Accuracy of Three Methods Used for Thai Children's Body Weight Estimation

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Background: *Accurate children's weight estimation is necessary and important for emergency pediatric care, particularly for drug dosages, electrical therapy, or equipment sizes. Children's weight is difficult to measure in critically ill patients. Several methods were developed to estimate children's accurate weight. Most methods were developed from western countries. The methods used currently might not work with Thai children.*
Objective: *To determine the accuracy of the Broselow tape, family member estimation and the 50th percentile of national weight for height correlation graph for Thai children's weight estimation.*
Material and Method: *The authors carried out a prospective study. Children from neonate to 12 years old who presented to the emergency department and general outpatient pediatric clinic were included. The patients were studied in both overall and subgroup analysis (less than 10 kg, 10 to 25 kg, 25 to 40 kg, and over 40 kg). The primary outcome was the accuracy within 10% error of the measured weight and the mean difference of the weight.*
Results: *Five hundred ninety five patients were included in the present study. There were 333 (55.97%) boys and 262 (44.03%) girls. Family member estimation was the most accurate method with the accuracy within 10% error 85.21% and had the lowest mean difference (-0.262 kg). Family members could estimate weight accurately for all weight subgroups. The Broselow tape was the second most accurate method with the accuracy within 10% error 56.13% and the low mean difference (-0.485 kg). The accuracy within 10% error of the 50th percentile of national weight for height correlation graph was 51.43% and the mean difference was -0.648 kg. Every method had the best estimation in the weight subgroup 10 to 25 kg except the Broselow tape.*
Conclusion: *Family member estimation was the most accurate method in the present study. The family member could estimate the children's weight within 10% error of the measured weight about 85% of cases. In case where family member estimation was not available, the Broselow tape was the next accurate alternative method.*

Keywords: Thai children's weight estimation, The Broselow tape, The family member estimation, The 50th percentile of national weight-height correlation graph

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The accurate weights of pediatric patients are necessary and important for the calculation of the drug doses, particularly in emergency pediatric patients. When rapid resuscitation is needed, it is almost impossible to weigh the patient. Many methods and formulae have been developed to estimate children's weight. Most are from western countries and some are studied to evaluate for the accuracy of children weight estimation. The methods used currently might not be suitable for Asian or Thai children.

The Broselow Tape (BT) is one of the most famous weight estimation tools for physicians, especially emergency physicians. It was developed by using American children's height-weight correlation[1] and currently is one of the most accurate methods of children weight estimation. However, there are still some limitations. Hofer et al[2] found that BT was more accurate in smaller children than in older children, which it underestimated. Nieman et al[3] suggested from their study that one third of children were inaccurately predicted by BT. From Thelon et al study[4], for Pacific Island and Maori children, BT underestimated.

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Lubitz et al[5] found that the accuracy of BT in children weighed over 25 kg was decreased significantly. DuBois et al[6] found that BT underestimated the children's weights. Argall et al[7] implied from their study that BT was more inaccurate with increasing children's ages and weights. For Asian children, Varghese et al[8] indicated that BT was accurate for Indian children's weight estimation, however, the accuracy tended to decrease when the children's weight increased, particularly above 15 kg. In 2008, Ramarajan et al[9] studied BT in Indian children and found that BT overestimated the weights in the children whose weight was more than 10 kg. Jang et al[10] also suggested that BT could be used in Korean children to estimate the children's weights and the sizes of the endotracheal tubes.

For the family member weight estimation method, Krieser et al[11] found that parental estimation predicted body weights of their children more accurately than the other weight estimation methods studied such as Advanced Pediatric Life Support formula, Broselow tape, and Best Guess.

In Thailand, there is no study to assess and evaluate the accuracy of these methods for Thai children's weight estimation.

Because BT was developed from national children's height-weight correlation and the postulation on the race and nationality are one of the important factors influencing the children's weight, so the 50th percentile (P50) from 'Thai national weight for height graph' may be used as the other method for Thai children's weight estimation.

Thus, the objective of the present study was to determine the accuracy of these three different methods, BT, family member estimation, and the 50th percentile of Thai national weight-height correlation graph for the weight estimation of Thai children or pediatric patients.

Material and Method

Study design

This prospective study was performed at the Emergency Department (ED) and general pediatric out patients department (OPD), Ramathibodi Hospital. The sample size was calculated by using the data of previous studies that 594 patients would be required ($\alpha = 0.05$, $d = 0.04$).

The primary outcome included the accuracy within 10% error of the measured weight and the mean difference for each method. The secondary outcome was the absolute percentage of body weight difference and the data of under or overestimation of the measured weight.

The present study was approved by the Institutional Ethic Committee Board of Ramathibodi Hospital Faculty of Medicine, Mahidol University.

Study setting and population

The present study was done in an academic tertiary care hospital and started in 2008.

The inclusion criteria were the pediatric patients from neonate to 12 year olds and the height less than 145 cm who visited the ED and the general pediatric OPD during the period of the present study.

The exclusion criteria were patients who needed immediate lifesaving procedures and whose measurement was not possible by the scales or refusal for consent by parents or caregivers.

Study protocol

All participants' data, which met the criteria, were collected with the convenience sampling method. 300 patients from ED and 295 patients from the general OPD were required. Parents or caregivers of each patient were requested to give the informed consent. The data were recorded by the trained senior nurses both in ED and OPD and included the name, hospital number, date of birth, current date, chief complaint, parental or caregivers estimation, measured body weight, measured height, estimated body weight and color from BT in the supine position.

Body weights and heights were measured by the standard, regular well calibrated weight and height scale. The current date and the date of birth were used to calculate for the age.

The height was plotted in the national weight-height correlation graph to predict the 50th percentile (P50) of the weight for a given height.

The weight from BT, parents or caregivers' estimation, and the P50 of the graph were used to assess the primary and secondary outcomes. Subgroup analysis, was also performed to evaluate each range of weight, which was < 10, 10 to 25, 25.01 to 40, and > 40 kg groups.

Data analysis

Data was collected by the EpiData software (EpiData Association, Denmark). Mean and SD were analyzed for continuous data. Frequency and percentage were used for categorical data.

The Pearson Chi square (X2) or Fisher's exact test was used for group comparisons. The modified

Bland-Altman method for mean difference analysis was employed and Kappa was used for inter-rater agreement.

Results

From the study protocol, 595 participants were included in the present study. Participant's demographic data are shown in Table 1. The persons who accompanied the patients were all family members.

The primary outcomes including the accuracy within 10% error of the measured weight and the mean difference (kg) are shown in Table 2 and 3. The authors found that family member estimation was the most accurate method with the accuracy within 10% error 85.21% and had the lowest mean difference (-0.262 kg). Family members were able to estimate weight accurately for all weight subgroups. The Broselow tape was the second most accurate method with the accuracy within 10% error 56.13% and the low mean difference (-0.485 kg). The accuracy within 10% error of the P50 of national weight for height correlation graph was 51.43% and the mean difference was -0.648 kg. Every method had the best estimation in the weight subgroup 10 to 25 kg except BT, which had the best estimation in the weight subgroup less than 10 kg. However, the estimations from BT in the weight subgroup less than 10 kg and 10 to 25 kg were very close (60.36%, 59.68%). The authors calculated the absolute percentage of body weight difference by using the difference between the actual weight and the measured weight in the percentages of the actual weight. The data of the absolute percentage of body weight difference are shown in Table 4. Family member estimation had the lowest absolute percentages of body weight difference.

Family member estimation and BT overestimated more than underestimated the patients' weight while the P50 of national weight for height correlation graph underestimated more than overestimated the patients' weight as shown in Table 5. When the authors compared the overall accuracy within 10% error between the patients who had and did not have underlying diseases, there was no statistically significantly different for every method (BT: $p = 0.415$, Family member estimation: $p = 0.361$, the 50th percentile: $p = 0.263$).

Table 1. Demographic data of 595 patients

Characteristic	Frequency (%)
Gender	
Male	333 (55.97)
Female	262 (44.03)
Age (yr), median (min-max)	3.98 (0.21-12.49)
Height (cm), mean (SD)	101.92 (22.47)
Height and weight percentile (percentile)	
> 97	66 (11.09)
91-97	10 (1.68)
76-90	38 (6.39)
51-75	173 (29.08)
26-50	131 (22.02)
11-25	76 (12.77)
3-10	95 (15.97)
< 3	6 (1.00)
Measured weight (kg), mean (SD)	17.64 (8.41)
Range of weight (kg)	
< 10	111 (18.66)
10-25	372 (62.52)
25.01-40	104 (17.48)
> 40	8 (1.34)
Underlying disease	
Yes	79 (13.28)
No	516 (86.72)
Main chief complaint	
Respiratory system	130 (21.85)
Infectious system	121 (20.34)
Hematologic system	94 (15.80)
Birth delivery history	
Normal	373 (62.69)
Abnormal	222 (37.31)

Discussion

In the present study, family member estimation of weight was the most accurate method. This result was consistent with other studies[11-14]. Family members or parents might be the persons who lived with the patients and followed the patients' growth development, so they might know the patients' body weights. However, the authors did not collect specific data of family members or caregivers who presented with the patients such as how they knew the patients' weight. This specific data would contribute or affect the speculation and led the authors to know the reason why family member estimation was the most accurate method. The BT was the second most accurate method. The subgroup 10 to 25 kg was the

Table 2. Percentage of the accuracy within 10% error of the patients' body weight (BW)

Methods	Overall	BW < 10 kg	BW 10-25 kg	BW 25.01-40 kg	BW > 40 kg
Broselow tape	56.13%	60.36%	59.68%	43.27%	00.00%
Family member estimation	85.21%	80.18%	87.10%	84.62%	75.00%
The 50th percentile	51.43%	49.55%	55.38%	43.27%	00.00%

Table 3. Mean difference (kg) of the patients' body weight (BW)

Methods	Overall	BW < 10 kg	BW 10-25 kg	BW 25.01-40 kg	BW > 40 kg
Broselow tape	-0.485 (-7.29-6.31)	0.197 (-2.68-3.08)	0.280 (-3.91-4.48)	-2.980 (-13.22-7.26)	-13.350 (-22.47-4.23)
Family member estimation	-0.262 (-3.178-2.655)	-0.049 (-1.40-1.31)	-0.135 (-2.53-2.26)	-0.706 (-5.02-3.60)	-3.350 (-10.83-4.13)
The 50th percentile	-0.648 (-7.879-6.582)	0.196 (-2.60-2.99)	0.271 (-4.53-5.07)	-3.736 (-13.3-5.83)	-14.975 (-24.22-5.73)

Table 4. The absolute percentage of body weight difference of the patients' body weight (BW) in each method

Methods	Absolute percentage [(measured BW – BW from the method) / measured BW * 100]
Broselow tape	8.91 (0-124.72)
Family member estimation	3.43 (0-63.64)
The 50th percentile	9.69 (0-81.82)

Table 5. The data of under or overestimation of the patients' body weight (BW) in each method

Methods	Underestimation (measured BW > BW from the method) frequency (%)	Overestimation (measured BW ≤ BW from the method) frequency (%)
Broselow tape	286 (48.07)	309 (51.93)
Family member estimation	191 (32.10)	404 (67.90)
The 50th percentile	330 (55.46)	265 (44.54)

most accurate subgroup in every method, except in the BT method. However, in the BT method, the number of the patients in the subgroup less than 10 and 10 to 25 kg were relatively close. So it might be acceptable to be used in both subgroups.

In the subgroup 25 to 40 kg and more than 40 kg, the accuracy trend for every method was lower. The result was consistent with other studies such as in Lubitz et al's study[5], which found that the accuracy of BT was decreased in children weighed over 25 kg and BT was accurate for children who weighed equal to or less than 25 kg in So et al's study[15].

In the present study, the BT method developed from American children's weight-height correlation was found to be more accurate than the 50th percentile of Thai weight for height correlation developed from Thai children. The explanation might be that the national weight-height correlation graph was developed from national growth references for children under 20 years of age in 1999 and that was 11 years ago. Therefore, the children of the same age, now might be bigger than the past. Their body habitus might catch up with western children's habitus. Thus, in the present study, the P50 of national weight for height correlation graph underestimated more than overestimated the patients' weight.

The authors found that the overall accuracy within 10% error between who had or did not have underlying diseases was not significant in every method. The authors implied that these methods could be used to estimate the weights in the patients who have underlying diseases also. However, in the present

study, the number of the patients with underlying diseases was limited. The most diagnosis in the underlying diseases group was asthma (17.72%), which might not affect the body weight. In the present study, there was a small number of cases who had severe chronic diseases such as cancer, which might affect the patients' growth. Therefore, future study in the special group of patients might be required.

Most studies that showed the result that parental estimation was the most accurate method were performed in developed countries[11-13]. In the present study, the family member estimation could be used for pediatric patients in this hospital or perhaps in hospitals located in Bangkok, which is the capital and the area studied. It might be difficult to conclude from the present study that the family member or parental estimation can be used to estimate the actual weight in any area in Thailand such as in the rural areas or in other developing countries, which may be affected by the culture or socioeconomic status or education of the population.

Apart from the family member weight estimation method, the other methods estimated the accurate weight of the patient less than two-third of all patients. Therefore, the other method or formulae should be studied and developed to estimate Thai children's weight.

Conclusion

Family member estimation was the most accurate method in the present study. The family member could estimate the children's weight within 10% error of the measured weight about 85% of cases. In case where family member estimation was not available, the Broselow tape was the next accurate alternative method.

Limitation

The authors studied the patients in only one hospital and in only one province, which may not or definitely represent all children in Thailand. Another factor was that the authors did not study other methods or formulae such as Pediatric Advanced Life Support (PALS) formula, which is commonly used by some physicians. However, this PALS formula can be used only for the children who are older than one year old.

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Potential conflicts of interest

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ความถูกต้องของวิธีการ 3 วิธีในการประมาณน้ำหนักของเด็กไทย

สาทริยา ตระกูลศรีชัย, ชัยพร บุญศรี, พรทิพย์ ฉัตรชัยพันธ์, อมรศรี ชุณหรัศมิ์

ภูมิหลัง: *การประมาณน้ำหนักของเด็กไทยที่ถูกต้องมีความจำเป็นและสำคัญในการดูแลผู้ป่วยเด็กฉุกเฉิน โดยเฉพาะอย่างยิ่งสำหรับขนาดยา การรักษาและกู้ชีพโดยใช้กระแสไฟหรือขนาดของเครื่องมือ การชั่งน้ำหนักเด็กโดยตรงทำได้ยากในผู้ป่วยวิกฤต มีหลายวิธีที่ถูกพัฒนามาเพื่อที่จะประมาณน้ำหนักที่ถูกต้องของเด็ก วิธีการส่วนใหญ่ถูกพัฒนาในประเทศทางตะวันตก วิธีการที่มีในปัจจุบันอาจไม่เหมาะกับเด็กไทย*

วัตถุประสงค์: *เพื่อจะบอกถึงความถูกต้องของบรอสโลว์เทป การประมาณจากสมาชิกในครอบครัว น้ำหนักที่เป็นเปอร์เซ็นต์ไทล์ที่ 50 จากกราฟความสัมพันธ์ของน้ำหนักและส่วนสูงแห่งชาติ ในการประมาณน้ำหนักของเด็กไทย*

วัสดุและวิธีการ: *ผู้นิพนธ์ทำการศึกษาแบบไปข้างหน้าในเด็กอายุตั้งแต่แรกเกิดจนถึง 12 ปีที่มาตรวจที่ห้องฉุกเฉินหรือแผนกตรวจผู้ป่วยนอกกุมารเวชกรรม โดยทำการศึกษาทั้งแบบโดยรวมและแบบแบ่งกลุ่มย่อย (น้อยกว่า 10 กิโลกรัม, 10-25 กิโลกรัม, 25-40 กิโลกรัม และมากกว่า 40 กิโลกรัม) ผลการศึกษาหลักของการศึกษาคือความถูกต้องโดยไม่เกินร้อยละ 10 ของน้ำหนักที่ชั่งได้ และค่าความแตกต่างของน้ำหนักเฉลี่ยที่ชั่งได้และจากการประมาณ*

ผลการศึกษา: *มีผู้ป่วยเข้าร่วมการศึกษาทั้งหมด 595 คน มีเด็กชาย 333 คน และเด็กหญิง 262 คน การประมาณจากสมาชิกในครอบครัวเป็นวิธีที่ถูกต้องที่สุดโดยมีค่าความถูกต้องร้อยละ 85.21 และมีค่าความแตกต่างต่ำที่สุด (-0.262 กิโลกรัม) สมาชิกในครอบครัวสามารถประมาณได้ถูกต้องในทุกกลุ่มย่อย บรอสโลว์เทปเป็นวิธีที่ถูกต้องที่สุดรองลงมาโดยมีค่าความถูกต้องร้อยละ 56.13 และค่าความแตกต่างต่ำ (-0.485 กิโลกรัม) ค่าความถูกต้องของค่าเปอร์เซ็นต์ไทล์ 50 จากกราฟความสัมพันธ์น้ำหนักและความสูงแห่งชาติได้ร้อยละ 51.43 และค่าความแตกต่างของน้ำหนักเท่ากับ -0.648 กิโลกรัม ทุกวิธีประมาณน้ำหนักได้ดีที่สุดในกลุ่มน้ำหนักย่อย 10-25 กิโลกรัม ยกเว้นบรอสโลว์เทป*

สรุป: *การประมาณจากสมาชิกในครอบครัวเป็นวิธีที่ถูกต้องที่สุดในการศึกษานี้ สมาชิกในครอบครัวสามารถประมาณน้ำหนักเด็กซึ่งอยู่ภายในร้อยละ 10 ของน้ำหนักที่ชั่งได้ ประมาณร้อยละ 85 ของเด็กทั้งหมด ในกรณีที่ไม่มีสมาชิกครอบครัวอยู่ บรอสโลว์เทปเป็นวิธีถัดมาที่ถูกต้องสามารถนำมาใช้ได้*