.3%)	45 (24.3%)
Group II (10-18 Kg)		
MPE ± SD (maximum–minimum)	3.51 ± 2.74 (-2.56 - 8.33)	-1.32 ± 12.08 (-41.77 - 28.57)

PW10, n (%)	136 (56.4%)	104 (72.7%)
PW20, n (%)	136 (54.6%)	121 (65.4%)
Group III (>18 Kg)		
MPE ± SD (maximum–minimum)	3.08 ± 1.91 (-2.56 - 5.26)	-20.96 ± 16.56 (-56.83 - 22.22)
PW10, n (%)	50 (20.7%)	9 (6.3%)
PW20, n (%)	50 (20.1%)	19 (10.3%)
All		
MPE ± SD (maximum–minimum)	3.16 ± 3.85 (-11.1 - 25.93)	-8.64 ± 21 (-136.4 -28.57)
PW10, n (%)	241(96.4%)	143(57.2%)
PW20, n (%	249(99.6%)	185(74%)

Fig. I: Regression of Actual Weight and BTM



Estimated weight by Broslow tape
Actual body weight
P<0.0001*
r2=0.929
0
5
10
15
20
25
30
35
40
45
50

Fig II: Bland and Altman Plot (BTM and different weight formulas)