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ORIGINAL ARTICLE

Estimating children's weight in a Rwandan emergency centre

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ABSTRACT

Introduction: Most drugs, fluids and ventilator settings depend on the weight of a paediatric patient. However, knowledge of the weight is often unavailable as the urgency of the situation may impede measurement. The most common methods for paediatric weight estimation are based on height or age. This study aimed to compare the accuracy of various weight estimation methods and to derive a dedicated age-based tool within a Rwandan setting.

Methods: This was a retrospective study using age, weight and height data from randomly selected charts of Rwandan children, aged between one and ten years, who attended the paediatric emergency centre, Centre Hospitalier Universitaire de Kigali, Rwanda. Weights were estimated using four versions of the Broselow Tape and several age-based formulae. Linear regression was used to derive a new age-based weight estimation formula, the Rwanda Rule. Weight estimations were then compared with actual weight using Bland-Altman analysis, and the proportions of estimates within 10 and 20% of actual weight.

Results: There were 327 children included in the study. The derived Rwanda Rule was: weight (kg) = [1.7 × age (years)] + 8. This formula and the original Advanced Paediatric Life Support formula (weight = [2 × age] + 8) performed similarly. Both were better than other age-based formulae (69% of estimates within 20% of actual weight). All editions of the Broselow Tape performed better than age-based rules. The 1998 version performed best with 84.8% of estimates within 20% of actual weight.

Discussion: This study is the first to compare paediatric weight estimation methods in Rwanda. Locally, and until we have evidence from further research that other methods are superior, we would advise use of the 1998 Broselow Tape in children aged one to ten years old. Where the Broselow Tape is not available, the original Advanced Paediatric Life Support formula should be used.

African relevance

- This is the first study of paediatric weight estimation methods in Rwanda.
- We have derived an age-based weight estimation formula specific to our context in Rwanda.
- Results are discussed in relation to previous African weight estimation studies.

Introduction

Most drug and fluid doses and ventilator settings depend on the weight of a paediatric patient. However, knowledge of the weight is often unavailable as the urgency of the situation may impede measurement, or because there may be no access to weighing scales in low-resource settings.

The most common methods for paediatric weight estimation are based on either height (e.g. Broselow Tape [1]) or age (e.g. Advanced Paediatric Life Support formulae [2]). The Broselow Tape tends to estimate weight more precisely than age-based rules, although both are less accurate in older or heavier children [3,4]. Age is routinely recorded, and height data often recorded in paediatric charts.

Newer methods of weight estimation have used mid-arm circumference (MAC), either alone as a formula [5] or in the Mercy Tape [6], using a combination of MAC and upper-arm length. The PAWPER tape [7] uses a combination of height with a measure of body habitus. Methods combining a length-based measurement and a body-habitus measurement outperform those using either alone [6,8]. However, MAC and body habitus data are not routinely recorded in paediatric charts.

The Broselow Tape was derived in the United States of America, and different age-based rules have been derived in several countries, including the United Kingdom [2,9], Australia [10], Hong Kong [4] and

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United States of America [11]. A recent systematic review of weight estimation systems in developing countries identified 11 studies from Africa using the Broselow Tape or age-based formulae in children to at least ten years old [8]. Overall, the Broselow Tape was more accurate than age-based formulae, but neither was considered acceptable. However, there was variability between countries and in some settings the Broselow Tape performed well.

It is important to ensure that weight-estimation methods are validated in one's own setting. No age-based formula has been derived and validated in Africa and no study has yet assessed the performance of Broselow Tape or age-based weight estimation methods in Rwanda. Wells et al. identified only one study from either East or Central Africa [8]. This study, from Kenya, did not present adequate data to assess the precision of age-based and Broselow Tape methods [12]. Even if it had, Rwanda has a much lower prevalence of underweight children one to five years old (11%) [13] than does Kenya (16.4%) [8]. There is therefore a need to assess weight estimation methods in a Rwandan population.

This study aimed to compare the accuracy of the Broselow Tape and age-based weight estimation methods in children and to derive a dedicated age-based formula within a Rwandan setting.

Methods

This was a retrospective, observational study of data from patient charts in the paediatric emergency centre (EC) of Centre Hospitalier Universitaire de Kigali (CHUK) in Kigali, Rwanda. CHUK is a government-run tertiary hospital, receiving patients by referral from district hospitals throughout Rwanda. Charts for children aged one to ten years old at their last birthday were obtained, using computerised random number sampling of attendances in 2015. Charts were excluded if no age or weight were recorded.

Age, height and weight data were extracted from the charts using a standardised data collection form. Each chart was cross-referenced with the hospital's electronic database. Data abstracted from all charts were double-checked by a second researcher.

For each subject, height data were converted to a Broselow Tape estimate of weight using data tables for each of the four editions of the Broselow Tape (1993, 1998, 2007 and 2011). Age was used to calculate an estimate of weight using six different formulae: the original and revised Advanced Paediatric Life Support (APLS) formulae [2], Luscombe [9], Best Guess [10], Chinese Age Weight Rule (CAWR) [4], finger-counting [11] and the newly derived Rwanda Rule (Table 1).

Linear regression of weight with age was used to determine a new age-based formula, the Rwanda Rule. All weight estimations were compared with documented weight using Bland Altman method comparison analysis to obtain bias (mean percentage error (MPE); a measure of bias, or trueness, of the estimate) and limits of agreement (LOA = MPE ± 1.96 SD; a measure of precision of the estimate). As an overall measure of accuracy, proportions were calculated for each method of weight estimates within 10 and within 20% of documented weight. These proportions were compared using chi-squared tests. MedCalc version 17.9.2 (MedCalc Software bvba, Belgium) was used for statistical analysis.

Table 1
Age-based weight estimation formulae.

Method	Formula	Age range (years)
Original APLS	2a + 8	1–12
Revised APLS	2a + 8	1–5
	3a + 7	6–12
Luscombe	3a + 7	1–10
Best Guess	2a + 10	1–4
	4a	5–14
CAWR	3a + 5	1–10
Finger-counting	2.5a + 7.5	1–9

Note. APLS, Advanced Paediatric Life Support; CAWR, Chinese Age Weight Rule; a, age in years as of last birthday.

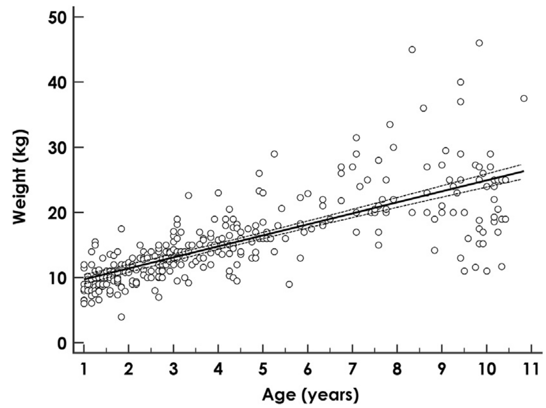

Fig. 1. Linear regression of weight vs age (with 95% CI for slope).

Sample size was based on Altman's estimate of 200 observations required for Bland Altman analysis [14]. Charts were collected until we obtained a total of 200 with age, weight and height data.

Ethical approval was obtained from the Institutional Review Board, College of Medicine and Health Sciences, University of Rwanda (reference 406/CMHS IRB/2016) and from the Ethics Committee, Centre Hospitalier Universitaire de Kigali (reference EC/CHUK/214/2016).

Results

Charts with age and weight data were obtained for 327 subjects, including 200 with documented height. All charts were used for analysis of age-based formulae; only charts with height data were used for analysis of the Broselow tape.

Mean age was 4.4 years (SD 2.9); mean weight was 15.5 kg (SD 6.6); mean height was 98.3 cm (SD 21.0). Linear regression (Fig. 1) determined a weight estimation formula, the Rwanda Rule: weight = 1.7 × age + 8.

Bland Altman analysis for each method in comparison with documented weight is in Table 2. Bias and LOA are presented as percentages, with 95% confidence intervals (95% CI). All methods overestimated weight except Best Guess. Rwanda Rule and original APLS performed similarly; CAWR had similar bias but much wider LOA. The LOA of all versions of the Broselow Tape had approximately the same width, narrower than any of the age-based formulae. The 1998 version of the Broselow Tape had the smallest bias. Fig. 2 presents the Bland Altman graph for the 1998 Broselow Tape.

For each method, numbers and percentages of weight estimates within 10% (PW10) and 20% (PW20) of documented weight are presented in Table 3. For PW10, original APLS and Rwanda Rule performed similarly and were significantly better than all other age-based rules except revised APLS (original APLS vs finger-counting, $p = 0.04$). All versions of the Broselow Tape had higher PW10 than any age-based method, but only the 1998 version was significantly better than original APLS ($p = 0.002$). For PW20, original APLS and Rwanda Rule significantly outperformed all other age-based rules (original vs revised APLS, $p = 0.03$). All versions of the Broselow Tape significantly outperformed original APLS except the 2011 version (1998 version vs original APLS, $p = 0.0002$).

Discussion

Our results demonstrate that in general the Broselow Tape provides better estimates of weight in Rwandan children than age-based formulae. This is in keeping with most other studies [8]. However, it does

Table 2
Bland Altman analysis.

Method	Bias	95% CI	Upper LOA	95% CI	Lower LOA	95% CI
Age-based formulae (n = 327)						
Original APLS	4.4	1.8–6.9	−41.7	−46.1 to −37.4	50.5	46.1–54.9
Revised APLS	11.5	8.5–14.4	−42.0	−47.0 to −36.9	64.9	59.8–70.0
Luscombe	17.2	14.3–20.0	−33.7	−38.6 to −28.9	68.0	63.2–72.9
Best Guess	−9.0	−13.3 to −4.8	−86.0	−93.4 to −78.7	68.0	60.7–75.3
CAWR	3.4	0.2–6.6	−54.0	−59.5 to −48.6	60.9	55.4–66.3
Finger-counting	11.1	8.5–13.8	−36.8	−41.4 to −32.3	59.1	54.5–63.6
Rwanda Rule	−2.3	−4.8 to 0.3	−48.2	−52.5 to −43.8	43.6	39.3–48.0
Broselow Tape versions (n = 200)						
1993	3.6	1.2–6.1	−30.8	−34.0 to −26.6	38.0	33.8–42.2
1998	0.2	−2.3 to 2.7	−34.1	−38.3 to −29.9	34.5	30.3–38.7
2007	3.7	1.3–6.1	−29.4	−33.4 to −25.3	36.8	32.7–40.9
2011	7.1	4.7–9.6	−27.2	−31.4 to −23.0	41.4	37.2–45.6

Note. All results are percentages to 1 dp. Negative values are underestimations; positive values are overestimations. CI, confidence interval; APLS, Advanced Paediatric Life Support; CAWR, Chinese Age Weight Rule.

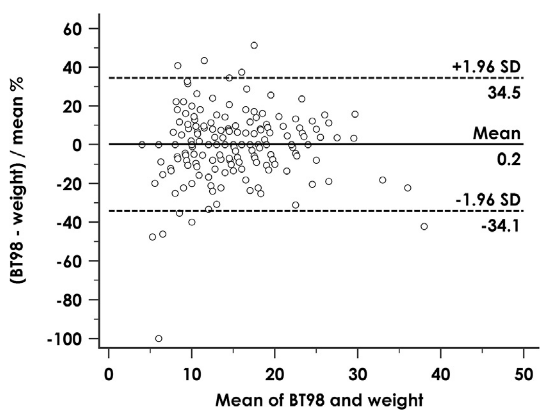

Fig. 2. Bland Altman graph for the 1998 version of the Broselow Tape (BT98).

Table 3
Estimates within 10 and 20% of documented weight.

Method	Number of estimates within 10% of documented weight	PW10 %	Number of estimates within 20% of documented weight	PW20 %
Age-based formulae (n = 327)				
Original APLS	132	40.4	225	68.8
Revised APLS	116	35.5	199	60.9
Luscombe	100	30.6	168	51.4
Best Guess	44	13.5	108	33.0
CAWR	94	28.7	184	56.3
Finger-counting	107	32.7	193	59.0
Rwanda Rule	129	39.4	224	68.5
Broselow Tape versions (n = 200)				
1993	94	47.7	161	81.3
1998	109	55.3	167	84.8
2007	95	48.0	162	81.8
2011	78	39.61	148	75.1

Note. PW10, percentage of weight estimates within 10% of documented weight; PW20, percentage of weight estimates within 20% of documented weight; APLS, Advanced Paediatric Life Support; CAWR, Chinese Age Weight Rule.

depend on which version of the tape is used. The 1998 version is the best, and the 2011 the worst. The original APLS formula and the Rwanda Rule performed similarly, better than other age-based rules, but significantly worse than all versions of the Broselow Tape except the 2011 version.

The study size was decided for Bland Altman analysis, not for our secondary aim of deriving a new age-based formula. This makes the derivation of the Rwanda Rule less reliable. Nor has the Rwanda Rule been validated, and any rule tested in its derivation data set will perform well. It is also more complex to calculate than the original APLS rule. For all these reasons we would not recommend its use unless later validation confirms its superiority.

Furthermore, the study was performed in a single hospital, albeit one that receives patients from across Rwanda. However, our results should only be applied in similar contexts.

It was a retrospective study relying on data in patient charts, and suffers from the inherent disadvantages of such studies: measurements may not have been accurate and data may have been entered incorrectly. However, the data obtained were simple numerals, not relying on any interpretation on the part of the researcher.

The original APLS, CAWR and Rwanda rules had small biases, similar to the Broselow Tapes. Bias, or trueness, is defined by the mean percentage error between the estimated and actual weights. It is easy to derive an age-based rule with minimal bias in a given population: the problem is the lack of precision. If a method of weight estimation has a small bias, it doesn't mean any individual measurement will actually be near to the true value. What is more important is precision, which in this study is reflected by a narrow LOA on Bland Altman analysis: LOA are the range 1.96 SD either side of the bias. PW10 and PW20 represent an overall measure of accuracy, dependent both on bias and precision. These give the clinician an understanding of how likely a particular tool will produce an estimate within a clinically acceptable margin of error. A good bias and a good precision will give a good PW. For a weight estimation tool, if the bias is large but the precision is narrow, it's relatively easy to adjust the rule to reduce the bias. If the precision is wide but the bias is small, it's difficult to correct. Unfortunately, age-based rules all have a higher intrinsic imprecision and modifying the formulae tends to improve the bias not the precision.

A key question though is how accurate we need a weight-estimation tool to be. PW10 was chosen because it was the most commonly used measure in Wells' recent meta-analysis [8]. In that study, the summary PW10 for the original APLS formula, Broselow Tape, Mercy tape and PAWPER tape were respectively: 39.5, 47.1, 71.4 and 86.9%. In our study, the APLS formula performed slightly worse and the Broselow Tape (except the 2011 edition) slightly better. We also used PW20 because for most clinical use, estimates within 20% of actual weight are probably acceptable [15]. These figures are debatable, but there are few drug or fluid doses in emergency settings that need to be given within limits of 10%.

Whether we use PW10 or PW20, we also need to ask what cut-off is acceptable: how often does our method predict weight within that margin? Wells et al. used a benchmark accuracy indicator of PW10 > 70% and PW20 > 95%, but these benchmarks are also debatable. The best age-based methods achieve PW20 > 70% [4], the Broselow Tape > 80% [5]; these have been used for many years in many countries. These are comparable to the results we obtained in our Rwandan population. However, now that there are better methods available, Wells et al. concluded that age-based rules should not be used at all because of the potential for patient harm. Of note, the latest APLS manual no longer describes age-based formulae [16].

Our opinion is that in Rwanda, until there is more local evidence, we should use the 1998 version of the Broselow Tape, one of the other versions if that is not available, and if none is available at all, the original APLS formula. We consider a PW20 of 69% acceptable when no other method is available.

However, it is clear from elsewhere that weight estimation methods using '2-dimensions' of anthropometric data (height or upper-arm length, together with MAC or other body habitus estimates) are superior to '1-dimensional' (height or MAC alone) [8]. Unfortunately, in this study we were unable to assess these tools because we didn't have arm measurement or body habitus data. Similarly, we were unable to assess whether parental estimate of weight is better than any of these tools. There is a need for a prospective study to validate the new Rwanda Rule in comparison with the Broselow, PAWPER and Mercy Tapes and parental estimates.

Furthermore, we also need methods for weight estimation in adolescents and adults. Because we know from elsewhere [3,4] that both Broselow and age-based methods are less accurate in older children, we chose to look only at one to ten year olds in this study. However, patients of any age might require weight-based dosing of drugs, fluids or ventilator settings. Age-based rules are clearly inappropriate in adults, and we know that the Broselow Tape is inaccurate in older children [3]. On the other hand, MAC-rules might be acceptably accurate in adolescents and adults [17], and the Mercy and PAWPER tapes could both be adapted for use in adults. Perhaps future studies could determine a weight-estimation method that is acceptably accurate for clinical use in people of all ages.

This study is the first to compare paediatric weight estimation methods in Rwanda. A new locally derived formula did not perform better than the original APLS formula and needs further validation. Locally, and until we have evidence from further research that other methods are superior, we would advise use of the 1998 Broselow Tape in children aged one to ten years old. Where the Broselow Tape is not available, the original APLS formula should be used.

Acknowledgements

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Conflicts of interest

The authors have no conflicts to declare.

Dissemination of results

These results were presented at the Rwanda Emergency Care Association conference, May 2017. It won the prize for best oral abstract. It was also presented as a poster at the Royal College of Emergency Medicine annual scientific conference, October 2017.

Authors' contributions

All authors were involved in the planning of the study, and the ethics and grant application processes. AM and SY collected the data. GC analysed the data and wrote the manuscript. All authors approved the final version of the manuscript.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.afjem.2018.03.003.

References

[1] Lubitz DS, Seidel 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;17:576–81.

[2] Advanced Life Support Group. Advanced paediatric life support: the practical approach. 5th ed. London: Wiley Blackwell; 2011.

[3] Cattermole GN, Leung PYM, Graham CA, Rainer TH. Too tall for the tape: the weight of schoolchildren who do not fit the Broselow tape. Emerg Med J 2014;31:541–4.

[4] Cattermole GN, Leung PYM, So HK, Mak PSK, Graham CA, Rainer TH. Age-based formulae to estimate children's weight in the emergency department. Emerg Med J 2011;28:390–6.

[5] Cattermole GN, Leung PYM, Mak PSK, Graham CA, Rainer TH. Mid-arm circumference can be used to estimate children's weights. Resuscitation 2010;81:1105–10.

[6] Abdel-Rahman SM, Ridge AL. An improved pediatric weight estimation strategy. Open Med Devices J 2012;4:87–97.

[7] Wells M, Coovadia A, Kramer E, Goldstein L. The PAWPER tape: a new concept tape-based device that increases the accuracy of weight estimation in children through the inclusion of a modifier based on body habitus. Resuscitation 2013;84:227–32.

[8] Wells M, Goldstein LN, Bentley A. A systematic review and meta-analysis of the accuracy of weight estimation systems used in paediatric emergency care in developing countries. Afr J Emerg Med 2017. http://dx.doi.org/10.1016/j.afjem.2017.06.001.

[9] Luscombe M, Owens B. Weight estimation in resuscitation: is the current formula still valid? Arch Dis Child 2007;92:412–5.

[10] Tinning K, Acworth J. Make your Best Guess: an updated method for paediatric weight estimation in emergencies. Emerg Med Australas 2007;19:528–34.

[11] Young TP, Chen BG, Kim TY, Thorp AW, Brown L. Finger counting: an alternative method for estimating pediatric weights. Am J Emerg Med 2014;32:243–7.

[12] House DR, Ngetich E, Vreeman RC, Rusniak DE. Estimating the weight of children in Kenya: do the Broselow Tape and age-based formulas measure up? Ann Emerg Med 2013;61:1–8.

[13] Mukabutera A, Thomson DR, Hedt-Gauthier BL, Basinga P, Nyirazinyoye L, Murray M. Risk factors associated with underweight status in children under five: an analysis of the 2010 Rwanda Demographic Health Survey (RDHS). BMC Nutrition 2016;2:40. http://dx.doi.org/10.1186/s40795-016-0078-2.

[14] Altman DG. Practical statistics for medical research. London: Chapman & Hall; 1991. p. 423.

[15] Lack JA, Stuart-Taylor ME. Calculation of drug dosage and body surface area of children. Br J Anaesth 1997;78:601–5.

[16] Advanced Life Support Group. Advanced paediatric life support: a practical approach to emergencies. 6th ed. London: Wiley Blackwell; 2016.

[17] Cattermole GN, Graham CA, Rainer TH. Mid-arm circumference can be used to estimate weight of adult and adolescent patients. Emerg Med J 2017;34:231–6.