



## Validity of Broselow tape for estimating weight of Indian children

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Received June 13, 2014

**Background & objectives:** The Broselow tape has been validated in both ambulatory and simulated emergency situations in the United States and is believed to reduce complications arising from inaccurate drug dosing and equipment sizing in paediatric population. This study was conducted to determine the relationship between the actual weight and weight determined by Broselow tape in the Indian children and to derive an equation for determination of weight based on height in the Indian children.

**Methods:** This cross-sectional study was conducted at a tertiary care hospital in Mumbai, India. The participants' weights were divided into three groups <10 kg, 10-18 kg and >18 kg with a total sample size estimated to be 210 (70 in each group). Using the tape, the measured weight was compared to Broselow-predicted weight and percentage weight was calculated. Accuracy was defined as agreement on Broselow colour-coded zones, as well as agreement within 10 per cent between the measured and Broselow-predicted weights. The resulting data were compared with weights estimated by advanced paediatric life support (APLS) and updated APLS formulae using Pearson's correlation coefficient.

**Results:** The mean percentage differences were -11.78, -17.09 and -14.27 per cent for <10, 10-18 and >18 kg weight-based groups, respectively. The Broselow colour-coded zone agreement was 33.3 per cent in children weighing <10 kg, but only 7.4 per cent in the 10-18 kg group and 33.9 per cent in the >18 kg group. Agreement within 10 per cent was 53.13 per cent for the <10 kg group, but only 21.08 per cent for the 10-18 kg group and 33.9 per cent for the >18 kg group. Application of 10 per cent weight correction factor improved the percentages to 79.2 per cent for the <10 kg category, to 55.70 per cent for the 10-18 kg group and to 61.0 per cent for the >18 kg group. The correlation coefficient between actual weight and weights estimated by Broselow tape ( $r=0.89$ ) was higher than that between actual weight and weight estimated by APLS method or updated APLS formulae ( $r=0.68$ ) in 12-60 months age group as well as in >60 months age group ( $r=0.76$ ).

**Interpretation & conclusions:** Broselow weight overestimated weight by >10 per cent in majority of Indian children. The weight overestimation was greater in children belonging to over 18 and 10-18 kg weight groups. Applying 10 per cent weight correction factor to the Broselow-predicted weight may provide a more accurate estimation of actual weight in children attending public hospital. Weights estimated using Broselow tape correlated better with actual weights than those calculated using APLS and updated APLS formulae.

**Key words** Anthropometry/instrumentation - body weight - medication errors/prevention

In contrast to adults, drugs are administered to infants and children on the basis of actual weight or surface area. When children present in a critical state, the caregivers are expected to provide instant care and administer drugs immediately. There is hardly any time to determine weight or height and calculate dosages of emergency drugs. In addition, when children present with shock or respiratory arrest or circulatory collapse, it may be necessary to carry out endotracheal intubation straight away. In such situations, various methods are used to determine the drug dosages and sizes of equipment: 'guesstimates' based on the child's apparent size or stature<sup>1</sup>, predicting it on the basis of length<sup>2</sup>, foot length<sup>3</sup>, age<sup>4</sup> or a combination of above<sup>4</sup>. It can also be predicted using age-based formulae such as advanced paediatric life support (APLS) formula or updated APLS formula<sup>5-7</sup>. The Indian Academy of Pediatrics supported Paediatric Advanced Life Support Programme recommends that Broselow tape is used in such circumstances<sup>8</sup>. The Broselow tape recommends dosages of emergency drugs and preferred equipment sizes, on the basis of predicted weight, which, in turn, is estimated on the basis of actual height (height-weight correlation). Although the Broselow tape has been validated in both ambulatory<sup>9-12</sup> and simulated emergency situations<sup>13</sup> in the United States and is believed to reduce complications arising from inaccurate drug dosing and equipment sizing, but given the prevalence of malnutrition and consequent aberration in growth in Indian children it may overestimate the weight of these children.

Hence, this study was undertaken to determine the accuracy of weight measured by Broselow tape and compare it with the actual weight of Indian children. The findings of Broselow tape were compared with those obtained using APLS and updated APLS formulae.

### Material & Methods

This cross-sectional study was carried out at the Paediatric Outpatient and Inpatient departments of BYL Nair Charitable Hospital, a tertiary care public hospital attached to TN Medical College in Mumbai, India, over a period of 18 months from April 2012. The study was initiated after obtaining ethical approval from the Institutional Ethics Committee and children aged 12-144 months were enrolled in the study after obtaining written informed consent from parents. If the prospective research participant was over seven years of age, his/her assent was also obtained before

enrolment. Children were excluded from the study if they required immediate or emergency management or weighed over 35 kg or had height exceeding 145 cm.

Demographic data were collected from the parents or guardians. Age was determined based on documentary evidence or on the basis of birth date, birth year or age stated by the care-giver. The weight of children was measured to the nearest 0.1 kg using an electronic weighing scale (IPA Devices Pvt. Ltd). The Broselow tape<sup>®</sup> (Armstrong Medical Industries, Lincolnshire, IL, USA) used for the estimation of weight based on the length has colour-coded segments depending on the weight estimated on the basis of length: grey (3-5 kg), pink (6-7 kg), red (8-9 kg), purple (10-11 kg), yellow (12-14 kg), white (15-18 kg), blue (19-22 kg), orange (24-28 kg) and green (30-36 kg). Each colour zone has dosages of emergency and premedication drugs, paralytic and induction agents and defibrillation written for children of corresponding estimated weights. For each child, the tape's colour code system was noted and compared. The data were recorded in a pre-designed proforma. Using the age provided by the caregiver, the child's weight was calculated using the APLS and updated APLS formulae<sup>5-7</sup>.

*Usage of Broselow tape:* To use the Broselow tape effectively, the child was made to lie down. While maintaining the position of the hand on the red portion at the top of the child's head, the free hand was used to run the tape down the length of the child's body until it was even with the child's heels. The tape that is level with the child's heels provided the child's approximate weight (kg) and the colour zone<sup>14</sup>.

*Sample size:* The sample size calculations were based on the study conducted by Ramarajan *et al*<sup>15</sup>. This study showed a consistent overestimate of the weight by the Broselow tape with a 10 per cent or more overestimation in children with >10 kg with an overall line of regression  $y=1.076x+0.27$ . At 5 per cent significance, 80 per cent power and assuming an  $f^2$  or effect size measure of 10 per cent, of weights between the two methods, and a single predictor variable, a sample size of 70 was calculated using an online regression calculator<sup>16</sup>.

*Statistical analysis:* Pearson's correlation was used for determining the association between predicted weights and actual weight and was followed by Bland-Altman plots<sup>17</sup> to determine the mean bias

and standard deviations (SDs) for the Broselow tape. The percentage difference between the Broselow-predicted weight and the measured weight was calculated as a measure of tape bias [ $100 \times (\text{measured weight} - \text{Broselow-predicted weight}/\text{measured weight})$ ]. As per the null hypothesis the Broselow-predicted weight was equivalent to the measured weight if the 95 per cent confidence interval (CI) for the mean percentage difference included  $\pm 5$  per cent. The SD of the percentage difference was also calculated to estimate tape precision.

To maintain consistency with previous literature on the Broselow tape, a Bland-Altman analysis was performed. This method combines bias and precision to determine upper and lower 'limits of agreement' by which the two methods differ. Accuracy of the tape was analyzed with respect to colour-coded zone prediction and weight prediction. First, percentage agreement on the same colour-coded zone by the Broselow tape and the measured weight, as well as percentage overestimation by one or two colour-coded zones, was calculated. Second, the number and proportion of times the Broselow-predicted weight was within 10 per cent of the measured weight was also determined<sup>15</sup>. Finally, a correction factor for the Broselow-predicted weight was derived by serially testing corrections until the accuracy within 10 per cent for each weight group was maximized. The correction factor was then tested by cross-validation against a random half of the sample as well as by linear regression. This correction factor was applied to the original Broselow-predicted weights, and the new corrected accuracies were obtained.

The Pearson's correlation coefficient was determined between the actual weight and the weights estimated using APLS and updated APLS formulae. For each of the above methods (weights estimated using APLS, updated APLS formulae and Broselow tape with or without 10% correction), the mean difference (the mean of differences between the actual weight and estimated weight and 95% CI) was computed using paired sample *t* test. The analysis was conducted using SPSS 14.0 (SPSS Inc., Chicago, IL, USA).

### Results

In this study, 356 children (age range: 12-138 month) were enrolled in the three groups (<10, 10-18, >18 kg). Girls accounted for 185 (52%) of the participants (M:F=1:1.08) and the maximum number

of children were in the 12-36 months age group (271, 76%). The number of participants enrolled in each of the weight slabs is shown in Table I. During the study period, only 48 children each were enrolled in the weight groups of 10-18 kg and over 18 kg. The *post hoc* analysis showed that the power of the study was 65 per cent as a result of the actual number of participants enrolled. In the study, 135 (37.9%) participants [including 60 (32.43%) boys and 75 (43.85%) girls] had weight-for-age lower than  $-2SD$ .

Table II shows the degree to which the actual weight bands matched with the Broselow tape weight bands. For example, weight of each of the 84 children in the weight range of 6-7 kg was overestimated: 64 (76.2%) of them were shown to be in the red (8-9 kg, overestimation by one colour) zone while 20 (23.8%) were shown to be in the purple (10-11 kg, overestimation by two colour) zone. The best convergence for colour zones was attained for 30-36 kg age group with all the six children in that weight group being shown to be in the corresponding green zone. For the 19-22 kg and 24-28 kg weight groups, the convergence was achieved in 7 (41.2%) and 6 (42.9%) children.

*Bias and precision of the Broselow tape in the study population:* Fig. 1 illustrates the Broselow-predicted weight for a given measured weight in the study population. There was a positive correlation between the actual weight and the Broselow tape estimated weight ( $R^2=0.956$ ;  $P<0.05$ ). Fig. 1 also showed that the Broselow tape overestimated the weight. The crowding of data points for actual weights below 15 kg as compared to those above 15 kg indicated that the accuracy of Broselow tape estimated weights decreased with increasing actual weights.

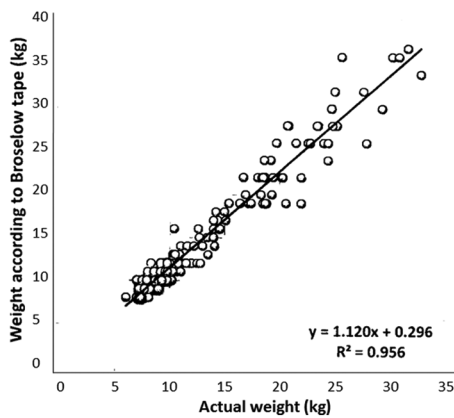
**Table I.** Demographic characteristics of the study population

Parameter	Boys	Girls	Total
Age-groups (Age in months)			
>12-36	130 (47.97)	141 (52.02)	271 (76.12)
>36-60	9 (31.03)	20 (68.96)	29 (8.14)
>60	32 (57.14)	24 (42.85)	56 (15.73)
12-138	171 (48.03)	185 (51.97)	356 (100.0)
Weight- groups (Weight in kg)			
<10	122 (46.92)	138 (53.07)	260 (73.03)
10-18	21 (43.75)	27 (56.25)	48 (13.48)
>18	28 (58.33)	20 (41.66)	48 (13.48)
<10->18	171 (48.03)	185 (51.96)	356 (100.00)

Figures in parentheses indicate percentages

Table III shows the mean percentage difference between the Broselow-predicted weight and the actual weight. The mean percentage difference was significantly greater in the 10-18 kg (-17.09%) and the <10 kg (-11.78%) group ( $P<0.05$ ).

The frequency of accurate colour-coded zone prediction and weight prediction within 10 per cent by the Broselow tape is shown in Table IV. Broselow tape had an accuracy of 33.3 per cent and 33.9 per



**Fig. 1.** Correlation between Broselow tape-predicted weight and measured weight.

cent in predicting the correct colour zone in the Broselow-predicted weight groups of <10 kg and over 18 kg. However, the corresponding accuracy in 10-18 kg group was only 7.35 per cent. After applying a 10 per cent correction factor, this accuracy improved to over 66 per cent in all the three weight groups.

After applying 10 per cent correction factor, the Broselow-predicted weights showed significant increase in the accuracy. The accuracy by colour code increased for all the three groups and reached 71.08 per cent for the <10 kg group. Fig. 2 shows the relationship of colour-code agreement before and after the application of 10 per cent correction. It was noted that in all the groups, the agreement of colour-codes increased after application of the 10 per cent correction, and in the 10-18 kg group, the overestimation by two colour codes vanished after this application. However, this resulted in underestimation of weight by one colour code in all the groups.

There was a positive correlation between Broselow and APLS method ( $r=0.68-0.89$ ) with Broselow weight estimation having a strong correlation with the estimated weights (Table V). The mean difference in 12-60 months age group was -0.3 for Broselow weight estimation after 10 per cent correction as compared to -2.8 for APLS and updated APLS formulae. Similarly,

**Table II.** Comparison between the actual weight and weight predicted by Broselow tape

Actual weight (kg)	Colour code on the Broselow tape (with corresponding predicted weight in kg)							Total
	Red 8-9	Purple 10-11	Yellow 12-14	White 15-18	Blue 19-22	Orange 24-28	Green 30-36	
6-7	64	20	0	0	0	0	0	84
8-9	32	123	21	0	0	0	0	176
10-11	0	6	13	1	0	0	0	20
12-14	0	0	7	11	0	0	0	18
15-18	0	0	0	2	18	1	0	21
19-22	0	0	0	0	7	10	0	17
24-28	0	0	0	0	0	6	8	14
30-36	0	0	0	0	0	0	6	6
Total	96	149	41	14	25	17	14	356

**Table III.** Bias & precision in Broselow predicted weight groups

Measurement of bias and precision	Broselow predicted weights (kg)		
	<10	10-18	>18
Mean per cent difference±CI	-11.78±1.52	-17.09±1.42	-14.27±3.04
SD of per cent difference	7.48	10.32	11.36
Bland-Altman limits of agreement (kg), lower, upper; ±CI	-1.90, 0.14±1.02	-3.3, 0.20±1.7	-8.2, 1.9±5.1

CI, confidence interval; SD, standard deviation

in >60 months age group, the mean difference varied for Broselow tape - estimated weights with 10 per cent correction was -0.6. The corresponding figures for APLS and updated APLS formulae were -3.3 and -11.0 (Table VI). The correlations between APLS and actual weight and that between advanced APLS and actual weight are shown in Figs. 3 and 4, respectively. These results showed that Broselow tape estimation with 10 per cent correction estimated weights were closer

to the actual weight than those calculated with APLS formulae.

**Discussion**

This study showed that the weight predicted by the Broselow tape correlated well with the measured or actual weight. When judged on the basis of colour code accuracy, it matched only in 33.3, 7.4 and 33.9 per cent in <10, 10-18 and >18 kg weight groups, respectively.

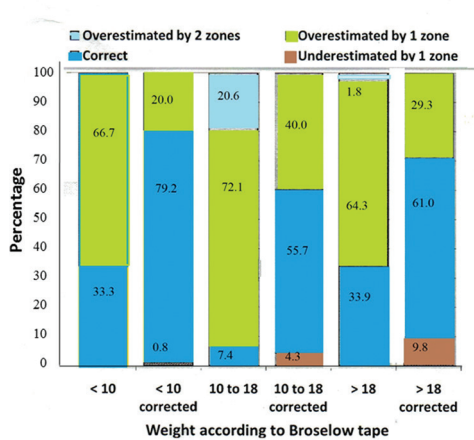


Fig. 2. Colour-coded zone agreement after 10 per cent correction.

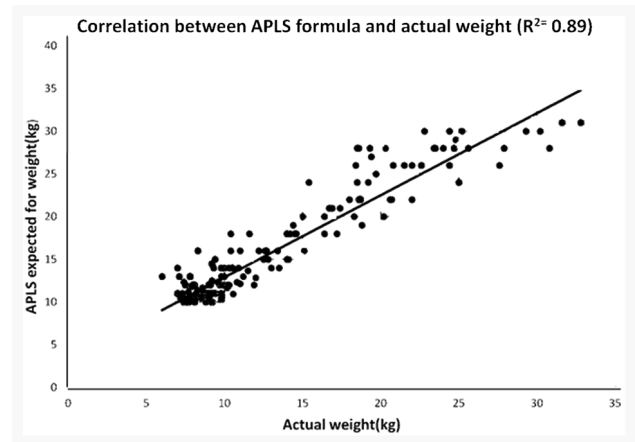


Fig. 3. Scatter graph showing correlation between Advanced Paediatric Life Support (APLS) and actual weight.

Table IV. Accuracy by weight and colour zone

Accuracy	Broselow predicted weights (kg)		
	<10	10-18	>18
Accuracy by weights			
Accuracy within 10%±CI (%)	53.13±10.23	21.08±5.68	33.9±12.8
Accuracy within 10%±CI after correction (%)	71.8±9.1	57.8±6.8	69.6±12.4
Accuracy by colour code			
Colour coded agreement±CI (%)	33.3±9.57	7.35±3.61	33.9±12.8
Colour coded agreement after correction±CI (%)	67.7±9.52	71.5±6.2	66.0±12.8

Table V. Mean differences and correlation between advanced paediatric life support (APLS) and Broselow tape in children 12-60 months of age

System for estimation of weight	Child's age group 12-60 months n=300		
	Mean difference	95% CI (lower, upper)	Pearson correlation (r)
APLS	-2.8	-2.95, -2.64	0.68
Updated APLS	-2.8	-2.9, -2.6	0.68
Broselow tape	-1.3	-1.37, -1.22	0.86
Broselow tape with 10% correction	-0.3	-1.1, 0.58	0.89

As per APLS weight is calculated as follows: Weight (kg) = (age+4) × 2. As per updated APLS, weight is calculated as follows: Children aged 1-5 yr: Weight (kg) = 2×age (yr) + 8. CI, confidence interval



However, after 10 per cent correction was applied, the colour code agreement increased to at least 66 per cent of observations in all the weight groups.

The Broselow tape was initially validated in the United States<sup>10,18,19</sup> and researchers in various countries<sup>2,10,15,18-27</sup> have attempted to check if it is appropriate for their populations (Table VII). It seems

appropriate that different populations check for the appropriateness of using the tape in their communities and at multiple intervals as nutritional status of children in their communities changes<sup>28</sup>.

An Indian study<sup>15</sup> has concluded that the Broselow tape is not accurate in predicting weights in Indian children and that the accuracy of the tape improved to

**Table VI.** Mean differences and correlation of weight estimation by Advanced Paediatric Life Support (APLS) and Broselow tape in children over 60 months of age

System for estimation of weight	Child's age group >60 months n=56		
	Mean difference	95% CI (lower, upper)	Pearson correlation ( <i>r</i> )
APLS	-3.3	-4.1, -2.5	0.76
Updated APLS	-11.0	-11.92, -10.08	0.76
Broselow tape	-3.2	-4.0, -2.52	0.89
Broselow tape with 10% correction	-0.6	-1.2, 0	0.89

As per APLS weight is calculated as follows: Weight (kg) = (age+4) × 2. As per updated APLS, weight in children aged 6-12 yr is calculated as follows: Weight (kg) = 3×age (yr) + 7. CI, confidence interval

**Table VII.** Salient features of selected studies related to the use of Broselow Tape for estimating weight

Author, yr and country	Main inference
Lubitz <i>et al</i> <sup>9</sup> 1988; USA	The tape was found to be extremely accurate for children from 3.5 to 10 kg, and from 10-25 kg. Reduced accuracy for those weighing over 25 kg
Luten <i>et al</i> <sup>10</sup> 1992; USA	Children undergoing elective surgery were included. Length-based ET tube selection was found to be superior to age-based rules
Black <i>et al</i> <sup>2</sup> 2002; Australia	Estimation of weight using the Broselow tape was highly accurate in 495 children attending the paediatric emergency department
Varghese <i>et al</i> <sup>21</sup> 2006; India	The Broselow tape correlated well with overall emergency decision making process in the tertiary care setting study enrolling 500 children. Especially validated in the age group 0.1-0.7 yr weighing <15 kg
DuBois <i>et al</i> <sup>19</sup> 2007; USA	Weights estimated by Broselow-Luten tape significantly correlated with actual weights, although it underestimated weights in all weight classes
Ramarajan <i>et al</i> <sup>15</sup> 2008; India	Study carried out in a government paediatric hospital enrolling 548 children. The Broselow tape overestimated weight by more than 10% in Indian children, especially those weighing over 10 kg
Knight, <i>et al</i> <sup>22</sup> 2011; USA	A study of participants aged upto 16 yr (2358) from trauma registry (2002-2006) showed that the Broselow tape was an ineffective tool to predict weight in more than 50% of paediatric participants
Geduld, <i>et al</i> <sup>27</sup> 2011; South Africa	The mean difference between the actual weight and that predicted by Broselow tape was 0.9%
Wells, <i>et al</i> <sup>23</sup> 2013, South Africa	The mean per cent difference error was -3.8% between Broselow tape and the actual weight. The Broselow tape predicted weight to within 10% of actual tape in 63.6% of participants
Abdel-Rahman <i>et al</i> <sup>2</sup> 2013	The proportion of children predicted within 10 and 20% of actual weight was 59 and 91%
House <i>et al</i> <sup>26</sup> Kenya, 2013	The overall mean percentage difference for the actual weight and Broselow tape was -2.2%. The corresponding figures for the APLS and Nelson's predictions were -5.2% and -10.4%, respectively

APLS, Advanced Paediatric Life Support, Superscript numerals denote reference number; ET, endotracheal tube

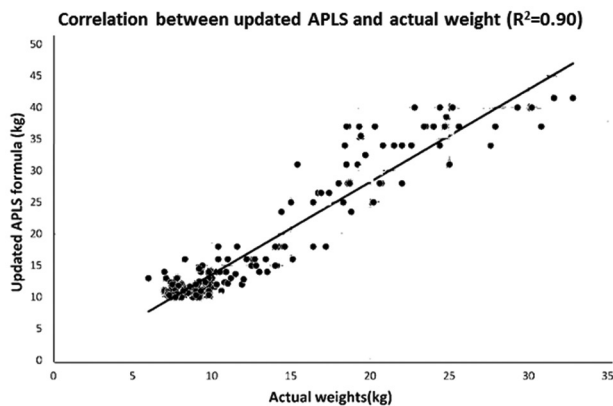


Fig. 4. Scatter graph showing correlation between updated Advanced Paediatric Life Support (APLS) and actual weight.

over 63 per cent after the application of a correction factor. Although our study had similar results, the accuracy determined in our study was lower. This marginal difference could be due to different population characteristics. Studies from Kenya<sup>26</sup> and South African population<sup>23,27</sup> showed that Broselow tape-estimated weights were only marginally different from actual weights. This indicated that children in the present study had greater deviations from the Western standards, as compared to the Kenyan and South African populations enrolled in those studies<sup>23,26,27</sup>. As proposed by House *et al*<sup>26</sup>, this could be attributed to greater frequency of childhood malnutrition in general and of severe malnutrition, in particular, in the Indian population.

Based on the findings of this study, it appears that use of Broselow tape without any modifications to Indian children would lead to administration of excessive doses. If the tape is to be used, modifications such as application of a correction factor or development of an indigenous tape based on local data would be helpful.

The findings of this study are applicable to children attending public hospitals in India. However, this can be confirmed by undertaking similar studies in other public hospitals in India with a similar patient profile. The data may not be applicable to children belonging to higher socio-economic groups, and those attending private healthcare facilities, as they have been shown to have growth patterns similar to those of children from the West<sup>29,30</sup>. Lack of reliable age data of participants forced us to undertake analysis based on weight groups rather than age groups.

While comparing the estimation of Broselow as against the APLS formulae, the Broselow tape

estimations were met with better accuracy as against the APLS formulae. Our study results are similar to those reported by Varghese *et al*<sup>21</sup>. However, Graves *et al*<sup>5</sup> demonstrated that APLS formula was the most accurate method for age-based weight estimation in infants and found that in children over one year of age, the Best Guess formulae should be used. While Luscombe *et al*<sup>6</sup> demonstrated that a single weight estimation ( $\text{weight} = 3 \times \text{age} + 7$ ) was better at estimating weights, Ali *et al*<sup>7</sup> opined that the APLS formula should be continued to be used as method of weight estimation.

Based on the study findings, it can be recommended that the Broselow tape cannot be used without modifications in Indian children attending public hospitals. As the application of 10 per cent correction factor to the Broselow-estimated weight increases the accuracy of the tape to over 60 per cent, this can be made use of in appropriate settings after these findings are validated in prospective studies.

**Conflicts of Interest:** None.

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