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ORIGINAL ARTICLE

A systematic review and meta-analysis of the accuracy of weight estimation systems used in paediatric emergency care in developing countries

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A B S T R A C T

Introduction: When weight cannot be measured during the management of medical emergencies in children, a convenient, quick and accurate method of weight estimation is required, as many drug doses and other interventions are based on body weight. Many weight estimation methodologies in current use have been shown to be inaccurate, especially in low- and middle-income countries with a high prevalence of underweight children. This meta-analysis evaluated the accuracy of weight estimation systems in children from studies from low- and middle-income countries.
Methods: Articles from low- and middle-income countries were screened for inclusion to evaluate and compare the accuracy of existing systems and the newer dual length- and habitus-based methods, using standard meta-analysis techniques.
Results: The 2D systems and parental estimates performed best overall. The PAWPER tape, parental estimates, the Wozniak method and the Mercy method were the most accurate systems with percentage of weight estimates within 10% of actual weight (PW10) accuracies of 86.9%, 80.4%, 72.1% and 71.4% respectively. The Broselow tape (PW10 47.1%) achieved a moderate accuracy and age-based estimates a very low accuracy (PW10 11.8–47.5%).
Conclusions: The PAWPER tape, the Wozniak method and the Mercy method achieved an acceptable level of accuracy in studies from low- and middle-income countries and should preferentially be used and further advanced for clinical emergency medicine practice. Parental estimates may be considered if the regular caregiver of the child is present and a recent measured weight is known. The Broselow tape and age-based formulas should be abandoned in low- and middle-income country populations as they are potentially dangerously inaccurate.

African relevance

- This is the first meta-analysis of weight estimation systems in low- and middle-income countries.
- The Broselow tape and age formulas are potentially harmful in low- and middle-income countries.
- The dual burden of over- and underweight children requires advanced weight estimation.
- The PAWPER tape, the Wozniak method or the Mercy method should be used in Africa.

Introduction

Throughout the world, the prevalence of obesity in children has increased to the point where "fat is the new normal" [1,2]. Low and middle income countries have not escaped the epidemic of obesity but also suffer from a high prevalence of underweight children: a dual burden of extremes of habitus [3]. These factors have a major impact on the accuracy and safety of paediatric weight-estimation systems.

Drug doses in children are commonly based on their total body weight, but children can seldom actually be weighed during the management of medical emergencies [4]. An accurate estimation of weight is required to facilitate accurate drug dose calculations under these circumstances [5–7]. The accuracy of the weight estimation is important to ensure that a sufficient dose is administered to ensure the efficacy of the treatment and, on the other hand, to

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minimise the likelihood of overdosing with the consequent potential negative effects [8–11]. Some of the older methods that are still commonly used to estimate weight include age-based formulas, length-based formulas, the Broselow tape, guesses by healthcare providers and estimates by parents – these can be classified as one-dimensional systems as only one parameter is used to generate a weight estimation. Many of these methods were derived from populations of well- or over-nourished children and have been shown to lack accuracy and consistency of performance, especially between different populations [12–14]. To limit the degree of underestimation of weight in high-income country populations, newer age-based formulas have been developed over the last decade to accommodate for the increasing prevalence of obesity in children [15,16]. The Broselow tape has also been updated and modified (to the current version: 2011 edition A) to reduce the risk of underestimation of weight [17].

Few of the older one-dimensional weight estimation systems have performed well in populations in low- and middle-income countries, where there is a higher prevalence of malnourished children [18–20]. The potential exists for significant overestimation of weight by methodologies that are derived from populations with a high prevalence of obesity, especially those developed more recently [20].

The newest generation of weight estimation systems, however, have been designed to be equally accurate in normal, under- and overweight children [21,22]. They are two-dimensional techniques that make use of dual length- and habitus-based parameters for weight estimation. These are the Mercy method, the PAWPER tape and the Wozniak method. Preliminary evidence in both high-income countries and low- and middle-income countries has shown that they are far superior in accuracy to traditional methods [5,6,12,18,19,23–30].

Given the differences between populations in high-income and middle or low-income countries, there is a need to establish which methods predict weight most accurately in children in under-resourced environments, to minimise potential medication errors and resultant patient harm. The objective of this study was therefore to determine which paediatric weight estimation systems predicted total body weight most accurately in children from developing countries (low- and middle-income countries). No systematic reviews or meta-analyses have addressed this topic before.

Methods

Search strategy

Online databases (MEDLINE, SCOPUS, Science Direct and Google) were searched for eligible studies, published between January 1986 and January 2017, using the following search terms: "paediatric weight estimation", "weight estimation children" and "Broselow tape". Articles in any language were included if English translations were obtainable. Potential studies for inclusion were also identified from the references sections and citations of reviewed articles. To minimise the possibility of publication bias, all studies with adequate reporting were included, whether full-text articles, research reports, abstracts, conference presentations or other unpublished data.

Study selection and eligibility criteria

All studies that evaluated or compared any of the weight-estimation methodologies described in Table 2 were assessed for inclusion into the study by two separate researchers (MW and LG). Only studies from low- and middle-income countries (as defined in the United Nations World Economic Situation and Prospects report) were included for further analysis [31]. Studies that did not include original data were excluded. Studies that did not include usable statistics–data describing bias and precision (mean percentage error with standard deviations or limits of agreement) or data describing overall accuracy (percentages of estimations within 10% or 20% of actual weight (PW10 and PW20))–were also excluded from the meta-analysis (see Fig. 1).

Data abstraction and analysis

Standard statistics for meta-analysis of method-comparison studies were used, with an emphasis on evaluating accuracy (pooled categorical data – PW10), bias (pooled mean differences – mean percentage error) as well as precision (pooled variance – limits of agreement) [32,33]. The included studies showed a large amount of within-study variance as well as between-study variance that needed to be considered. Two methods of represent-

Table 1
Prevalence of underweight, overweight and obese children in the countries and regions represented in this study. Data from three developed countries is shown for comparison.

Country	Prevalence of overweight and obesity (age 2–19) 2013[1] %	Prevalence of obesity (age 2–19) 2013[1] %	Prevalence of underweight by region 2015[2,3] %	Prevalence of underweight (age <5) 2000–2014[2,3] %
Botswana	14.4	4.5	13.3	11.2
Egypt	35.4	13.6	4.2	6.8
India	5.2	2.4	28.7	43.5
Iran	23.9	6.5	9.2	4.6
Kenya	11.3	2.8	23.6	16.4
Malawi	18.4	6.2	13.3	16.7
Mali	11.6	3.8	26.2	27.9
Mexico	28.8	10.1	3.4	2.8
Philippines	5.5	2.4	17.9	20.2
South Africa	22.5	8.3	13.3	8.7
Sudan	12.8	5.7	33.3	27.6
Thailand	14.4	5.2	17.9	9.2
Trinidad	20.2	7.5	2.8	4.4
Australia	23.7	7.1	0.9	0.2
USA	29.2	12.9	0.9	0.5
UK	27.6	7.7	0.9	0.9

[1]Global Burden of Disease Study 2013. Global Burden of Disease Study 2013 (GBD 2013) Obesity Prevalence 1990–2013. Seattle, United States: Institute for Health Metrics and Evaluation (IHME); 2014.
[2]de Onis M, Blossner M, Borghi E, Frongillo EA, Morris R. Estimates of global prevalence of childhood underweight in 1990 and 2015. JAMA. 2004;291(21):2600–2606.
[3]Prevalence of underweight, weight for age (% of children under 5): The World Bank; 2016 [cited 2017]. Available from: http://data.worldbank.org/indicator/SH.STA.MALN.ZS.

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