Broselow Tape Validation in Bahraini Population

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Due to the high load of pediatric patients in emergency department with the urgency to intervene in such situations, a color coded Broselow Pediatric Emergency Tape (BPET) was designed, with pre-calculated medication doses to the corresponding weight estimations. The invention BPET of was based in the United States population data and accepted globally as an emergency tool to estimate the pediatric weight for rapid emergency management.

Objectives: As Broselow Tape may over or underestimate the weights in children of Kingdom of Bahrain, leading to inaccurate dosing and equipment sizing in the emergency setting. the validation study was conducted to determine correlation between Broselow tape determined weight and actual weight in Bahraini children with a possible creation of a correction factor to the Broselow tape to remodel it for the Bahraini pediatric population.

Methods: The actual weight of our studied population was measured using an electronic weighing machine, rounded to the nearest whole number. All subjects will be measured for their body length with the measuring tape from the top of the head to heel. The data was recorded manually on a standardized form and on an excel spreadsheet.

Results: There is significant variation in weight estimation of the local Bahraini studied pediatric population by the globally validated BPET displayed in number and percentage.

Conclusion: Based on the findings of our study, it appears that use of Broselow tape without any modifications to Bahraini children would lead to variation in administration of medications, mostly excessive doses in some categories (particularly in the orange category). Application of a correction factor or development of an indigenous tape based on local data might be the best solution to the suggested problem.

Keywords: Broselow tape, Pediatric resuscitation, Weight estimation in critical patients, Bahraini pediatric population

INTRODUCTION

In pediatric emergency units across the globe, physicians and nurses are facing challenges to treat critically ill children. Various clinical conditions require fast and prompt interventions and resuscitation. This particular need is problematic because these interventions are often weight based, and conditions such as: acute respiratory distress, active seizure and shock often do not allow the time for the selection of the correct instrumentation size and medication dose in an acutely ill patient. In order to mitigate this problem, many methods are used to estimate the child's body weight indirectly which can expedite the process. One of these methods is the Broselow Pediatric Emergency Tape (BPET) which is an immediate and effective solution to overcome the weight estimation difficulty[1].

The Broselow Pediatric Emergency Tape (BPET) is a color-coded tape measure that is used throughout the world for pediatric emergencies. The BPET is designed for children up to approximately 15 years of age who have a maximum weight of 36 kg. BPET relates a child's height as measured by the tape to his/her weight to provide medical instructions including medication dosages, the size of the equipment that should be used, and the level of shock voltage when using a defibrillator. Particular to children is the need to calculate all these therapies for each child individually. In an emergency, the time required to do this detracts from valuable time needed to evaluate, initiate, and monitor patient treatment[2].

Consumption of fast food among children seems to have an adverse effect on dietary quality in ways that plausibly could increase risk for obesity[3], concerns have been raised as to the accuracy of the tape to determine acceptable weights and subsequently acceptable doses of emergency medications. A review of the literature revealed contradictory data related to the accuracy of length-based measurements which may depend on the obesity rate of the population studied. A study conducted in 2006 in Victoria, Australia, concluded that length-based estimations were superior when compared with other calculation aids[4]. Similarly, a study conducted by Varghese et al. (2006) on Indian children showed that the BPET was the most accurate method of weight estimation in children less than 1 year of age[5]. On the contrary, Ken Milne et al. (2012) reported that although the BPET remains an effective method for estimating pediatric weight. However, a study on Ontario children revealed that it was not accurate and tended to underestimate the weight[6]. When the BPET was used in Indian children, weight overestimation had been observed as a reason for serious concern[7]. The effectiveness of the BPET has been studied with mixed results in Switzerland[8], Australia[9], South Korea[10], Saudi Arabia[11] and other countries.

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Compared to WHO reference standards, the median height of Bahraini children and adolescents in the age range of 6 to 18 years was close to the 25th percentile or lower. While the median Body Mass Index (BMI) during adolescent years was comparable in boys, but higher than WHO standards in girls, reaching the 75th percentile. The cut-off values of BMI for overweight/obesity status (85th and 95th percentile) were higher by 3-6 kg/m2 compared to WHO standards[11].

Over or under estimation of equipment size or medication doses by the Broselow Pediatric Emergency Tape (BPET) may lead to serious injury or potentially life-threatening time delays during procedures. Therefore, the need arises to determine the validity of the BPET in Bahraini pediatric population.

METHODS

Study Design: A cross sectional study was conducted between 2018 to 2019, to assess the accuracy of the Broselow tape (BT) [Version 2017] in estimating weight among the local Bahraini Pediatric population. The study was approved by our Review board and Ethics Committee. The study was exempted from obtaining written informed consent as this is a standard health procedure for children being admitted and poses no harm to the participants involved.

Length based weight estimation was compared to the actual weight and height of the patients in order to evaluate the validity of the Broselow Tape (BT) at estimating weights in the Bahraini pediatric population.

Setting and Participation: The study and data collection was performed in two major tertiary hospitals in the Kingdom of Bahrain. King Hamad University Hospital, and The Royal Medical Services Hospital. Anthropometric measurements were obtained in the Pediatric Emergency Departments as well as the pediatric outpatient clinics across the two hospitals.

In this study we divided the subjects into 9 categories based on the nine color coded zones (2017 Version) of the BT (Table.1). A target sample of at least 250 patients in each color code was needed, for a total sample size of 2250 patients. Data from 2,250 patients was collected over a period of 18 months in the pediatric outpatient departments and emergency departments; measurements were obtained by nurses using consistent validated techniques with high reliability. Children were weighed in kilograms using electronic standing weighing machines after removal of their outer clothing and shoes, and the weight was rounded do the nearest whole number. Younger children who were unable to stand were weighed without diapers, in a supine electronic weighing scale, and their weight was also rounded up to the nearest whole number.

Height was measured while standing and was measured from the top of the head to the heel, in centimeters. Those unable to stand or if younger than 1 year, a supine position length was measured. Data was recorded manually on a standardized data collection sheet which included, a serial number, name of investigator, location, CPR (or National ID) number, age, gender, length, weight, date of birth.

TW=Broselow tape predicted weight, TL=Broselow tape length, BH=Body Height

Eligibility:

Inclusion criteria: All children who are Bahraini nationals and who presented below the age of 14 years, with a height between 46cm and 146cm were eligible for enrollment.

Exclusion criteria: Children who are not Bahraini nationals. Children who are below 46cm in length or more than 146cm. Any child needing resuscitation or with a triage category of I, II or III based on the Manchester triage system in the emergency department. Any child who presented in severe dehydration. Children with a past history of chronic or congenital disease or failure to thrive, or delay in developmental milestones, or who were admitted within a week of the data collection.

Table 1: BT Color Code Zones (2017 Version)

Color	TW(Kg)	TL = BH (cm)	
		Min	Max
Grey	3	46.1	52.0
Grey	4	52.1	56.9
Grey	5	57.0	60.7
Pink	6	60.8	64.2
Pink	7	64.3	67.7
Red	8	67.8	71.4
Red	9	71.5	75.2
Purple	10	75.3	79.9
Purple	11	80.0	84.9
Yellow	12	85.0	89.6
Yellow	13	89.7	94.0
Yellow	14	94.1	97.9
White	15	98.0	101.7
White	16	101.8	104.5
White	17	104.6	107.7
White	18	107.8	110.2
Blue	19	110.3	113.8
Blue	20	113.9	116.7
Blue	22	116.8	122.0
Orange	24	122.1	126.3
Orange	26	126.4	130.2
Orange	28	130.3	133.9
Green	30	134.0	136.7
Green	32	136.8	140.0
Green	34	140.1	143.4
Green	28	143.5	146.7

RESULTS

Of the 2250 children who met the study criteria, 54.8% (1233) were males and 45.2% (1017) were females. A wide range of ages (14 days – 4745 days) and weights (3.0 – 68 kg) were represented. Age-distribution of the study participants is shown in Figure 1. The age, height and weight characteristics of the children in the study are presented in Table 2.

Table 2: Characteristics of the Study Participants

	Minimum	Maximum	Mean ± Standard Deviation	Median
Age	14 days	4745 days (13 years)	1202.639 ± 1165.7 days (3 years and 2 months ± 3 years and 1 month)	730.0 days (2 years)
Height (cm)	46.8	143.5	93.032 ± 26.1189	91.000
Measured weight (kg)	3	68	15.98 ± 10.051	13.00
Predicted weight (kg)	3	36	15.24 ± 8.575	13.00

The number of males and females across the weight and height groups are almost equal (no significant difference). There is no significant difference between the mean heights of boys and girls in the studied population. Hence gender differences can be ruled out in this study table 3.

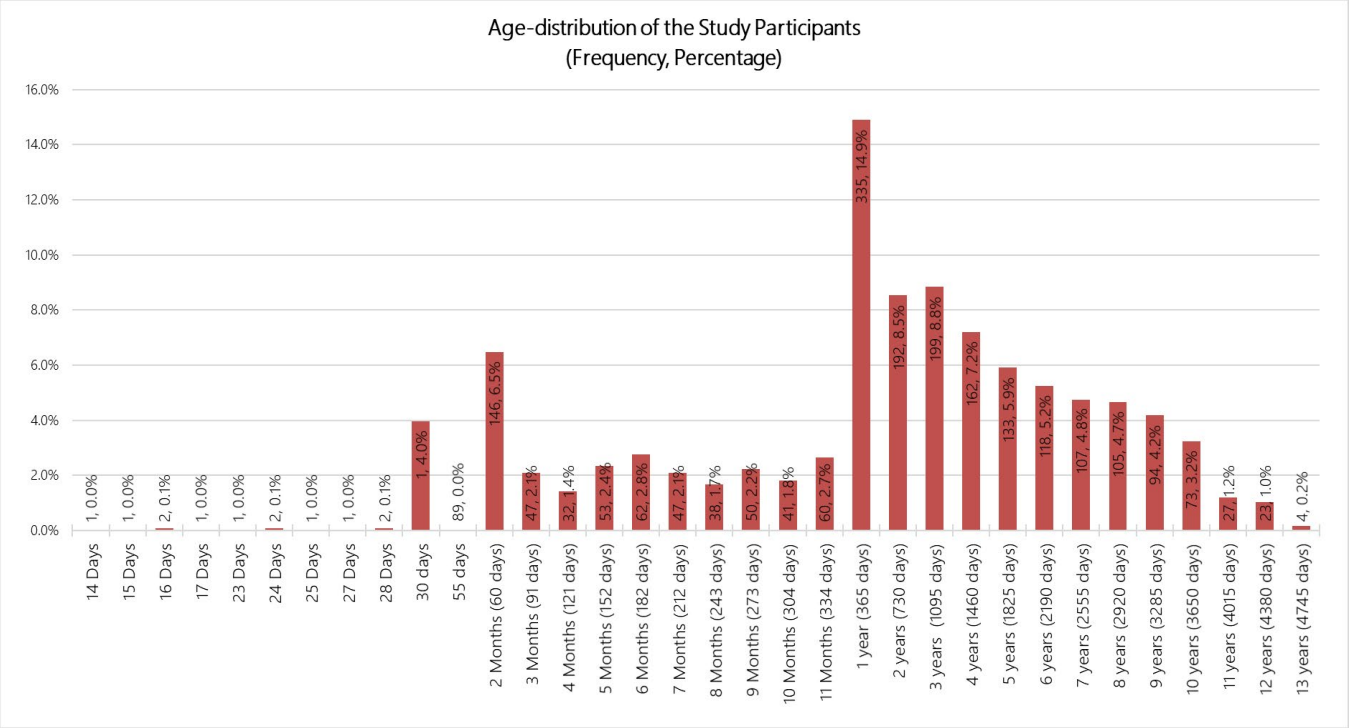

Figure 1: Age Distribution of the Study Participants

Table 3: Descriptive Statistics and Selected Characteristics of the Subjects (n= 2250)

	Girls n (%)	Boys n (%)	
	1017 (45.2%)	1233 (54.8%)	p value
Age groups			
0-6 months	194 (19.1%)	248 (20.1%)	
6 months- 1year	250 (24.6%)	321 (26.0%)	
2- 4 years	257 (25.3%)	296 (24.0%)	0.331
5- 7 years	177 (17.4%)	181 (14.7%)	
> 7 years	139 (13.7%)	187 (15.2%)	
Actual Weight groups (kg)			
3 - < 6	124 (12.2%)	121 (9.8%)	
6 - < 9	94 (9.2%)	117 (9.5%)	
8 - < 10	119 (11.7%)	149 (12.1%)	
10 - < 12	114 (11.2%)	140 (11.4%)	
12 - < 15	142 (14.0%)	176 (14.3%)	
15 - < 19	139 (13.7%)	171 (13.9%)	0.526
19 - < 24	95 (9.3%)	138 (11.2%)	
24- < 30	78 (7.7%)	104 (8.4%)	
30 - < 37	61 (6.0%)	73 (5.9%)	
>37	51 (5.0%)	44 (3.6%)	
Height			
46- 59	111 (10.9%)	108 (8.8%)	
59.1- 67	100 (9.8%)	130 (10.5%)	
67.1 – 74	104 (10.2%)	138 (11.2%)	
74.1 – 84	129 (12.7%)	161 (13.1%)	
84.1 – 96	115 (11.3%)	137 (11.1%)	0.816
96.1 – 109	159 (15.6%)	181 (14.7%)	
109.1 – 122	115 (11.3%)	139 (11.3%)	
122.1 – 131	86 (8.5%)	108 (8.8%)	
>131	98 (9.6%)	131 (10.6%)	
Height (Mean ± SD)	92.68 ± 26.15	93.32 ± 26.09	0.584 (Mann-Whitney test)

	Mean ± SD
Age (months)	39.54 ± 38.31
Actual height (cm)	93.03 ± 26.11
Actual Weight (kg)	15.93 ± 10.04
Broselow weight (kg)	15.24 ± 8.57
Absolute percent difference in weight (Actual – Broselow)	2.04 ± 14.96

This is much higher than the p-value significance threshold implying there is no statistically significant difference in the mean height and mean weight between boys and girls. Therefore, gender-segregated analysis need not be performed. Table 4 show the agreement between Broselow colour coding and actual weight in all patients. 95 children whose actual weight measurements were beyond the limit of Broselow Tape were excluded. Figure 2 depicts the percentage agreement between the colour zone based on the predicted weight and measured weight.

Overall, the Broselow tape correctly predicted the weight in 62% of the cases. The predicted weight was underestimated in 16% and overestimated in 22% of the cases.

Figure 3 illustrates the Broselow-predicted weight for a given measured weight in Bahraini children. The regression line indicates an overestimation of weight by the tape. The accuracy of the Broselow-predicted weights decreased with increasing patients' weights.

The difference between Broselow Tape predicted weight and actual weight for the study participants as a whole and by colour zone is shown in Table 5.

Broselow tape gives a difference in the weight by a mean of around 0.7 kg, but the range goes from -32 to 19. Also, the increase in the difference in weight as height goes up (Figure 4), indicates a proportionate bias - as the height goes up, the correction factor also will be bigger. This means we cannot use a uniform correction factor.

So, results measured by actual weight may be 1.3 units below or 2.1 units above Broselow tape measured weight for < 10 kg Broselow tape

Table 4: Agreement Between Broselow Colour Coding and Actual Weight in all Patients, (n)

		Colour Zone based on Actual Measured Weight									
		Grey	Pink	Red	Purple	Yellow	White	Blue	Orange	Green	Total
Colour Zone based on Broselow Tape	Grey	204	40	0	0	0	0	1	0	0	245
	Pink	16	149	44	2	0	0	0	0	0	211
	Red	1	38	157	69	2	1	0	0	0	268
	Purple	0	0	39	156	58	1	0	0	0	254
	Yellow	0	0	2	60	160	90	4	2	0	318
	White	0	1	0	3	29	202	70	2	3	310
	Blue	0	0	0	0	1	34	138	54	6	233
	Orange	0	0	0	0	2	5	39	77	59	182
	Green	0	0	0	0	0	0	8	37	89	134

***Excludes 95 children whose actual weight measurements were beyond the limit of Broselow Tape.**

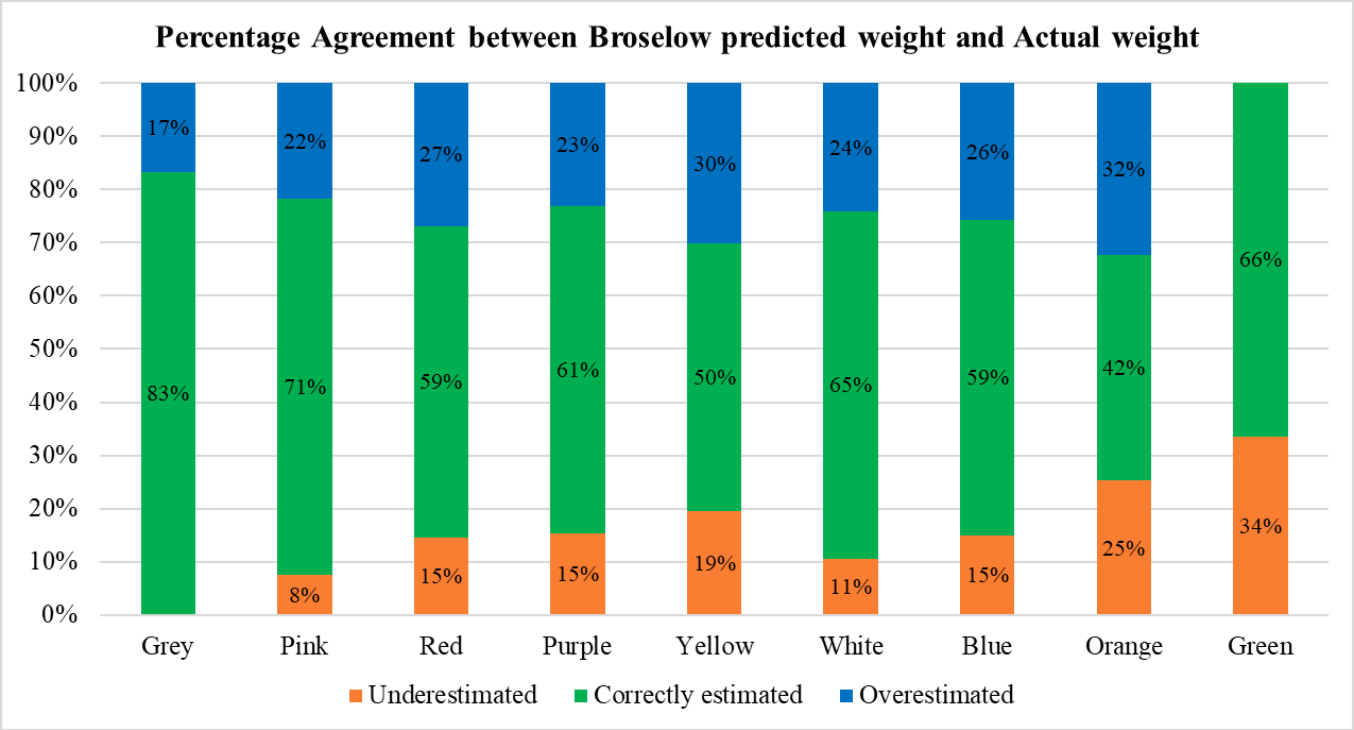

Figure 2: Colour-Coded Zones Agreement for Each Colour Zone of Broselow Tape

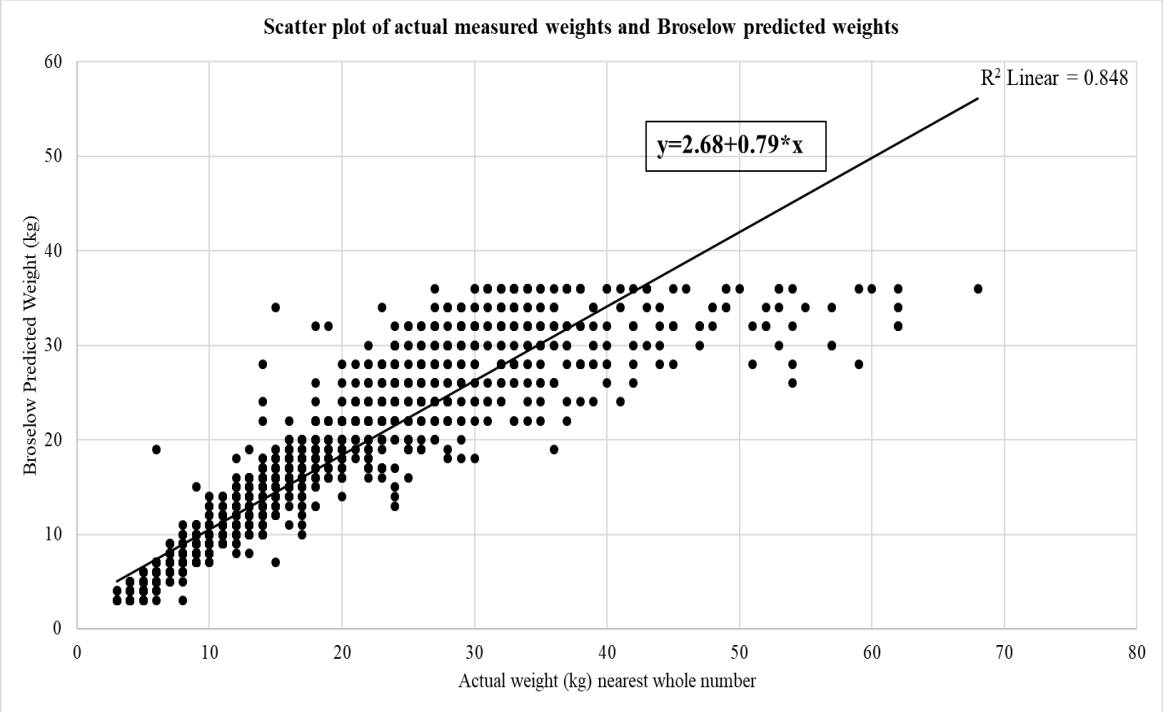

Figure 3: Scatter Plot Showing Relation Between the Actual Weight and Predicted Weight

Table 5: Difference Between Broselow Tape Predicted Weight and Actual Weight

	MEAN ± STD. DEVIATION	MINIMUM	MAXIMUM
Grey	-0.5385 ± 0.76552	-5.00	1.00
Pink	-0.3772 ± 0.99240	-8.00	1.00
Red	-0.4752 ± 1.01922	-5.00	2.00
Purple	-0.5103 ± 1.35226	-7.00	3.00
Yellow	-0.1746 ± 1.79676	-11.00	4.00
White	0.1231 ± 2.34261	-11.00	6.00
Blue	-0.4598 ± 3.70905	-17.00	13.00
Orange	-2.1856 ± 6.55756	-31.00	14.00
Green	-2.8384 ± 8.89535	-32.00	19.00
Total	-0.7400 ± 3.97384	-32.00	19.00

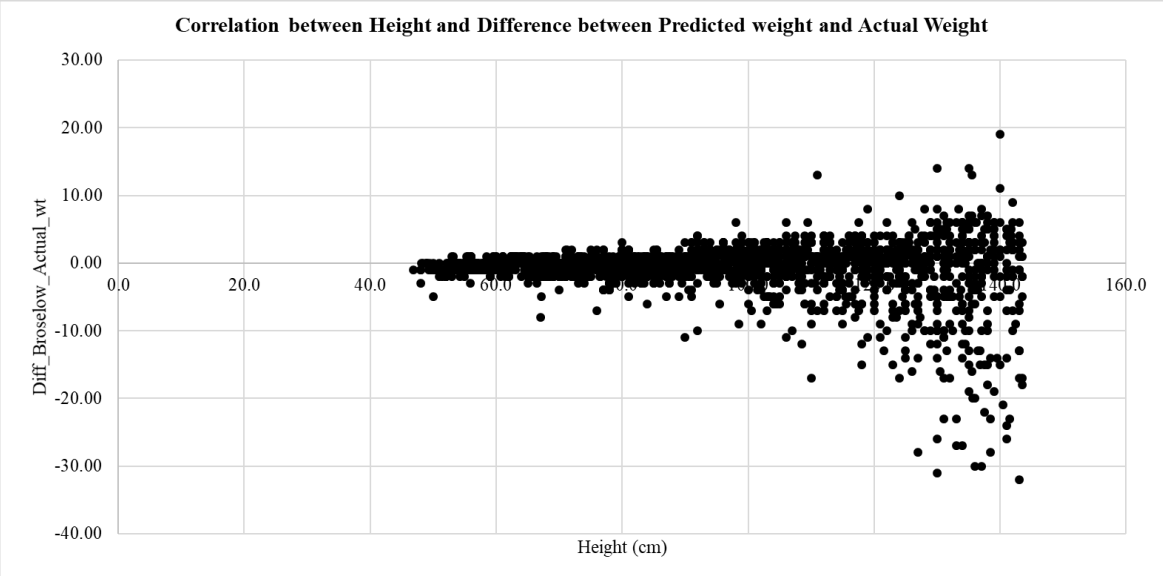

Figure 4: Correlation Between Height and Difference Between Predicted Weight and Actual Weight

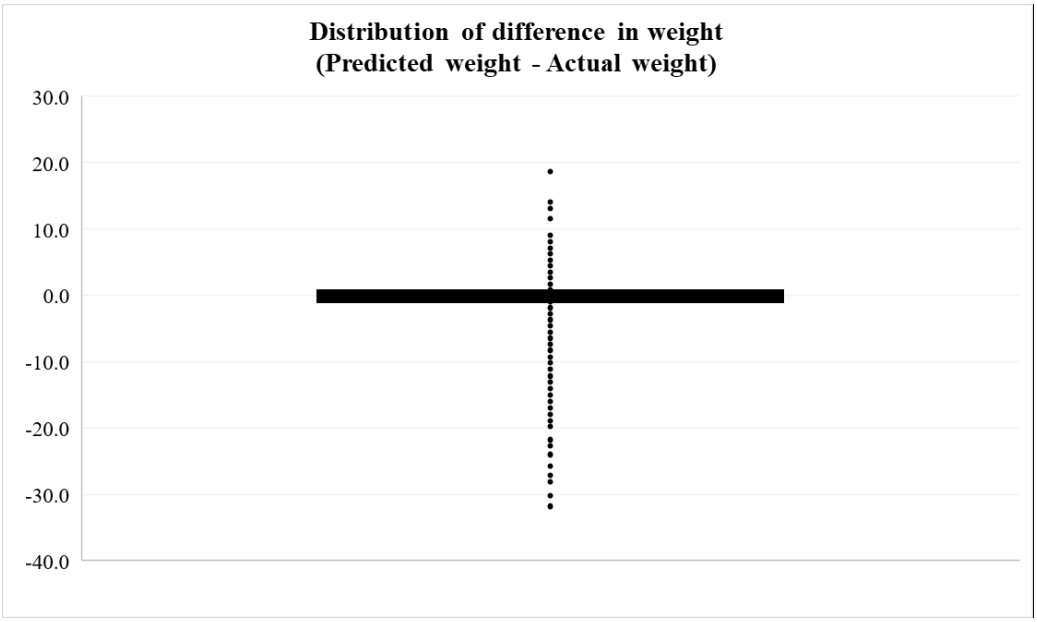

Figure 5: Distribution of Difference in Weight

category. 390 (17.33%) of the children's weight were overestimated by the BPET with more than 10% of mean percent difference. 119 (5.28%) of the children's weight were overestimated by the BPET with more than 20% of mean percent difference, with 11 in <10, 45 in 10-18 and 63 in >18 age groups. 594 (26.4%) of the children's weight were underestimated by the BPET with more than 10% of mean percent difference. 225 (10.0 %) of the children's weight were underestimated by the BPET with more than 20% of mean percent difference, with 60 in <10, 49 in 10-18 and 116 in >18 age groups.

The differences in the weight are mostly distributed on both sides of the zero value, and it is almost symmetrically distributed (Figure 5). So, we attempt a regression at predicting the correction factor using height and Broselow tape predicted weight.

REGRESSION ANALYSIS RESULTS FOR PREDICTING CORRECTION FACTOR

Correction factor (CF) = -3.643 + (0.087*Height in cms) - (0.339* Broselow tape predicted weight)

Therefore, Corrected weight = Broselow tape predicted weight – CF

DISCUSSION

Due to the high load of pediatric patients with urgency to intervene in emergency situations, color coded BPET was designed with pre-calculated medication doses to the corresponding weight estimations. The invention was based in the United States population data and accepted globally as an emergency tool to estimate the pediatric weight for rapid emergency management of 65.1% accuracy[12]. Our results revealed that there is significant variation in weight estimation of the local Bahraini studied pediatric population by the globally validated BPET displayed in (Table 2) in number and percentage.

The highest agreement between Broselow colour coding and actual measured weight for Bahraini pediatric population was the grey category (46 cm to 59.2 cm) with 96.05% agreement in measurement, the lowest measured agreement was in orange category (121.6 cm to 131cm) with percentage of 44.21%.

Based on the findings of our study, it appears that use of Broselow tape without any modifications to Bahraini children would lead to variation in administration of medications, mostly excessive doses in some categories (particularly in the orange category

Therefore, if the tape is to be used, we suggest a modification such as application of a correction factor or development of an indigenous tape based on local data. The formula used worked well with our studied population, yet, for further validation, more studies must be conducted, and CF should be tested out on a further sample where the height and real weight are known and working to get the real weight.

The findings of our study are applicable to children attending the studied hospitals in Bahrain. However, this can be confirmed by undertaking similar studies with wider population range in other local health centers, public and private hospitals in Bahrain with similar patients' profile. Our study main limitation is lacking certain age group participants mainly (Orange and Green), increasing the study population number in order to confirm the overestimation of the Broselow Tape. Yet one of the challenging limitations which was faced in previous validation studies was reaching a correction factor which can be applied to our studied population.

CONCLUSION

BPET was not found to be very accurate with the local Bahraini pediatric population. We found that as tape is more accurate for younger age group, but older age group shows variation from the BPET. Moreover, there is a proportionate bias, with the overestimation tending to increase with height. Therefore, using a uniform correction factor may not be the best option for the Bahraini population. Further studies might help finding a uniform trend in order to create a special Bahraini Broselow Tape or add special correction factor to the existing one.

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Competing Interest: None.

Sponsorship: None

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Ethical Approval: Not Applicable

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