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Original Contribution

Finger counting: an alternative method for estimating pediatric weights ☆

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ABSTRACT

Objectives: We compared the accuracy of a conceptually simple pediatric weight estimation technique, the finger counting method, with other commonly used methods.

Methods: We prospectively collected cross-sectional data on a convenience sample of 207 children aged 1 to 9 presenting to our pediatric emergency department. Bland-Altman plots were constructed to compare the finger counting method to the Broselow tape method, parental estimate, the Luscombe formula, and the advanced pediatric life support (APLS) formula. Proportions within 10% and 20% of measured weight were compared.

Results: Mean difference and range of agreement in kilograms for Bland-Altman plots were as follows: −1.8 (95% confidence interval [CI], −2.3 to −1.3) and 15.4 (95% CI, 13.6-17.2) for the finger counting method; −1.4 (95% CI, −2.0 to −0.9) and 15.8 (95% CI, 13.9-17.6) for the Broselow method; −0.02 (95% CI, −0.53 to 0.49) and 14.8 (95% CI, 13-16.6) for parental estimate; 0.2 (95% CI, −0.33 to 0.72) and 15.3 (95% CI, 13.5-17.2) for the Luscombe formula; and −3.8 (95% CI, −4.4 to −3.2) and 17.2 (95% CI, 15.2-19.2) for the APLS formula. The finger counting method estimated weights within 10% in 59% of children (95% CI, 52%-65%) and within 20% in 87% of children (95% CI, 81%-91%). Proportions within 10% were similar for all methods, except the APLS method, which was lower.

Conclusions: The finger counting method is an acceptable alternative to the Broselow method for weight estimation in children aged 1 to 9 years. It outperforms the traditional APLS method but underestimates weights compared with parental estimate and the Luscombe formula.

1. Introduction

Estimation of pediatric weights for resuscitation purposes is necessary in the emergency department (ED). Administration of intravenous fluids and medications and delivery of electrical current to the heart are all dictated by the child's weight. Although determining weights using a scale is ideal, this is often not possible in a resuscitation environment. Various methods have been described for estimating pediatric weights for this purpose. The Broselow tape method of estimating pediatric weight is commonly used in the United States [1]. Using a parent's estimate of the child's weight has also been described [2-4]. Both methods have outperformed age-based formulas [5]. The advanced pediatric life support (APLS) formula [weight (kg) = (age + 4) × 2] is one age-based formula in widespread use [6]. Recently, it has been suggested that age-based formulas have not kept up with changes in pediatric weights over time, and new formulas have been generated. The Luscombe formula [(age × 3) + 7] has outperformed older formulas [7] and has been suggested as a viable option when parent estimation or a Broselow tape is not available [7-10]. The Luscombe formula was incorporated into updated APLS recommendations in 2011, which now endorse the use of 3 different formulas depending on age group [11].

In our practice, we have found these methods to be limited by several factors. Formulas may be difficult to remember and hence error prone, whereas length-based devices do not allow for equipment and medications to be prepared in advance of the child's arrival. Parents are not always available to estimate weights. We prefer to use an easily taught and remembered method to estimate weight using finger counting. To the best of our knowledge, this method was first advocated by Dr Alson Inaba in 1991 [12], and he has taught it to thousands of trainees throughout his career (written communication, September 2013), including one of the investigators (L.B.). More recently, there have been other claims to the creation of the technique [13]. At our institution, we teach this method to our trainees, who comment that they find it easier to remember than other methods.

We sought to examine our practice and compare the accuracy of this finger counting method with other commonly used methods. Our hypothesis was that this easily remembered finger counting method would be equally as accurate as, and hence an acceptable alternative

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to, other commonly used methods. This is the first study, to our knowledge, to describe the accuracy of this technique.

2. Methods

2.1. Study design

We prospectively collected cross-sectional data on an age-cohorted convenience sample of children without chronic illness presenting to our pediatric ED. This study was approved by our institutional review board. Informed consent was obtained from families of all subjects by one of the investigators (B.C.).

2.2. Study setting and population

Our hospital is a level 1 pediatric trauma center and tertiary care referral center. Our 18-bed pediatric ED has an annual volume of approximately 22 000 children. The subjects in our study represent a sample of children enrolled by one of the investigators (B.C.), between the dates of September 1, 2012 and September 30, 2013. Children aged 1 to 9 years were enrolled. Children were not considered for the study when they had chronic illness, including the presence of a tracheostomy, cerebrospinal fluid shunt, any indwelling catheter or feeding tube, the inability to stand or lay down, or a chronic illness known to affect size and growth.

2.3. Study protocol

Families were approached for enrollment after children had been registered and triaged, and a triage weight had been obtained. Once a subject was enrolled, it was confirmed that the weight recorded on the triage sheet came from an actual weight and not an estimate. Weights were obtained by trained technicians, by having children stand on the scale if they were old enough to do so. When children were too young to step on the scale, weights were obtained by first weighing the child with an accompanying adult, then weighing the adult alone and subtracting the adult's weight. Children were weighed in their clothes, which is our customary triage practice in this age group. Weights were obtained using a Scale-Tronix model 6006 scale (Scale-Tronix, Inc, White Plains, NY). According to the manufacturer, this scale is accurate to ± 100 g (E. Blatz, written communication, October 2013). The child's length was then measured using a model 45 Prestige tape measure (Prestige Medical Company, Northridge, CA). If the child could stand, height was taken against a wall. If the child could not stand, the child was laid flat and measured from head to heel. The parents were then asked to estimate the child's weight in pounds, and this weight was recorded. That weight was converted to kilograms. Later, Broselow weight estimates were obtained by laying out the Prestige tape measure at the child's recorded length on a standard Broselow-Luten tape (Armstrong Medical, Lincolnshire, IL) and recording the corresponding weight. The Broselow tape system does not give instructions for how to handle children who are longer than the length of the tape [14]. Recommendations have been made that these patients be treated using adult protocols [15]. Problems with this approach in schoolchildren have been described [16]. Therefore, we decided that if a child between the ages of 1 and 9 years in our cohort would fall outside the length of the tape, we would record the weight of the highest Broselow category. The child's weight was then estimated using the finger counting method, as described in the next subsection. We also estimated weights using the traditional APLS course formula [6] and the Luscombe formula [8].

Sample size was determined based on Bland's recommendation that a sample size of 100 subjects is adequate, and a sample size of 200 subjects is better, to accurately estimate the limits of agreement between 2 methods of measurements [17]. Multiple studies comparing 2 methods of measurement have used this recommendation [18,19]. To avoid a skewed age distribution, we enrolled an equal number of children in each age cohort (1-9 years). To achieve our goal of 200 subjects, we enrolled 23 subjects in each age group for a total of 207 subjects.

2.4. Finger counting method

The finger counting method involves counting on the fingers of both hands (Fig. 1). Age in years is counted on the left hand, starting with 1 on the thumb and counting by odd numbers to 9 on the small finger. Weight in kilograms is counted on the right hand, starting with 10 kg on the thumb and counting by 5 to 30 kg on the small finger. Fingers are matched to estimate weight. The method is used for children aged 1 to 9 years. Our video description of the technique can be found online [20].

2.5. Outcome measures

Our primary outcome was to compare the child's weight as estimated by the finger counting method to that obtained using the Broselow tape method, parental estimate of weight, the Luscombe formula, and the APLS formula using Bland-Altman plots, with corresponding mean differences, limits of agreement, and ranges of agreement. Our secondary outcome was to compare the proportion of weights estimated within 10% and 20% of measured weight for each method.

2.6. Data analysis

Descriptive statistics were calculated using Stata 12 (Stata Corporation, College Station, TX). The Bland-Altman method is a graphical means of comparing 2 methods of measurement that plots differences between the 2 methods against a mean of the 2 methods. Mean difference between the 2 methods and the limits of agreement, which contain 95% of the differences between the methods, are plotted and allow the interpreter to make a clinical decision about the agreement between the methods [21]. Bland-Altman plots were generated with Stata to visually assess the agreement with measured weight for each estimation method. Mean differences, limits of

Digit	Left Hand (Age in Years)*	Right Hand (Weight in kg)
Thumb	1	10
Index	3	15
Long	5	20
Ring	7	25
Small	9	30

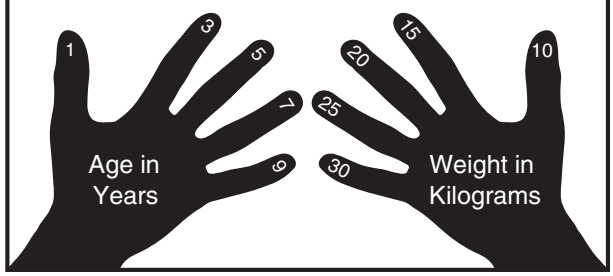

Fig. 1. The finger counting weight estimation method. *For even ages, average the adjacent weights (eg, age 4 years yields 17.5 kg).

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agreement, and ranges of agreement (the sum of the absolute value of the upper and lower limits of agreement), along with 95% confidence intervals (CIs), were calculated in Stata for comparison. Proportions within 10% and 20% of measured weight were calculated using Excel for Mac 2011 (Microsoft Corporation, Redmond, WA). Ninety-five percent CIs for proportions were calculated in Stata using the modified Wald technique.

3. Results

One hundred six of the subjects were boys (51.2%). Median height was 111 cm (interquartile range, 94-125 cm). Median body mass index (BMI) was 17.2 kg/m^2 (interquartile range, 15.8-18.6 kg/m^2).

There were 5 children (2.4%; 95% CI, 0.9%-5.7%) who were taller than the longest category on the Broselow tape.

Bland-Altman plots for the finger counting method, the Broselow tape method, parental estimate, and the Luscombe formula were visually similar (Figs. 2-5). Our data were compatible with no difference existing between any of the methods in the ranges of agreement (Table 1). The finger counting method, the Broselow method, and the APLS formula underestimated weights when compared with the Luscombe formula and parental estimate. The APLS formula underestimated weights to a larger degree than did the finger counting method and the Broselow method. The lower limit of agreement of the APLS method (Fig. 6) was further from zero than any of the limits of agreement of the other methods (Table 1).

The finger counting method estimated weights within 10% of actual weight in 59% of children and within 20% of measured weight in 87% of children (Table 2). Ninety-five percent CIs for proportions within 10% were similar for the finger counting method, parental estimate, Broselow tape, and the Luscombe formula, but each of these was higher than the traditional APLS formula.

4. Discussion

The finger counting method estimated pediatric weights as accurately as the Broselow method. It underestimated weights when compared with parental estimate and the Luscombe formula. It was more accurate than the traditional APLS method.

In our study, parents' accuracy in estimating weights within 10% of measured weight was lower than in previous studies, which have found accuracies within 10% ranging from 73% to 78% [2-5]. The Broselow tape performed similarly in our study when compared with previous studies, which have reported accuracies within 10% from 60% to 63% [1,22]. The Luscombe formula estimated weights within 10% in 45% of children in a previous study [9], lower than its performance in our study. Similar to our findings, the APLS formula performed poorly in a previous study, estimating weights within 10% in 34% of children [5]. Our findings for bias are similar to those of Krieser and colleagues, who reported mean differences of −0.6, −1.8, and −4.2 kg for parental estimate, the Broselow method, and the APLS formula, respectively [5]. Comparisons with previous studies regarding limits of agreement are more difficult because they are often not explicitly reported [5,9]. Krieser et al graphically depicted limits of agreement of slightly less than −10 kg and slightly more than 5 kg for the performance of the Broselow tape, which is similar to our findings.

The finger counting method performed similarly to the Broselow method for the age range of children we evaluated in this study. Advantages to using this method as an alternative to the Broselow method include the following: it can be performed without specialized equipment (other than one's hands), it allows for medication preparation in advance of the child's arrival, and it does not require that time be spent measuring length after the child's arrival. Although parental estimate and the Luscombe formula showed a range of agreement and accuracy within 10% that was similar to the finger counting method, both methods showed a smaller bias than the finger counting method. Our Bland-Altman plots visually display a decrease in accuracy with increasing weight for each of the methods, but this

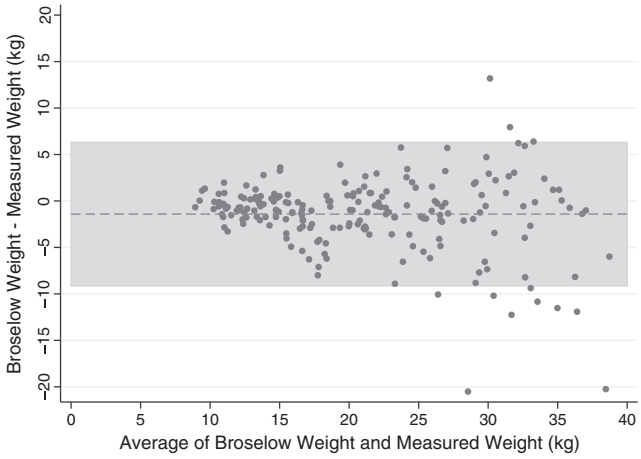

Fig. 3. Bland-Altman plot for Broselow tape estimated weight and measured weight.

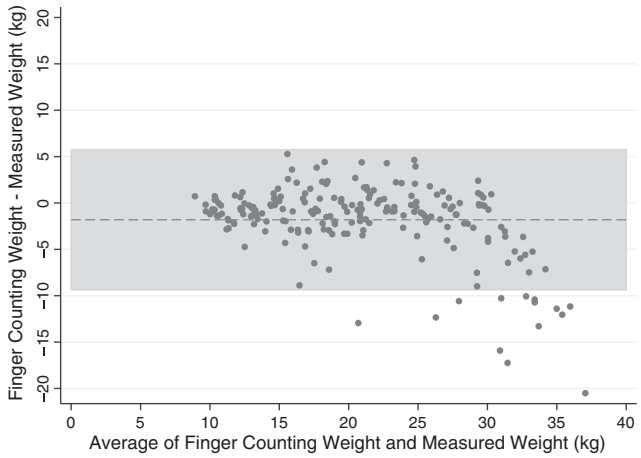

Fig. 2. Bland-Altman plot for finger counting method of weight estimation and measured weight. For Bland-Altman plots, the dashed line indicates the mean difference, and the borders of the shaded area denote the 95% limits of agreement.

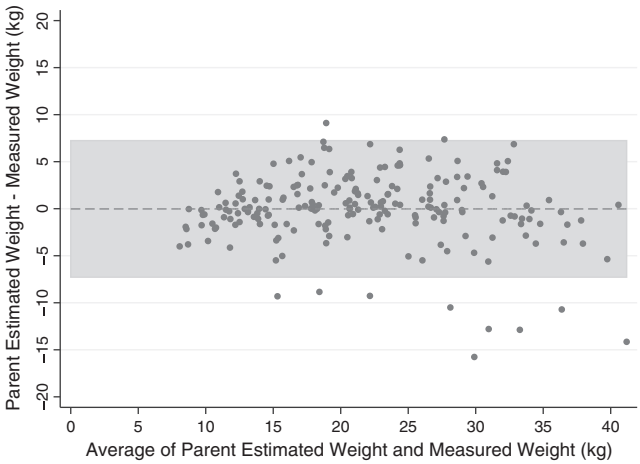

Fig. 4. Bland-Altman plot for parent estimated weight and measured weight.

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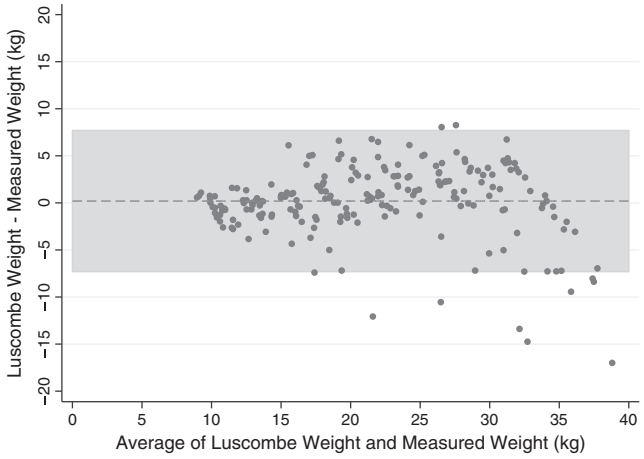

Fig. 5. Bland-Altman plot for Luscombe formula weight and measured weight.

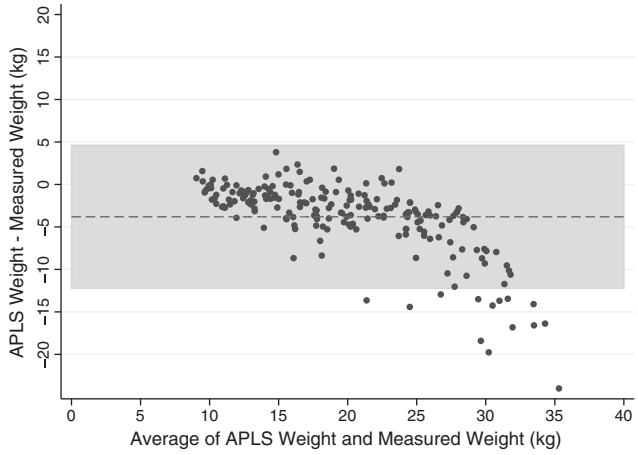

Fig. 6. Bland-Altman plot for APLS formula weight and measured weight.

effect seems less pronounced for parental estimate. This may indicate that, when available, parental estimate of weight may be a better option for larger children.

Counterintuitively, the movement toward more accurate methods for pediatric weight estimation in recent years may be in opposition to the movement to decrease medical errors. It is not known whether minimal differences in accuracy actually impact patient outcomes. What is known is that increased stress levels such as those seen in resuscitation settings lead to decreased performance and recall [23-26]. However, methods such as the best guess formula [27] and the updated APLS formula [11] have become more complex, involving multiple formulas for different age groups. Marikar and colleagues [10] found that 92% of pediatric trainees were unable to recall the new, multiple APLS formulas, and often fell back on the old formula. The Luscombe formula performed well in comparison with other methods in our study and has previously shown promising performance as a single formula [9], but the introduction of new formulas leaves the potential for errors to be made when formulas are recalled incorrectly or confused. Luscombe himself erroneously transcribed his formula in Fig. 1 of the derivation study [8], misplacing the parentheses and reporting the formula as weight = 3(age + 7), in a format similar to the original APLS formula and hence a completely different equation. We believe that a weight estimation technique that does not rely on remembrance of an equation, but is still accurate, has a place in the current climate of weight estimation methods.

Like the Luscombe formula [7], the finger counting method outperformed the widely used APLS formula. This is not surprising because the finger counting technique essentially uses the formula weight (kg) = (2.5 × age) + 7.5, without a reliance on remembering that formula. In Luscombe's derivation study involving more than 17 000 British children, the formula that best fit his data was weight (kg) = (2.57 × age) + 7.24, but this formula was thought to be too complicated to remember and so was changed to the recommended formula, weight (kg) = (3 × age) + 7. The best-fit formula is shockingly similar to the formula that the finger counting method uses, yet the finger counting method retains the simplicity of counting on one's hands. A similar study of 1723 Trinidadian children reported a best fit line of weight (kg) = (2.4 × age) + 8.25 [28].

5. Limitations

This was a single-site study describing children living in the United States, and results may not be applicable to children in other settings. However, our median BMI of 17.2 kg/m^2 was similar to the mean BMI of 17 kg/m^2 reported by 2 studies of weight estimation techniques including children in Australia [9,29]. Likewise, the similarity of the finger counting method equation to the best-fit lines of the British and Trinidadian studies makes the generalizability of our results more likely.

In our study, parents were asked to estimate weights after triage weights were obtained, raising the possibility that parents had seen the child's weight on the scale and that this had influenced their estimate. However, our scale displayed weight in kilograms, and parents were asked to estimate weight in pounds. It is unlikely that parents were able to convert weights in real time. Had this affected parents' estimates, it would be expected to bias them toward greater accuracy, and we found that estimates within 10% of measured weight were lower than in previous studies.

We did not undress children to measure weights in our study. Hence, measured weights overestimated actual weights. In practice, we do not have children in this age group undress in the ED to be weighed. We were interested in how well the finger counting method and other weight estimation techniques served as surrogates for our current clinical standard.

The finger counting method as we described and assessed it in this study is only useful for estimating the weight of children between the ages of 1 and 9. Dr Inaba extends the technique to estimate the weights of older children [12], designating a weight of 35 kg for an 11-year-old, 45 kg for a 13-year-old, 55 kg for a 15-year-old, and 65 kg for a 17-year-old. We did not test this part of his technique. We find that as children approach puberty, weights become much more variable, and any type of weight estimation technique becomes less useful.

Table 1
Bland-Altman plot statistics for each method

Method	Mean difference (kg; 95% CI)	Lower limit of agreement (kg; 95% CI)	Upper limit of agreement (kg; 95% CI)	Range of agreement (kg; 95% CI)
Finger counting	−1.8 (−2.3 to −1.3)	−9.5 (−10.4 to −8.6)	5.9 (5.0 to 6.8)	15.4 (13.6 to 17.2)
Broselow tape	−1.4 (−2.0 to −0.9)	−9.3 (−10.2 to −8.4)	6.5 (5.5 to 7.4)	15.8 (13.9 to 17.6)
Parental estimate	−0.02 (−0.53 to 0.49)	−7.4 (−8.3 to −6.5)	7.4 (6.5 to 8.3)	14.8 (13 to 16.6)
Luscombe formula	0.2 (−0.33 to 0.72)	−7.5 (−8.4 to −6.6)	7.8 (6.9 to 8.8)	15.3 (13.5 to 17.2)
APLS formula	−3.8 (−4.4 to −3.2)	−12.4 (−13.4 to −11.4)	4.8 (3.8 to 5.8)	17.2 (15.2 to 19.2)

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Table 2
Proportion of estimated weights within 10% and 20% of measured weight for each method

Method	Proportion within 10% (95% CI)	Proportion within 20% (95% CI)
Finger counting	59% (52%-65%)	87% (81%-91%)
Broselow tape	56% (49%-63%)	81% (75%-86%)
Parental estimate	54% (47%-61%)	79% (73%-84%)
Luscombe formula	52% (45%-59%)	84% (78%-89%)
APLS formula	33% (27%-40%)	72% (66%-78%)

6. Conclusion

Pediatric weight estimation using the finger counting method for children between the ages of 1 and 9 is an acceptable alternative to the Broselow method. It outperforms the traditional APLS method but underestimates weights when compared with the Luscombe formula and parental estimate of weight. It is conceptually simple and may be especially suited as an easily remembered method that does not rely on remembrance of a mathematical equation or presence of the child or the child's parents.

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