


Estimating Weight in Children With Down Syndrome

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Abstract

Objective. Significant attention has been paid to weight estimation in settings where scales are impractical or unavailable; however, no studies have evaluated the performance of published weight estimation methods in children with Down syndrome. This study was designed to evaluate the predictive performance of various methods in this population with well-established differences in height and weight for age. **Methods.** This was a prospective study of children aged 0 to 18 years with Down syndrome. Anthropometric measurements including height, weight, humeral length, and mid-upper arm circumference were collected and applied to 4 distinct weight estimation strategies based on age (APLS), length (Broselow), habitus (Cattermole), and length plus habitus (Mercy). Predictive performance was evaluated by examining residual error (RE), percentage error (PE), root mean square error (RMSE), limits of agreement, and intraclass correlation coefficients. **Results.** A total of 318 children distributed across age, gender, and body mass index percentile were enrolled. APLS and Mercy showed the smallest degree of bias (PE = $7.8 \pm 24.5\%$ and $-3.9 \pm 12.4\%$, respectively). Broselow suffered the most extreme underestimation (-63%), whereas the APLS suffered the greatest degree of overestimation (107%). Mercy demonstrated the highest intraclass correlation coefficient (0.987 vs 0.867–0.885) and predicted weight within 20% of actual in the largest proportion of participants (88% vs 40% to 76%). All methods were less robust in children with Down syndrome than reported for unaffected children. **Conclusions.** Mercy offered the best option for weight estimation in children with Down syndrome. Additional anthropometric data collected in this special population would allow investigators to refine existing weight estimation strategies specifically for these children.

Keywords

general pediatrics, APLS, Broselow, Cattermole, Mercy

Introduction

Pediatric health care providers use weight to assess normal growth and development and guide nearly all therapeutic and medical interventions that their patients require. As such, significant attention has been paid to weight estimation in settings where the use of a scale is impractical or unavailable. In fact, nearly 2 dozen weight estimation strategies have been devised to assist with pediatric weight estimation.¹ Notably, all of these methods have been tested in neurotypical children.

One of every 847 children in the United States is born with Down syndrome,² and virtually all require medical care throughout their lives. Importantly, children with Down syndrome demonstrate differences in height and weight for age when compared with neurotypical

children.^{3,4} These anatomic differences should influence the accuracy of different weight estimation methods to varying degrees depending on the variables incorporated into those strategies. To date, not a single study has evaluated the performance of weight estimation methods in children with Down syndrome. This study was designed to evaluate the predictive performance of 4 representative weight estimation strategies in this special population.

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Patients and Methods

Subjects and Study Design

This was a prospective, single-site study conducted over a 12-month period. Children 0 through 18 years of age with Down syndrome were eligible for participation. All children presenting to the research center were enrolled unless: (a) there were limb deformities, (b) they were unable to be positioned for height/length measurements, or (c) the parents and/or children were unwilling to provide permission and assent for participation. Children were enrolled with informed permission, and assent where appropriate (ie, >7 years of age), under a protocol that was reviewed and approved by the Children's Mercy Hospital Institutional Review Board.

Data Collection

Anthropometric measurements required for application of the selected weight estimation strategies were obtained on each child. These included height, weight, humeral length, and mid-upper arm circumference. Infants unable to stand were positioned on an infantometer to obtain recumbent length. Children who were able to stand unassisted were positioned against the height rule of a portable stadiometer to obtain their height. Weight was obtained in as little clothing as possible using a calibrated scale. Humeral length was measured from the upper edge of the posterior border of the acromion process, down the posterior surface of the arm, to the tip of the olecranon process using a standard vinyl tape measure. Mid-upper arm circumference (MUAC) was measured at the midpoint of the humerus with the arm hanging down at the child's side. Length and weight measurements were recorded to the nearest millimeter and tenth of a kilogram, respectively, with the exception of infants where weight was recorded to the nearest gram. All raters obtaining measurements were required to undergo a quality control assessment prior to their involvement with the study with intrarater reliability required to be less than 5% for each anthropometric measure.

Data Analysis

The anthropometric data were applied to 4 representative weight estimation strategies: one based on age (Advanced Pediatric Life Support [APLS]),⁵ a second based on length (Broselow),⁶ a third based on habitus (Cattermole),⁷ and a fourth based on both length and habitus (Mercy).⁸ Data on age were applied to the revised APLS equations where weight was estimated in children 1 to 5 years of age according to $[2 \times (\text{age in}$

years + 4)] and children 6 to 12 years of age according to $[(3 \times \text{age in years}) + 7]$. The Broselow tape (2007 Edition B) was used to generate a weight estimate based on the child's length. Data on MUAC were applied to the Cattermole equation $[(\text{MUAC in cm} - 10) * 3]$ for the range of ages defined by the author (ie, 6-11 years). Finally, data on MUAC and humeral length were applied to the Mercy method as previously published. Given that age may be unavailable at the time of weight estimation (eg, in a trauma setting), the methods were initially applied to those children who fell within the bounds of the method, as defined in the literature, and then separately to all children to explore the impact of extrapolation beyond the bounds of each method.

The difference between predicted and actual weight was used to determine residual error (RE). Percentage error (PE) was calculated by dividing the actual weight into the RE and multiplying by 100. Root mean square error (RMSE) was calculated by taking the square root of the average squared error. Accuracy was assessed by evaluating the percentage of estimated weights that fell within 20% of actual weight. Differences in RE, PE, and percentage within 20% of actual between methods was determined by analysis of variance (ANOVA). Bland-Altman plots using log-transformed data were constructed to evaluate agreement between the various weight estimation methods and the observed weight and the 95% limits of agreement calculated accordingly. Agreement was also assessed by calculating the intraclass correlation coefficient (ICC) using a 2-way random effects model and an absolute agreement definition. Statistical analyses were performed for the methods as published (ie, with only those children who satisfied the criteria for that method); however, graphical presentations depict the method applied with and without restrictions. All mathematical and statistical analyses were performed with Microsoft Excel 2007 and SPSS v20.

Results

A total of 318 children were enrolled in this study. Participants were evenly divided between the genders (51% male) although they were more heavily distributed throughout the younger age brackets. Their corresponding age, height, and weight distributions are detailed in Figure 1. Body mass index (BMI) percentiles, as classified by the Centers for Disease Control,⁹ favored children who were normal (41%), followed by obese (21%), overweight (15%), and underweight (1%). The remaining children (22.6%) fell into the infant category and ranged from <3rd to >97th percentile in weight-for-height. As published, the Mercy method could be applied to 99% of the enrolled children followed by 94% for

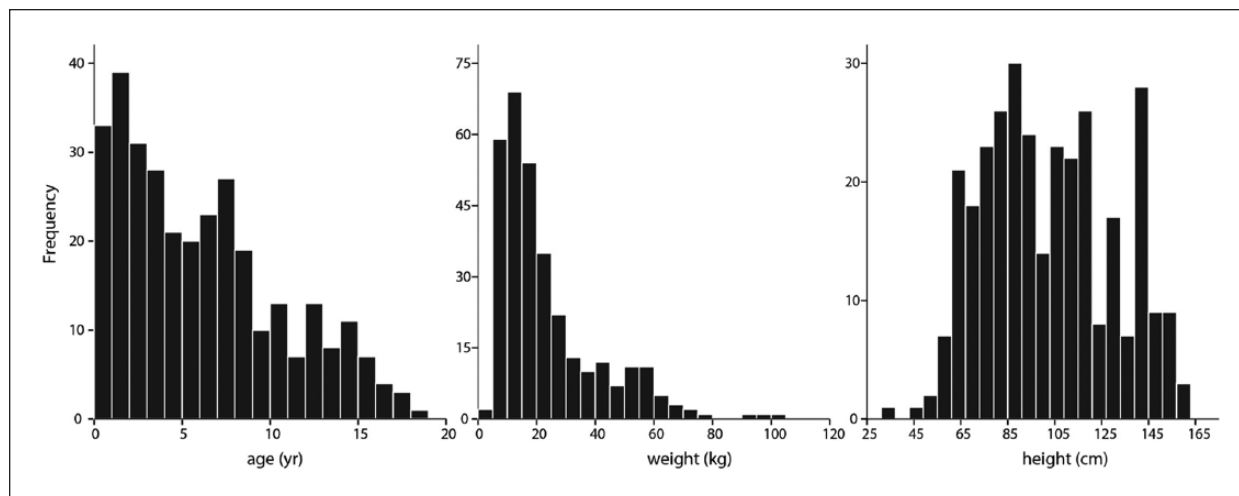


Figure 1. Histograms depicting the distribution of age, weight, and height among the study participants.

Table 1. Predictive Performance of the Selected Weight Estimation Methods^a.

	APLS	Broselow	Cattermole	Mercy
Number eligible for estimation	249	300	99	314
Agreement within 20% of actual ^b	61%	76%	40%	88%
Residual error (kg) ^b	0.4 ± 7.6	-4.0 ± 7.2	5.9 ± 4.4	-1.4 ± -3.3
Percentage error (%) ^b	7.8 ± 24.5	-11.9 ± 14.2	24.1 ± 18.1	-3.9 ± 12.4
Range for percentage error (%)	-56.0 to 106.7	-63.2 to 30.0	-9.0 to 72.5	-37.1 to 35.5
Root mean square error	7.58	8.21	4.46	3.54
95% limits of agreement	0.66-1.67	0.61-1.23	0.92-1.64	0.74-1.23
Intraclass correlation coefficient	0.882	0.867	0.885	0.987

^aAll data are presented as mean ± standard deviation unless otherwise indicated.

^b $P < .01$ between all methods.

Broselow, 78% for APLS, and 31% for Cattermole (Table 1). These rates would be expected to drop markedly for APLS, Broselow, and Cattermole if enrollment had been balanced to include older children.

There were significant differences in bias between all methods ($P < .01$). The age-based (APLS) and length-based plus habitus-based (Mercy) methods showed the smallest degree of bias in children with Down syndrome as reflected by the average RE and average PE (Table 1 and Figure 2). The length-based method (Broselow) demonstrated a tendency to underestimate weight, whereas the habits-based method (Cattermole) overestimated weight (Table 1 and Figure 2). Broselow suffered the most extreme underestimation (-63%), whereas APLS suffered the greatest degree of overestimation (107%; Table 1). Only Mercy reflected balance with respect to the degree of overestimation and underestimation (Table 1).

There were also significant differences in accuracy between all methods ($P < .01$). Mercy demonstrated the

highest ICC (0.987 vs 0.867-0.885) and predicted weight within 20% of actual in a greater proportion of children (88% vs 40% to 76%) when compared with the other methods (Table 1). Performance of the Cattermole, and to a lesser extent Broselow, suffered to a greater extent when applied beyond the bounds defined in the literature (Figure 2). Performance statistics remained unchanged for APLS and Mercy when extended beyond their published criteria; however, it is unclear whether this finding would persist for APLS were older children adequately represented.

Discussion

The availability of weight estimation tools in settings where there is no opportunity to obtain a child's weight can be critical for the immediate medical management of children. Accurate weight estimation tools are also valuable for routine care in populations where obtaining a scale-based weight can be challenging. This may

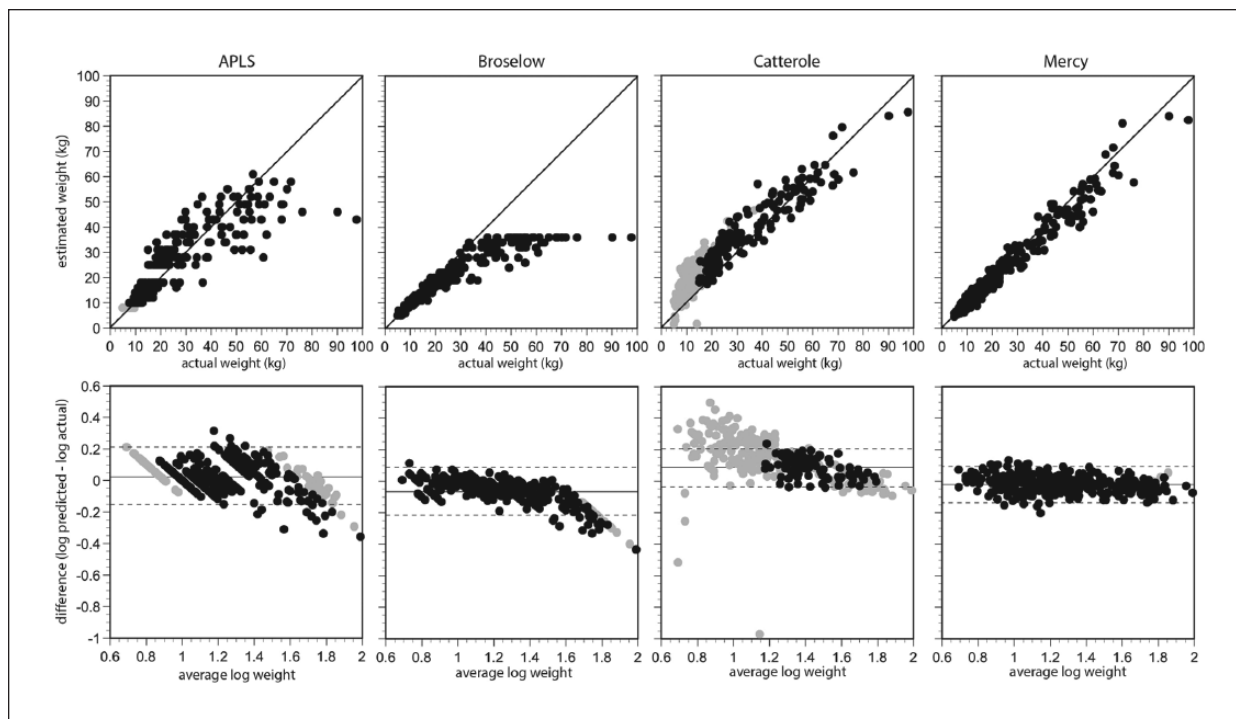


Figure 2. (Upper) Actual versus predicted weight for the selected estimation methods. The solid diagonal line represent the line of unity. (Lower) Modified Bland–Altman plots depicting the log-transformed difference between predicted weight and actual weight versus average log weight. Dashed lines depict the 95% limits of agreements.

For all graphs, the black symbols represent participants who fell within the published criteria for the method, and the grey symbols reflect values for participants who exceed the bounds of the published methods. Statistical analyses were performed only for children depicted by the black symbols.

include children affixed to medical equipment (eg, ventilators), children immobilized in casts, postsurgical children who cannot be easily moved, and children with intellectual or cognitive disabilities who may be excessively anxious or uncooperative with weight assessment using a standard scale.

There are established differences in stature for children with Down syndrome and a higher incidence of developmental disabilities that pose a challenge to weight assessment. Yet ours is the first study to examine whether existing weight estimation methods are valid for use in this special population. We chose to evaluate 4 weight estimation strategies, each relying on a different anthropometric or demographic surrogate. Those strategies that failed to account for body length (eg, APLS, Cattermole) fared worse than those that incorporated some measure of length (eg, Broselow, Mercy). These qualitative differences are also observed in studies evaluating from neurotypical children. Not surprisingly, the method that incorporated 2 variables (eg, Mercy) displayed the best overall performance characteristics relative to methods that incorporated a single variable.

Irrespective of their basis, each weight estimation method demonstrated poorer performance characteristics in children with Down syndrome than reported for unaffected children.⁸ This finding would suggest that the predictive performance of these methods can be optimized by incorporating data that account for the growth patterns unique to children with Down syndrome. At present, the Mercy TAPE appears to offer the best option for weight estimation in children with Down syndrome.¹⁰ Additional anthropometric data collection should allow investigators to refine existing weight estimation strategies for use in children with Down syndrome.

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Author Contributions

N.J.T. contributed to conception; contributed to acquisition, analysis, and interpretation; drafted manuscript; critically

revised manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

G. R. contributed to conception; contributed to acquisition; drafted manuscript; critically revised manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

S. A.-R. contributed to conception and design; contributed to acquisition, analysis, and interpretation drafted manuscript; critically revised manuscript; gave final approval; agrees to be accountable for all aspects of work ensuring integrity and accuracy.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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References

1. Abdel-Rahman SM, Ridge A, Kearns GL. Estimation of body weight in children in the absence of scales: a necessary measurement to insure accurate drug dosing. *Arch Dis Child*. 2014;99:570-574.
2. Shin M, Besser LM, Kucik JE, Lu C, Siffel C, Correa A; Congenital Anomaly Multistate Prevalence and Survival Collaborative. Prevalence of Down syndrome among children and adolescents in 10 regions of the United States. *Pediatrics*. 2009;124:1565-1571.
3. Parker SE, Mai CT, Canfield MA, et al; National Birth Defects Prevention Network. Updated national birth prevalence estimates for selected birth defects in the United States, 2004-2006. *Birth Defects Res A Clin Mol Teratol*. 2010;88:1008-1016.
4. Myrelid Å, Gustafsson J, Ollars B, Annerén G. Growth charts for Down's syndrome from birth to 18 years of age. *Arch Dis Child*. 2002;87:97-103.
5. Advanced Life Support Group. *Advanced Paediatric Life Support: The Practical Approach*. 5th ed. Chichester, England: John Wiley; 2011.
6. Lubitz D, Seidal JS, Chameides L, Luten RC, Zaritsky AL, Campbell FW. A rapid method for estimating weight and resuscitation drug dosages from length in the pediatric age group. *Ann Emerg Med*. 1988;17:576-581.
7. Cattermole GN, Leung PY, Mak PS, Graham CA, Rainer TH. Mid-arm circumference can be used to estimate children's weights. *Resuscitation*. 2010;81:1105-1110.
8. Abdel-Rahman SM, Ridge AL. An improved pediatric weight estimation strategy. *Open Med Dev J*. 2012;4:87-97.
9. Centers for Disease Control and Prevention. BMI for children and teens. http://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/about_childrens_bmi.html. Accessed March 25, 2013.
10. Abdel-Rahman SM, Paul IM, James LP, Lewandowski A. Evaluation of the Mercy TAPE: performance against the standard for pediatric weight estimation. *Ann Emerg Med*. 2013;62:332-339.