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How Good is the Broselow Tape Measurement for Estimation of Body Weights in Paediatric Patients for Application in Hong Kong

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Abstract In general, the calculation of drug dosage for children is based on their body weights. However, in emergency situations, the body weights of sick children cannot be accurately determined and need to be estimated, which pose a great problem to emergency physicians. In this regard, Broselow tape is widely accepted and used in emergency departments in Hong Kong for body weight estimation in children. We have estimated the body weights of 909 children using the Broselow tape and then measured their actual body weights. Tape-estimated body weights derived from the Broselow tape are found to be within ±10% error in 69.5% of children and ±15% in 84.5% of children. There is no significant difference in the accuracy rate between boys and girls. The tape-estimated body weights are more accurate in children with body weights in the range of 10 to 25 kg (±10% error in 76.2% of children), than in the range of less than 10 kg (±10% error in 56.6% of children) or more than 25 kg (±10% error in 52.3% of children). We concluded that the Broselow tape provides satisfactory estimated body weights in Hong Kong Chinese children attending our emergency department, especially for those children with body weights between 10 and 25 kg.

Key words Broselow tape; Weight estimation; Emergency department

Introduction

Paediatric resuscitation is challenging for both emergency physicians and paediatricians. Paediatric cardio-respiratory arrest is an infrequent occurrence and most practising physicians have limited experience in dealing with these situations. Appropriate dosing of the drugs for resuscitation and choice on the size of equipment in these circumstances are crucial, which depend very much on the body weights of the children concerned. Unfortunately it is usually not feasible to weigh the sick child in an emergency situation. The problem is even more significant in the emergency department as most patients are attended without prior knowledge of their status. Therefore there is the need for a fast, convenient and reliable method for body weight estimation in children, which serves as the basis for determination of the appropriate drug dosage or equipment size.

Previously, body weight estimation was usually performed with visual assessment by the attending doctor, or derived from the age of the patient using certain formula. Occasionally, the body weight can be obtained from a close relative. However, visual assessment is not scientific and is affected by individual experience and perception. Great discrepancy is not uncommon. Updated local growth reference charts are not convenient for use in emergency situations. There are also remarkable variations in the body weights of children with the same age. In addition, an informant is not always available to provide the body weight of the paediatric patient.

To enhance accuracy, speed and reduce observer bias, James Broselow has developed a simplified method for quick estimation of body weight based on body length. Based on the data from the National Center for Health Statistics (NCHS) published in 1979, he determined the 50th percentile body weights for a wide range of body lengths. This was translated to a measuring tape with spaces labeled with weights in kilogram instead of units

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in length.[1] The appropriate doses for most resuscitation drugs, size of resuscitation instruments under the recommendation of American Heart Association (AHA) are printed in each space according to the tape-estimated body weights.

In 1991, Dr. Golden expanded the concept of Broselow tape in the design of the paediatric resuscitation area, developing a "Color-Coded Paediatric Resuscitation Room".[2] Once a child was placed on the resuscitation stretcher, his or her body length would fall into a color band similar to that in the Broselow tape. The attending doctor could then read from a large simplified wall chart containing the same color codes as the Broselow tape the appropriate drug dosages, size of instruments, as well as defibrillation and cardioversion settings.

Thus body length based estimation has become one of the commonest methods used in emergency departments for estimation of body weights of children requiring resuscitation. With the introduction of the Paediatric Advanced Life Support Course in 1990s, the use of the Broselow tape has become well known and widely employed by emergency physicians in Hong Kong.

The translation of body lengths to weights in the Broselow tape currently under use is derived from the data of National Center for Health Statistics (NCHS) published in 1979.[1] The accuracy of the Broselow tape has been validated in studies conducted in the United States and Britain.[1,3] However, the degree of applicability of this tape in Hong Kong is still questionable. Hence we conducted this study to test the accuracy of the Broselow tape on estimating body weights from body lengths of Chinese children in our locality at the present time, by comparing the actual and tape-estimated body weights.

Materials and Methods

Children aged 7 days to 12 years who attended the Accident and Emergency Department of Kwong Wah Hospital in Hong Kong from August to September 1999 were enrolled in our study. Children with triage categories I and II (Desperate or Emergency) were excluded to avoid delay in providing appropriate treatment in these circumstances.

All demographic data including age in months and sex were recorded for each child. Tape-estimated body weight of the child was read by our nursing staff using the standard Broselow tape - the space marks on the tape into which the child fell in supine position and from crown to heel was determined and the corresponding body weight estimation noted and recorded.

The actual body weight of the child was measured by a standard electronic digital weighing machine, to one-decimal place in kilograms. To reduce errors, only light clothing or underwear was allowed during body weighing. Different observers were involved in taking the actual and tape-estimated body weights to avoid observer bias.

As Broselow tape only provided body weight estimation in the range from 3 kg to 34 kg, children in our study with tape-estimated body weights beyond such range were excluded when our results were analyzed.

The tape-estimated and actual body weights were compared and the percentage error was calculated as follows: -

$$\frac{\text{(Tape-estimated body weight - Actual body weight) X 100}}{\text{Actual body weight}}$$

The statistical method of chi-square test, with derivation of confidence intervals will be employed for analysis of the data. In previous studies,[1,3] correlation was employed to analyze the relationship between tape-estimated and actual body weights. However, correlation is inappropriate for our data analysis as it can only prove the association but cannot compare the tape-estimated body weight with the actual body weight. The slope of the straight line (tape-estimated versus actual body weights) β, would be selected according to our sample but not the ideal slope of 1. The Pearson product moment correlation coefficient, r, reflects only the "fitness" of the sample with this straight line. Therefore their values do not enable us to comment on the accuracy of the tape-estimated body weights nor can we assess the accuracy rate of the tape-estimated body weights by correlation as we predicted a linear relationship between tape-estimated and actual body weights. Nevertheless, the result of correlation is provided for comparison.

Results

The children enrolled in this study (N=930) were aged from 7 days to 11 years and 11months. 21 children were excluded from the study because their tape-estimated body weights did not fall into the standard range from 3 kg to 34 kg. The remaining 909 patients consisted of 544 boys (59.8%) and 365 girls (40.2%). Their body weights and age distribution were showed in Table 1.

The body weights of these children ranged from 3.2 kg to 59.2 kg. The relationship between the actual and tape-estimated body weights was plotted under the scatter diagram (Figure 1). Linear relationship was confirmed.

When further elaborated the actual versus tape-estimated body weights by correlation, we obtained a β value of 0.872 (95% CI of 0.852-0.892) with r =0.940. When adjusting the regression line to pass through the

Table 1 Body weights and age distribution of our sample

	Frequency	Percentage
below 1 year	107	11.8
1 - 4 years	358	39.4
4 - 8 years	299	32.9
8 - 12 years	145	16.0
Total	909	100.0

	Frequency	Percentage
below 10 kg	129	14.2
10 - 25 kg	631	69.4
above 25 kg	149	16.4
Total	909	100.0

origin, the β value was 0.959 (95% CI of 0.951-0.968) with r=0.990. As the r-value is close to 1, this suggested a linear relationship between actual and tape-estimated body weights as anticipated. Unfortunately, it was impossible to correlate the r-value with the accuracy rate of the tape-estimated body weights for reasons mentioned above.

The overall accuracy rate of tape-estimated body weights was evaluated by computing the percentage error for each subject using the formula quoted above (Table 2).

From Table 2, 69.5% (95% CI of 66.5 to 72.5%) of tape-estimated body weights was within ±10% error of actual body weights, and 84.5% (95% CI of 82.1 to 86.9%) of the tape-estimated body weights was within

Table 2 The overall accuracy rate of tape-estimated body weights

Percentage error	Frequency (%)	Cumulative Percent (%)
below 5%	373 (41.0)	41.0
5 -10%	259 (28.5)	69.5
10 - 15%	136 (15.0)	84.5
15 - 20%	62 (6.8)	91.3
20 - 25%	38 (4.2)	95.5
above 25%	41 (4.5)	100.0
Total	909 (100)	

±15% error of actual body weights.

The accuracy rates of tape-estimated body weights in boys were 70.2% (95% CI of 66.4 to 74.0%) and 85.7% (95% CI of 82.8 to 88.6%) within a ±10% and ±15% error respectively. For girls, the values were 68.5% (95% CI of 63.7 to 73.3%) and 82.7% (95% CI of 78.8 to 86.6%) within a ±10% and ±15% error respectively (Table 3). It seemed that there was no statistically significant difference in the accuracy rate between boys and girls.

The data was further elaborated with reference to the different ranges of body weights and the results were presented in Table 4.

From Table 4, the tape-estimated body weights seemed to be most accurate in children with body weights in the range from 10 to 25 kgs, with accuracy rates of 76.2% (95% CI of 72.9 to 79.5%) and 90.3% (95% CI of 88.0 to 92.6%) with ±10% and ±15% errors respectively. The tape-

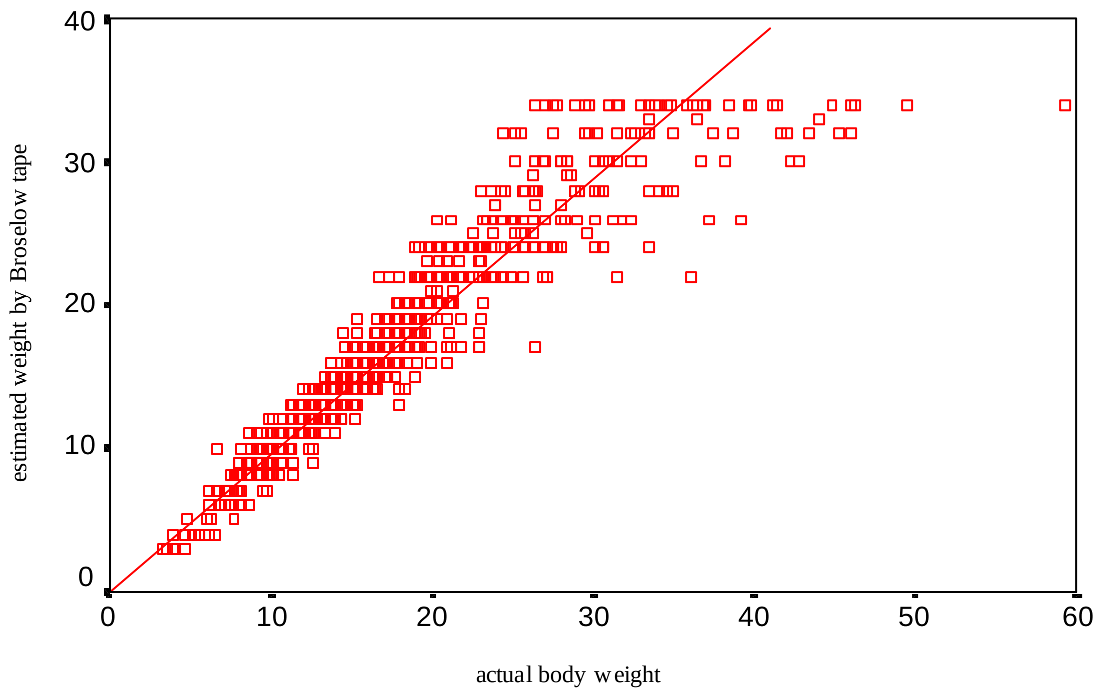

Figure 1 Scatter diagram of tape estimated weight versus actual weight of children.

estimated body weights were much less accurate for body weights in the ranges below 10 kg and above 25 kg. For body weights below 10 kg, the accuracy rates were only 56.6% (95% CI of 48.0 to 65.1%) and 76.7% (95% CI of 69.4 to 84.0%) with ±10% and ±15% errors respectively. For body weights beyond 25 kg, the accuracy rates were 52.3% (95% CI of 44.3 to 60.4%) and 66.4% (95% CI of 58.9 to 74.0%) with ±10% and ±15% errors respectively. By utilizing the chi-square test the accuracy rates in these 3 ranges of weights are proved to be different with p value <0.0005.

When we looked at the difference between the actual and tape-estimated body weights (i.e. tape-estimated body weight - actual body weight), it ranged from -25.2 kg to +7.6 kg with a mean of -0.4083 kg (95% CI -0.2345 to -0.5820 kg). As the confidence interval did not include zero, there was statistically significant difference between actual and tape-estimated body weights with a weight underestimation of less than 0.5 kg in average. As a 0.5 kg error had only little effect on calculating the exact drug dosage, the final error in the amount of medicine used was minimal. However, we could not simply deduce the child's body weight by adding 0.4083 kg in each estimation.

Further evaluation according to the difference in tape-estimated and actual body weights for different groups of children with different ranges of body weights were as follow (Table 5).

From Table 5, the overall discrepancy of tape-estimated weights was shown. There was no statistically significant difference between the means of tape-estimated body weights and actual body weights for children with body weights in the range 10-25 kg. However, children with body weights below 10 kg and above 25 kg did have certain underestimation in tape-estimated body weights.

Discussion

Selection of appropriate drug dosage and size of

Table 3 The accuracy of the estimation of different sex

	Male		Female	
Percentage error	Frequency (%)	Cumulative %	Frequency (%)	Cumulative %
below 5%	222 (40.8)	40.8	151 (41.4)	41.4
5 - 10%	160 (29.4)	70.2	99 (27.1)	68.5
10 - 15%	84 (15.4)	85.7	52 (14.2)	82.7
15 - 20%	37 (6.8)	92.5	25 (6.8)	89.6
20 - 25%	22 (4.0)	96.5	16 (4.4)	94.0
above 25%	19 (3.5)	100.0	22 (6.0)	100.0
Total	544 (100.0)		365 (100.0)	

Table 4 The accuracy of estimation of different weight group

	Below 10 kg		10 - 25 kg		Above 25 kg	
Percentage error	Frequency (%)	Cumulative %	Frequency (%)	Cumulative %	Frequency (%)	Cumulative %
Below 5%	45 (34.9)	34.9	292 (46.3)	46.3	36 (24.2)	24.2
5-10%	28 (21.7)	56.6	189 (30.0)	76.2	42 (28.2)	52.3
10 - 15%	26 (20.2)	76.7	89 (14.1)	90.3	21 (14.1)	66.4
15 - 20%	9 (7.0)	83.7	31 (4.9)	95.2	22 (14.8)	81.2
20 - 25%	9 (7.0)	90.7	19 (3.0)	98.3	10 (6.7)	87.9
Above 25%	12 (9.3)	100.0	11 (l.7)	100.0	18 (12.1)	100.0
Total	129 (100.0)		631 (100.0)		149 (100.0)	

Table 5 The mean difference of different weight group

		Below 10 kg	10-25 kg	Above 25 kg
Mean of difference (kg)		-0.2969	0.005864	-2.2584
95% Confidence Interval for Mean of difference (kg)	Lower Bound	-0.4808	-0.1190	-3.1107
	Upper Bound	-0.1130	0.1307	-1.4061
Range of difference (kg)		-2.60 to 3.40	-5.80 to 7.60	-25.20 to 7.60

equipment in emergency situations can be a difficult and frustrating experience for emergency physicians and paediatricians. This is evidenced by numerous resuscitation aids designed to accomplish this task. Several reports has mentioned techniques for estimating a child's total body weight based on age, height, body habitus or even "hanging leg" weight.

The Advanced Paediatric Life Support textbook has cited methods for estimating weight based on age.[4] Formulas like B.W. (kg)= (age in years + 4) X 2 and B.W. (kg)= 8 + (2 X age in years), were commonly coded for body weights estimation. These estimations were inaccurate because of the variation in time of growth spurt and nutritional status of different children. And in some occasion when the child's age is not available, these formulas are no longer helpful.

In 1986, Garland et al. proposed a technique called the devised weight estimation method (DWEM), which used supine length and body habitus (slim, average or heavy) to derive a table from which total body weight could be estimated.[5] 61% of estimations (N=258) made by this method were within 10% or less of the actual known body weights. It gave a reasonable satisfactory estimation but the accuracy was subjected to individual's perception of the body habitus.

Dr. Haftel and a group of anaesthetists described a method of using hanging leg weight for the estimation of total body weight in 1990.[6] They performed a study on anaesthetized children (N=100) by measuring both legs and body weights with a spring scale. Percentage error analysis showed that for all these children, 73.7% of estimations were within ±10% of the actual body weights. This method was much more superior for children above 25 kg in which 90% of the estimated body weights were within ±10% of their actual body weights. However, the specific derived table on which the estimation depends is not easily available.

Dr. Oakley published a paediatric resuscitation reference chart in 1988, in view of the poor performance of junior hospital doctors in simulated cardio-respiratory arrests of children.[7] This chart enabled the attending doctor to estimate the body weight of a child by referring to the age or body length through a curve. This chart gained widespread acceptance in emergency departments.[9] Unfortunately, the applicability of this chart in Hong Kong children is still questionable.

Despite the above methods, length-based estimation is still the commonest means for estimation of body weight in emergency departments in Hong Kong. However, some problems have been encountered on directly applying this tape in our locality. First, the drug nomenclature in the Broselow tape is not exactly the same as that utilized in Hong Kong. Translation is sometimes required before application, for example, the name "Lidocaine" is used in the tape instead of the more commonly used name "Lignocaine". Secondly, the drug preparation mentioned in the Broselow tape is sometimes different from that available in our locality, for example, the recommended preparation of Atropine injection in the tape was 0.1 mg/ml instead of the standard of 0.6 mg/ml in Hong Kong. This may create difficulties when we use the tape in our locality. In 1995, Dr. Lo and his colleagues suggested a modification of the Broselow tape to suite the local drug preference, available drug preparations and protocols of their choices through a home made system with computer print-outs of drug dosage charts and equipment size charts.[10] Such a modification does solve part of the problems in which on time calculation and correction is no longer necessary during critical situations.

Thirdly, as the Broselow tape was derived from the data of American children collected from 1963 to 1975, the accuracy of body weight estimations by directly applying the tape in our locality is subjected to controversy. In 1995, Dr. Leung et al presented the body weight-for-height references of children in Hong Kong. The weight-for-height data of Hong Kong children were similar in distribution to those of the NCHS in 1979 but they are not exactly the same. There are differences between the curves. In particular, boys in Hong Kong with body heights of 110 - 145 cm were slightly more obese as pointed out by the authors.[10]

As the Broselow tape was designed with the median weights for body lengths, inherent errors in estimating the body weights amount to the variations around the medians are certain. Studies with Caucasians have been performed to estimate these errors.[1] It is the purpose of our study to evaluate the accuracy of the tape and compare the Hong Kong population with others.

In 1988, Dr. Lubitz et al described the method of body weight estimation by using supine body length in a literature, using the Broselow tape that based on the non-linear relationship of length to weight.[1] They studied 937 American children in different centers with good overall accuracy. From their study, they found that the error in body weight estimation was 10% or less in 59.7% of all children. The result of using the Broselow tape was even better when applied to Hong Kong children in our study. We found that the error of body weight estimation was 10% or less in 69.5% of all children. Accordingly, the Broselow tape can provide reasonable satisfactory body weight estimation for children in Hong Kong in comparison with Dr. Lubitz's study.

On further evaluation of Lubitz's study, the Broselow tape yielded errors in body weight estimation of 10% or less in 55.9%, 65.0% and 49.5% of patients in the body weight subgroups of less than 10 kg, 10 to 25 kg, and more than 25 kg respectively. But in our study that involved children in Hong Kong, the results are better in all three weight subgroups. The errors in body weight estimation were 10% or less in 56.6% of children in the study below 10 kg in body weight, 76.2% of children of 10 to 25 kg, and 53.2% of children above 25 kg. It also demonstrated that the relatively more accurate result in our study was not due to difference in distribution of different body weight subgroups.

Unfortunately not many validation studies of the Broselow tape have been performed in other countries despite its popularity. They were carried out upon the initial introduction of this tape, that is, in the late 80's, and the subjects studied were Caucasians.

Hughes et al presented another study in London in 1990.[3] They compared the accuracy between nursing staff estimation and tape estimation of body weight. They reported a difference in the means of -0.017 kg in 139 patients. Regrettably, the result was analyzed by linear correlation and the percentage error was not published.

In our study, tape-estimated body weights were less accurate in children with body weights less than 10 kg. This can be explained by the relatively large increment in body weight estimation in the Broselow tape in reference to the actual body weights of children, as there is one-kilogram increment over each consecutive space. Therefore small difference may make up large error in estimation. Moreover, the data from NCHS was collected from 1963 to 1975, in which the information from younger children was collected in the earlier part of this period. That may explain the lower accuracy for those below 10 kg.

For children more than 25 kg in body weights, the decrease in accuracy in our study was most probably due to the wide variations in body habitus of these older children. These were well shown in the previous scatter diagram. Perhaps some modification to include the body habitus as a variable in this weight subgroup should be considered in order to improve the accuracy, especially in some extreme cases. In our study, we have found an 11 years and 6 months old child with an actual body weight of 59.2 kg versus an estimated weight of 34 kg.

For those with body weights between 10 and 25 kg, our study does show reasonable accuracy in estimation. The error in body weight estimation were 10% or less in 76.2% of patients and 15% or less in 90.3% of patients, bearing in mind that around 4.7% of estimations (Table 4) have errors more than 20%, and the actual differences range from -5.8 kg to +7.6 kg. It may produce significant inappropriate drug dosage in those patients. So we should be on the alert for those patients who are significantly obese or malnourished and adjustment by the observer based on body habitus may be necessarily. Information from a caretaker may be valuable in these circumstances.

Conclusion

We concluded that the Broselow tape for estimation of body weights in children is a simple, useful, and generally accurate aid to emergency physicians and paramedics who care for critically ill children, especially in settings where ages are unknown and relatives are not available. This tape provides satisfactory body weight estimations in Hong Kong children, especially when they weigh between 10 to 25 kg.

Nevertheless, certain modifications of the Broselow tape like drug nomenclature and dosage are necessary to suit our locality and adjustment by observer may be necessary in case of extreme body habitus.

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