Asian Biomedicine Vol. 8 No. 6 December 2014; 799 - 807 DOI: 10.5372/1905-7415.0806.360

Brief communication (Original)

The accuracy of the Broselow tape in the weight estimation of Thai children

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Background: The effectiveness of medical treatment depends on proper drug dosing. The most accurate measurement of a child's weight is by weighing the child on a scale, and can be done for stable children. However, an emergency, or other conditions may preclude normal weighing. The child's weight must then be estimated quickly for treatment including drug dosages, equipment sizes, ventilator volume settings, and cardioversion-defibrillation.
Objectives: To assess the accuracy of the Broselow tape in the weight estimation of Thai children.
Methods: Retrospective analysis reviewing the hospital-based data of 4746 Thai children aged less than 15 years. Demographic data, measured weight (MW), and height were collected. The subjects were divided into nine color-coded groups according to the Broselow tape color range and the actual weight plotted according to their groups. Comparison between Broselow tape-predicted weight (TW), height and MW was explored.
Results: A total of 3869 children met the inclusion criteria, of whom 2121 (54.8%) were male. The overall agreement between actual weight and predicted weight was 62.1% (range 36.4–90.5 depending on color-code). The mean difference between TW and MW was –3.56% (95% CI –3.964 to –3.150) with SD 12.91%, $P < 0.001$. TW was within a 10% error for 58% of children.
Conclusions: The accuracy of the Broselow tape in the weight estimation of Thai children decreases with increasing height. The Broselow tape underestimates Thai children's weight.

Keywords: Accuracy, body height, body weight, Broselow tape, estimation

The accurate estimation of a child's weight is very important in acute treatment of severely ill or traumatically injured children and is a critical first step in their management because most drug dosages (resuscitative or sedative medications and antibiotics), equipment sizes, ventilator volume settings, and cardioversion-defibrillation parameters are calculated using body weight. The effectiveness of emergent intervention may depend on the accuracy of weight estimation. Most medication errors and adverse drug effects are related to improper dosing [1, 2]. Noncritically ill children or stable patients can of course be weighed normally on a scale, but in an emergency situation there may be no time for this, or the condition of the patient may preclude normal weighing. The patient's weight must then be estimated to calculate medication dosages or other needs. There are a number of methods currently used to estimate a child's weight such as visual assessment, parental estimation [3, 4], an age formula [5, 6], and length-based estimations such as that using the Broselow tape [7-16].

The Broselow tape is recommended by the Advanced Trauma Life Support protocol [17]. Although many studies have confirmed the usefulness of the Broselow tape [10, 11, 15, 18], other studies have found that the accuracy of the Broselow tape varies in different populations. To our knowledge, there has been just one study assessing the accuracy of the Broselow tape in Thai children [19]. The aim of this study was to assess the accuracy of the Broselow tape in a large cohort of Thai children.

Methods

Study design and setting

This was a retrospective analytical study, in which computerized hospital data from the pediatric out-patient department (OPD) of Songklanagarind Hospital were reviewed for the 4-month period from

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01 January to 30 April 2010. The study was approved by the Research Ethics Committee of the Faculty of Medicine, Prince of Songkla University (EC: 54-117-10-1-3-7).

Sample size estimation

In this study, we used body height (BH) to divide the subjects into nine color-coded groups, based on the color-coded zones of a Broselow tape (Broselow Pediatric Emergency Tape; 2007 Edition A, Armstrong Medical Industries, Lincolnshire, IL, USA). The color-coded zones of the Broselow tape were accurately measured on a hard surface (**Table 1**). The calculated sample sizes for this study allow detection of a 5% difference (95% accuracy) between measured weight (MW) and Broselow tape-predicted weight (TW) indicated we needed at least 142 subjects per group and a minimum aggregate of 1,278 total subjects.

Inclusion and exclusion criteria

Data from all of the children <15 years old who visited the pediatric outpatient department of Songklanagarind Hospital, diagnosed using the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) in codes D, F, H, J, L, and Z (clinically stable/healthy) were included. Non-Thai children were excluded. Children whose data were incomplete or who had BHs <46.1 or >146.7 cm, which are lower or higher than the Broselow tape measures, respectively, were excluded.

Outcome measure

Age, sex, date of birth, date of visit, MW (kg), and BH (cm) were recorded in an anonymized manner. Body mass index (BMI) was calculated using the standard formula of: weight in kilograms divided by height in meters squared. Broselow tape length (TL) was measured. The actual BH was marked on the Broselow tape to determine the TW and corresponding color-coded zone. The primary outcome was the comparison of the TW and MW. Percent agreement of weight on color-coded zones, a Bland–Altman analysis, and the proportion of estimates that were within 10% of the MW were calculated.

Table 1. Color code zone

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	36	143.5	146.7

TW = Broselow tape-predicted weight, TL = Broselow tape length, BH = body height

Data analysis

Data were recorded in Microsoft Excel 2007 and analyzed using the R-program (version 2.15.0). Descriptive statistical variables for age, sex, MW, BH, and BMI were calculated. TW was recorded by used BH as TL. Scatter plots were used to show the relationships between MW and TW, and MW and BH. Logarithmic transformations of MW and appropriate power transformations of predictor variables were used to approximate normality and reduce heteroscedasticity. Polynomial regression models to predict body weight using TW and BH together with sex as predictors were constructed and used to develop prediction graphs. Fit of the models was evaluated using residual versus prediction plots.

TW were compared with the MW of the patients. A Pearson correlation coefficient analysis and the paired *t* test were conducted to compare TW and MW. The accuracy of the Broselow tape was assessed by calculating the percentage agreement of weight on each color-coded zone that used the number of children who had MW in same range of TW divided by total number of children in each color-coded zone. Percentage differences from the MWs were used to determine the mean magnitude of variation. The proportion of estimates which were within 10% error of the MW, were measured.

Results

From a total of 4746 children initially recruited in the sample and categorized into 9 groups based on the color-coded zones of the Broselow tape, 3869 children met the inclusion criteria and were included in the present study (Table 2). They comprised 2121 boys (54.82%) and 1748 girls (45.18%); ICD-10 in code D (0.7%), F (9.7%), H (3.7%), J (37.3%), L (8.9%), and Z (39.6%). The regression models predicting estimated body weight (EBW) for all patients and separately for boys and girls between sexes using TW and using BH are shown in **Table 2** and **Figure 1**. The coefficients of determination (R^2) were high (exceeding 0.94) for all models.

Overall, there was a 62.1% agreement MWs and TWs in all color-coded zones. There were no significant differences between the numbers and percentage agreement of weight between girls and boys with each color-coded zone, $P > 0.05$ (**Table 3**). The most accurate TW was found with the grey zone (90.5%), followed by the pink (74.0%), and red (66.5%) zones. For children ≤122 cm (grey to blue zones) the percentage agreement of weight with the color-coded zones was 65.8%, while for children >122 cm the agreement was only 41.1%. Percentage agreement differed significantly across color-coded zones ($P < 0.001$).

A paired *t* test was used to compare the means of TWs and MWs (**Table 4**), and the TWs and MWs were significantly different ($P < 0.001$). The estimated mean difference (TW–MW) was –0.87 kg (95% confidence interval –0.971, –0.774 kg). According to the confidence interval, the mean weight given by the Broselow tape was significantly less than the mean of the measured body weights. However, the mean differences between TWs and MWs of the 9 color-coded zones varied from –3.501 kg in the green zone ($P < 0.001$), through –0.033 kg in the red zone ($P > 0.05$) and +0.089 kg in the purple zone ($P > 0.05$), indicating that the weights were underestimated in the green zone by average of 3.501 kg.

Table 2. Prediction models of estimated body weight (kg) for height of children from 46.1 to 146.7 cm

	Adjusted R^2
Using Broselow tape-predicted weight (kg)	
Boys and girls combined: $EBW = \exp(1.035 + 0.144TW - 0.002TW^2)$	0.943
Boys: $EBW = \exp(1.056 + 0.143TW - 0.002TW^2)$	0.942
Girls: $EBW = \exp(1.013 + 0.146TW - 0.002TW^2)$	0.945
Using body height (meters)	
Boys and girls combined: $EBW = \exp(-6.43 + 28.92BH - 37.06BH^2 + 22.22BH^3 - 4.90BH^4)$	0.953
Boys: $EBW = \exp(-6.30 + 28.16BH - 35.40BH^2 + 20.73BH^3 - 4.43BH^4)$	0.952
Girls: $EBW = \exp(-6.52 + 29.52BH - 38.46BH^2 + 23.52BH^3 - 5.31BH^4)$	0.955

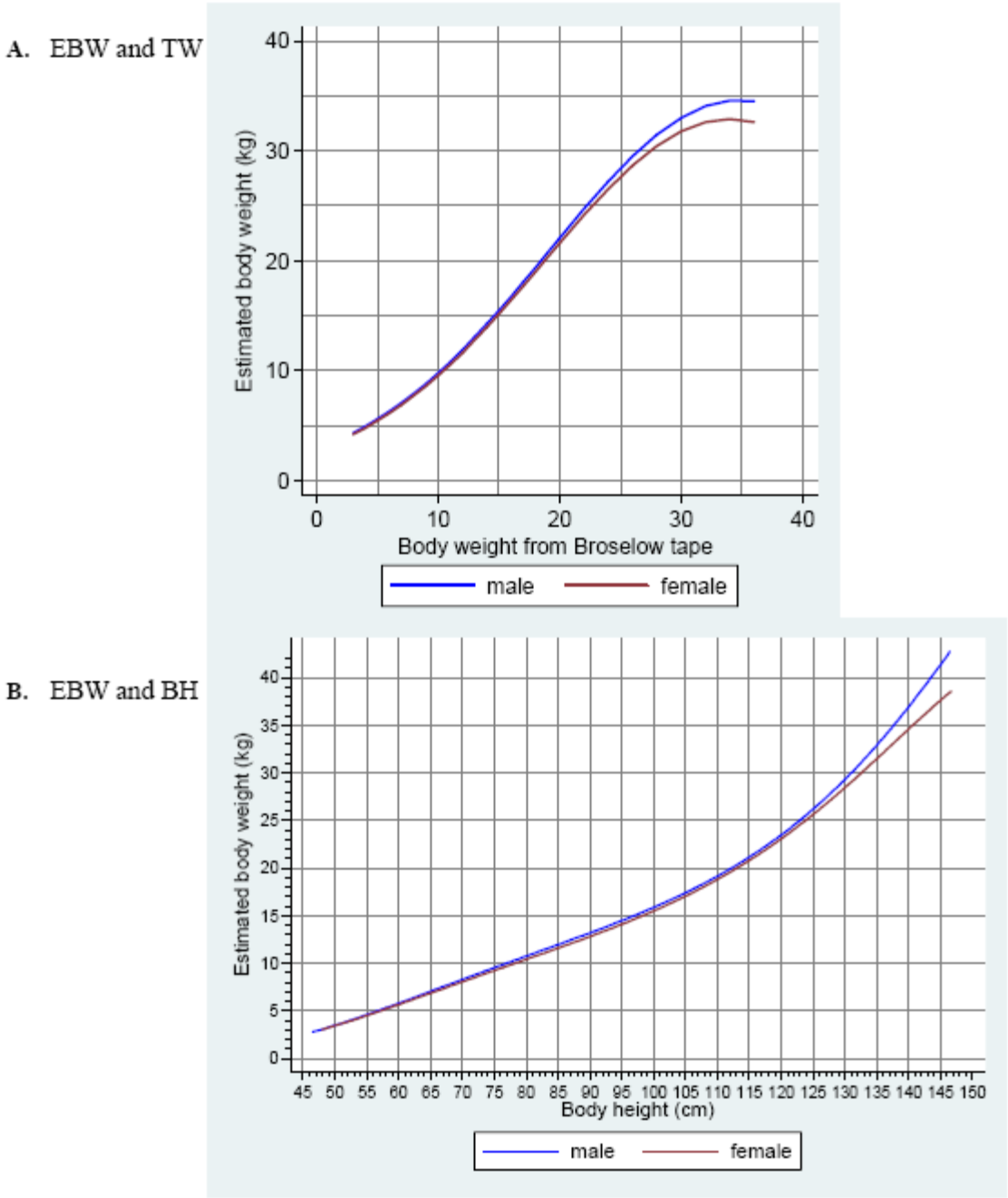

Figure 1. Graphs of prediction models of estimated body weight (kg) using TW and BH.

The mean percentage difference between the TWs and MWs was –3.557 (95% CI –3.964 to –3.150) with SD 12.91% and $P < 0.001$, indicating an underestimation of the actual weights by the Broselow tape. The mean percentage difference in the red zone was 0.518% (95% CI –0.527 to 1.563, $P > 0.05$), indicating an accurate estimation of the actual weight in this zone by the Broselow tape. Comparing MWs with TWs with a 10% error range, the TWs were found to be within the 10% error for 58% of children (**Table 4** and **Figure 2**).

Table 3. Distribution of all children in the color-coded zones and the percentage agreements of weight between the Broselow tape-predicted weight and measured weights

Color	TW (kg)	TL (cm)	Age (y) median(IQR)	MW (kg) median(IQR)	BH (cm) median (IQR)	BMI (kg/m^2) median (IQR)	Zone agreement$^+$ Total n/N (%)	Girls n/N (%)	Boys n/N (%)	*P**
Grey	3–5	46.1–60.7	0 (0, 0)	4.7 (4.2, 5.4)	56 (54, 58.2)	15 (14.1, 16.2)	447/494 (90.5)	203/221 (91.9)	244/273 (89.4)	0.43
Pink	6–7	60.8–67.7	0 (0, 1)	7 (6.3, 7.5)	64.2 (62.8, 66)	16.6 (15.6, 17.8)	282/381 (74.0)	147/199 (73.9)	135/182 (74.2)	0.96
Red	8–9	67.8–75.2	1 (1, 1)	8.5 (7.9, 9.1)	71.5 (70, 73.5)	16.6 (15.5, 17.6)	232/349 (66.5)	100/160 (62.5)	132/189 (69.8)	0.18
Purple	10–11	75.3–84.9	1 (1, 2)	10.4 (9.6, 11.2)	80.5 (78, 82.8)	16.2 (15.2, 17.2)	230/428 (53.7)	108/218 (49.5)	122/210 (58.1)	0.09
Yellow	12–14	85.0–97.9	3 (2, 3)	13.4 (12.1, 14.6)	91.3 (88, 94.5)	15.9 (14.9, 17.2)	354/601 (58.9)	143/253 (56.5)	211/348 (60.6)	0.35
White	15–18	98.0–110.2	4 (4, 5)	16.9 (15.5, 18.5)	105 (101.8, 107.5)	15.4 (14.4, 16.7)	358/577 (62.1)	172/269 (63.9)	186/308 (60.4)	0.43
Blue	19–23	110.3–122.0	6 (6, 7)	21 (19.2, 23.3)	116 (113, 119.3)	15.5 (14.2, 17.1)	263/463 (56.8)	101/194 (52.1)	162/269 (60.2)	0.098
Orange	24–29	122.1–133.9	8 (7, 9)	26.6 (23.9, 31)	127.4 (124.6, 130.2)	16.4 (14.9, 18.9)	161/367 (43.9)	54/142 (38.0)	107/225 (47.6)	0.09
Green	30–36	134.0–146.7	10 (10, 11)	34.8 (30.4, 40.5)	139 (136.3, 142.5)	17.9 (15.7, 20.6)	76/209 (36.4)	36/92 (39.1)	40/117 (34.2)	0.55
Total			3.5 (1, 6)	13.2 (8.1, 20)	91 (70, 112)	15.9 (14.8, 17.4)	2403/3869 (62.1)	1064/1748 (60.9)	1339/2121 (63.1)	0.16

TW = Broselow tape-predicted weight, TL = Broselow tape length, MW = measured weight, BH = body height

$^+$ Zone agreement = define agreement e.g. for orange the TW is considered between 24.0 to <30.0.

**P* between sexes in color-code zone agreement

Table 4. Comparing Broselow tape-predicted weights and measured weights

Color	Pearson correlation between MW and TW correlation (95%CI)	mean differences (TW-MW) (kg) (95%CI)	*P*	Proportion of percent differences* TW within 10% error n/N (%)
Grey	0.735 (0.691, 0.773)	–0.467 (–0.517, –0.417)	<0.001	244/494 (49.4)
Pink	0.537 (0.461, 0.604)	–0.456 (–0.531, –0.381)	<0.001	211/381 (55.4)
Red	0.429 (0.339, 0.511)	–0.033 (–0.122, 0.056)	0.47	240/349 (68.8)
Purple	0.438 (0.358, 0.512)	0.089 (–0.014, 0.193)	0.09	287/428 (67.1)
Yellow	0.510 (0.449, 0.567)	–0.670 (–0.814, –0.525)	<0.001	382/601 (63.6)
White	0.396 (0.3251, 0.463)	–0.897 (–1.124, –0.669)	<0.001	350/577 (60.7)
Blue	0.353 (0.271, 0.430)	–1.100 (–1.428, –0.772)	<0.001	256/463 (55.3)
Orange	0.362 (0.269, 0.448)	–2.280 (–2.828, –1.733)	<0.001	190/367 (51.8)
Green	0.333 (0.207, 0.449)	–3.501 (–4.494, –2.507)	<0.001	83/209 (39.7)
Total	0.943 (0.939, 0.946)	–0.872 (–0.971, –0.774)	<0.001	2243/3869 (58.0)

TW = Broselow tape-predicted weight, MW = measured weight, *percent differences = (TW–MW) × 100/MW

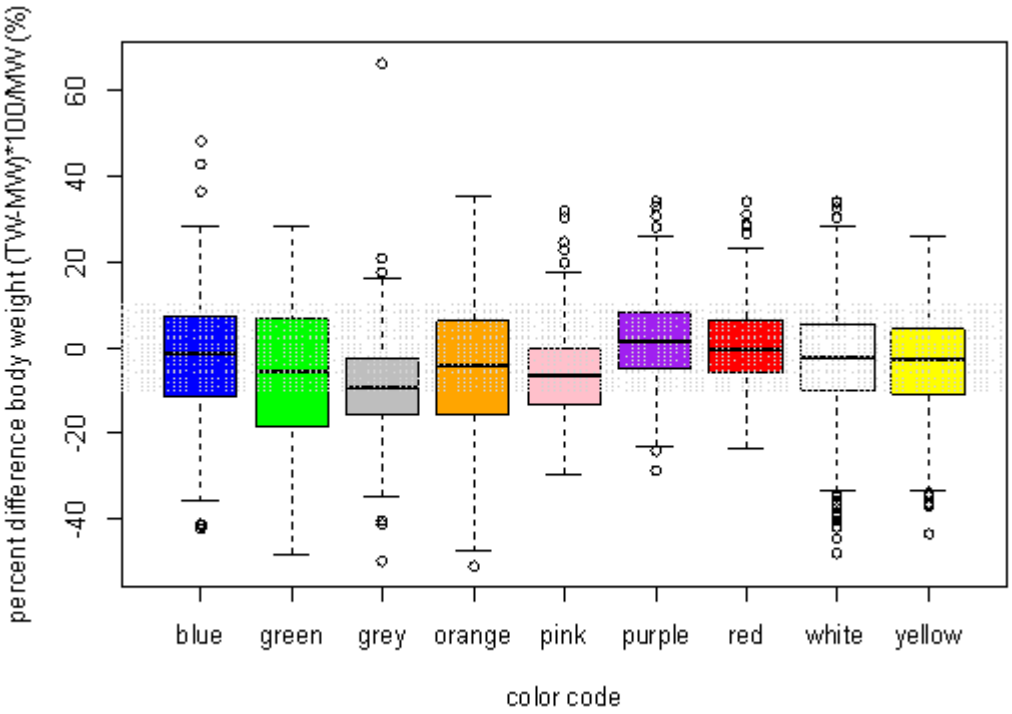

Figure 2. Percent difference of body weight determined by the Broselow tape on each color-code zone

Discussion

The Broselow tape [18] is the recommended method [10, 11, 15, 17, 18] to estimate a child's weight in the emergency department where a patient is critically ill and whose weight is unknown or cannot be weighed on a scale [16].

In the present study, overall, the Broselow tape-predicted weights correlated well with measured weights, with the children's measured weights 0.87 kg heavier on average than the weights estimated by the Broselow tape. If the Broselow tape-predicted weights are used in a clinical setting for Thai children we suggest adding 0.87 kg or use the graphs of the prediction models of estimated body weight in **Figure 1**. The accuracy of the Broselow tape as found in various studies and our study are compared in **Table 5**, which concludes that most studies [7, 8, 11, 13, 15, 16, 19], including the present study found the Broselow tape to underestimate weight by 0.5 to 2.6 kg.

Table 5. Studies examining accuracy of Broselow tape results

Author	Study site	N	Analysis	Mean difference (kg)	Precision SD (kg)	Limits of agreement (kg)		Percent difference mean (%)	Within 10% error (%)	Summary estimation
						lower	upper			
Hofer et al., 2002 [7]	Zurich, Switzerland	585	TW–MW	–0.52		–5.8	2.6		65	under
Nieman et al., 2006 [8]	Cleveland, Ohio	7,500	TW–MW	–1.01	3.68			–3.9	55.3	under
Varghese et al., 2006 [10]	Karnataka, India	500	TW–MW	0.034	1.185					over
Jang et al., 2007 [11]	Seoul, Republic of Korea	665	MW–TW	1.54		6.3	9.39		57.9	under
Bourdeau et al., 2011 [13]	Western Ontario, London	243	MW–TW					11.9	43.2	under
Rosenberg et al., 2011 [15]	Orlando FL, USA	372	TW–MW					–3.0	63	under
Sinha et al., 2012 [16]	Phoenix, AZ	118	MW–TW	2.6		–8.3	13.5			under
Trakulsrichai et al. [19]	Bangkok, Thailand	595	MW–TW	–0.485				8.91	56.13	under
Present study	Songkla, Thailand	3,869	TW–MW	–0.87	3.13	–7.01	5.27	–3.56	58	under

The relationship between measured weight and body height was strong. The regression models for body weight can predict an estimated body weight based on body height. We recommend using body height for weight estimation of Thai children of unknown weight or who cannot conveniently be weighed on a scale who visit an emergency department when they are critically ill.

Based on the findings of this study, the Broselow tape underestimates the weights of Thai children. However, the inaccuracy varies depending on the height of the child, and for children in the 'red zone' of the tape, the estimation corresponds very closely to measured weights, and is more accurate in children ≤122 cm tall.

The Broselow tape-predicted weights and measured weights were compared using a 10% error range. The Broselow tape-predicted weights for these study subjects was within the 10% error in 58% of children, which is essentially the same as for the study by Jang et al. [11], which reported the Broselow tape-predicted weights to be within a 10% error in 57.9% of their children, and as consistent with the study of Thai children by Trakulsrichai et al. [19].

Conclusion

The Broselow-predicted body weights were underestimated in both sexes and most color-code zones, with the only exceptions being in the red and purple zones where the mean weights between the TWs and MWs were not significantly different.

However, the Broselow tape underestimates Thai children's weight, and the accuracy decreases with increasing height, and is significant when the child's height is ≥122 cm.

Acknowledgments

Our findings were presented at the 2013 Annual Meeting of The Royal College of Surgeons of Thailand. Rattaporn Donnapee, Piyawan Chiengkraiwate, Sakda Patrapinyokul, Surasak Sangkathat. The Accuracy of the Broselow tape in weight estimation of Thai children [abstract]; Pediatric Surgery: free papers p. 281.

Rattaporn Donnapee was supported by a research support grant from the Faculty of Medicine, Prince of Songkla University, Songkla, Thailand. The authors thank Mr Dave Patterson of the Office of International Affairs of the Faculty of Medicine, Prince of Songkla University, for English language editing of the manuscript.

The authors have no conflict of interest to declare.

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