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Clinical paper

Paediatric weight estimation by age in the digital era: optimising a necessary evil

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ABSTRACT

Background: Age-based weight estimation methods are regularly used in paediatric emergency medicine despite their well-established inaccuracy.
Aim: Determine the potential improvement in accuracy achievable by the use of a new mobile application, based on CDC/WHO weight-for-age centile data, which incorporates a gender assignment, a body habitus assessment, and which is capable of an age-in-months based calculation.
Methods: A theoretical, simulated validation study, comparing the performance of the widely used APLS/EPALS formulae against two contemporary habitus-adjusted methods, and the Helix Weight Estimation Tool. 1,070,743 children from the 2015/2016 UK National Child Measurement Program dataset, aged between 4 and 5 and 11 and 12 years, had age-based weight estimates made by all five methods.
Results: Primary outcomes were the percentage of weight estimations within 10%, 20%, and those greater than 20% discrepant from actual weight for each method. Our theoretical, gender-dependent, habitus-adjusted method performed better than all other methods across all error thresholds. The overall number of estimations within 10% was 70.4%, and within 20% was 95.45%. The mean percentage error was −1% compared to actual weight.
Conclusion: The use of a digital tool incorporating a subjective assessment of body habitus, gender assignment, and the ability to estimate weight based on age-in-months might be able optimise the process of paediatric weight estimation by age, making this practice as safe and accurate as possible for the occasions when weight estimation by age is chosen over length-based methods.

Introduction

Background

Why do we estimate bodyweight?

Drugs for children are generally prescribed on the basis of age and on body weight. However, frequently a critically ill child arrives in the Emergency Department resuscitation room with his/her weight unknown to the care team, under conditions where it is not possible to weigh the patient before commencing emergency care. Examples of conditions which make weighing the child unfeasible include spinal immobilisation, ongoing cardiopulmonary resuscitation, emergency airway management, or severe pain that inhibits movement of the child [1–3].

The accurate estimation of weight is important in paediatrics, e.g. for the calculation of drug doses, the determination of equipment size for each child, and the energy levels required for defibrillation. Inaccurate and imprecise weight estimation techniques contribute to the high incidence of drug errors in paediatric emergency medicine [4,5].

Current methods of weight estimation

Estimation of weight by age. In spite of the fact that age-based formulae have consistently demonstrated poor predictive accuracy, particularly in older children [6–8], there has been a constant appetite to improve these methods, and from the 1950's onwards, at least 22 age-based formulae have been derived to estimate the bodyweight of children. Some of these calculations require complex workings which, in a stressful clinical environment, provide additional opportunities for erroneous arithmetic to contribute to drug error [9].

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What methods offer acceptable accuracy?. There is some consensus in the literature that an 'accurate' method would demonstrate *accuracy* as 60-70 60–70% of weight estimations within 10% of actual weight (PW10) and a moderate *critical error rate* as having 90-95 90–95% of estimations within 20% of actual weight (PW20) [10,11].

It is well established that the most accurate methods of paediatric weight estimation are length-based methods rather than age-based methods [6,8,12–14], and only length-based methods have ever achieved this level of accuracy.

Five age-based formulae have been validated in the UK in at least sixteen studies we are aware of. The best performing formulae have been the Luscombe-Owens Formula [2] (derived in Sheffield), with PW10 = 43%, and the Tinnings Formula [15], PW10 = 43.7% – both in a 2011 validation by Marlow et al. [6]. The Luscombe-Owens formula has been incorporated in part into the new Advanced Paediatric Life Support (APLS) formula.

Paediatric weight estimation and the childhood obesity pandemic. The increasing incidence of childhood obesity [16] has recently led to the reinvigorated interest in methods that can adjust for the variability in body habitus in children which was first introduced with the Derived Weight Estimating Method (DWEM) [17] in 1986. This has until recently been predominantly applied to length-based methods, and examples of this include the Paediatric Advanced Weight Prediction in the Emergency Room (PAWPER) tape [13], Mercy method [18,19] (using mid upper arm circumference and humeral length), Yamamoto Obesity Icon system [20], and the waist-circumference modified Broselow system [21].

Two studies have evaluated how the addition of an assessment of body habitus could improve the accuracy of age-based weight estimation methods.

These are (where Z = age in years):

TheErkerformula[22]

$$Wt = (2 \times Z) + 6 \text{ For 'tall 'n thin' children}$$

$$Wt = (3 \times Z) + 6 \text{ For 'normal' children}$$

$$Wt = (4 \times Z) + 6 \text{ For 'tiny 'n thick' children}$$

The Wells 'derived formula' [7]

$$HS1: Wt = (1.9 \times Z) + 5.8$$

$$HS2: Wt = (2.3 \times Z) + 5.8$$

$$HS3: Wt = (2.4 \times Z) + 7.5$$

$$HS4: Wt = (2.9 \times Z) + 8.3$$

$$HS5: Wt = (3.7 \times Z) + 8.1$$

In the PAWPER system, Wells et al [13] have added to the area of subjective assessment of habitus (improving upon the Yamamoto method) by developing a 5-point (later 7-point) [10] visual scale of body habitus scores (HS), and these scores have been used in the multipart formula above.

Both of these methods have only been the subject of investigation in one validation study (in a South African population, n = 963 for Erker, n = 635 for Wells) where neither demonstrated 'acceptable accuracy', or 60% of estimations within 10% of actual bodyweight. Additionally, without the use of a digital tool, these increasingly complex equations pose the risk of miscalculation error.

To our knowledge, no habitus-adjusted age-based methods have ever been validated in the United Kingdom.

Why do age-based methods continue to be used?. Despite the availability of more accurate methods, weight based formulae are used throughout the world, and taught on all paediatric life support courses. Principally, however, it is because age-based methods do not require any specific equipment that their use endures.

There is therefore a need to examine the performance of the newest age-based weight estimation methods in English children, and to see if the development of a simple digital tool might be able to add accuracy and safety to weight estimation by age where this method is chosen over length-based methods.

Objectives

1. Determine the accuracy of the APLS/European Paediatric Advanced Life Support (EPALS) formulae and two age-based, habitus-adjusted body weight estimation methods in a large, 2 age-banded cohort of English children.
2. Determine the potential improvement in accuracy achievable by the use of a new mobile application, based on CDC/WHO weight-for-age centile data, which incorporates a gender assignment, a body habitus assessment, and which is capable of an age-in-months based estimation.

It was our hypothesis that this experimental method would demonstrate improved accuracy of body weight estimation over currently taught and used methods.

Methods

Study Design

This was a theoretical, simulated validation study, comparing the performance of the widely used APLS/EPALS formulae with the Wells and Erker formulae, and a new mobile application based method using WHO/CDC centile data, a correction for body habitus, and a gender assignment. All estimates and comparisons were made based upon and compared with English data from the 2015/2016 UK National Child Measurement Program (NCMP) dataset [23].

Data sources

NHS Digital publishes publicly available data from the annual NCMP survey on every child across the UK, as each has their height and weight measured in Reception Year (age 4-5 4–5), and again in Year 6 (age 10-11 10–11). In addition to multiple anthropometric parameters derived from comparison to the UK 1990 Growth Standard [24], each entry contains the school local authority code. WHO and CDC centile datasets are freely available from the US National Center for Health Statistics [25]. For this study, only CDC centile data were required as the CDC recommendation is to use WHO centiles for children under the age of two, and all children in the dataset used for this two age-banded validation were older than two.

Data management

The NCMP dataset is made available after suppression in line with the NHS Anonymisation Standard. Extreme outliers of age-for-weight above the 99.995th percentile (3192 records) and below the 0.005th percentile (631 records) were removed from the dataset. In addition to this, 89260 records were suppressed where the local authority code and a locally small population might have allowed for identification of an individual.