African Journal of Emergency Medicine 8 (2018) 43–50

Contents lists available at ScienceDirect

African Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/afjem

ORIGINAL ARTICLE

The accuracy of paediatric weight estimation during simulated emergencies: The effects of patient position, patient cooperation, and human errors

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ARTICLE INFO

Keywords:
Body weight
Resuscitation
Paediatric weight estimation
Broselow tape
PAWPER tape
Mercy method

ABSTRACT

Introduction: The effect of patient position and patient cooperation on the accuracy of emergency weight estimation systems has not been evaluated previously. The objective of this study was to evaluate weight estimation accuracy of the Broselow tape, the PAWPER XL tape, the Mercy method, and a custom-designed mobile phone App in a variety of realistic simulated paediatric emergencies.

Methods: This was a prospective study in which 32 emergency medicine volunteers participated in eight simulations of common paediatric emergency conditions, using children models. The participants used each of the four methods to estimate the children's weight. The accuracy of and time taken for the weight estimations were evaluated for each method. A regression analysis determined the effects of patient position and cooperation on weight estimation accuracy. Evaluation of subgroups of best-performers and worst-performers among the participants provided information on the effects of human user-error on weight estimation accuracy.

Results: The Broselow tape, Mercy method, App and the PAWPER XL tape achieved percentages of weight estimation within 10% of actual weight in 47.7, 57.3, 68.1, and 73.0% of estimations, respectively. Patient position and cooperation strongly impacted the accuracy of the Broselow tape, had a minimal effect on the Mercy method and the App, and had no effect on the PAWPER XL tape. The best performing participants achieved very high accuracy with all methods except the Broselow tape.

Discussion: The Mercy method, the App, and the PAWPER XL tape achieved exceptionally high accuracy even in uncooperative and sub-optimally positioned children when used by the best-performing participants. Human error, from inexperience and inadequate training, had the most significant impact on accuracy. The Mercy method was the most subject to human error, and the PAWPER XL tape, the least. Adequate training in using weight estimation systems is essential for paediatric patient safety.

African relevance

- Children in Africa and other low- and middle-income countries are vulnerable to inaccurate weight estimation in emergencies.
- The effect of paediatric patient position on emergency weight estimation is unknown.
- The effect of paediatric patient cooperation on emergency weight estimation is unknown.
- Accurate weight estimation in children in emergencies is feasible with economical equipment options.

Introduction

During the management of paediatric emergencies, errors in drug dosing arising from inaccurate estimations of weight can potentially lead to poor outcomes [1–3]. It is therefore imperative that weight-estimation errors be minimised, so that optimum treatment can be delivered during emergency care. Weight estimation systems that have been proven to be accurate should be used and healthcare providers should be well-trained in their use [4,5]. An accurate weight estimation system, however, may not necessarily lead to accurate weight determination as there are other potential sources of errors that must be considered [6–8]. Health care providers must account for the complexity of the weight estimation system, the experience of the users in weight estimation, and patient factors. These include: inherent limitations of the weight estimation system itself (e.g., age-based weight estimation is not accurate) [9], incorrect use of the device or system [10,11] (even simple systems are susceptible to error when used by

Peer review under responsibility of African Federation for Emergency Medicine.
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https://doi.org/10.1016/j.afjem.2017.12.003
Received 6 June 2017; Received in revised form 7 October 2017; Accepted 13 December 2017
Available online 19 January 2018

under-trained individuals [12–14]), or there may be difficulty in using the device or system because of suboptimal patient positioning or uncooperative patients (e.g., the use of a length-based tape in a sitting patient or in a combative, hypoxic child).

Two-dimensional weight estimation systems, which make use of length and habitus to estimate a weight, such as the Mercy method and the PAWPER XL tape, are the most accurate of all the existing weight estimation methodologies [2,15]. However, they have never been evaluated under real or simulated resuscitation conditions. These systems are slightly more complex than simple length-based methods and so, may be more vulnerable to human errors during the stress of emergency care. A weight estimation system that is accurate, but unusable during emergencies, would be of little value.

Advances in technology can also be applied in this setting to reduce errors and cognitive load in emergencies. A mobile-phone App that could rapidly provide accurate point-of-care estimations of weight could be extremely useful. The *Emergency Drug Dosing 4 Children* App was designed to generate estimations of weight, but it has not previously been formally evaluated for patient and human factors [16].

The aim of this study was primarily to evaluate the accuracy of the four weight estimation systems, the Broselow tape, the Mercy method, the PAWPER XL tape, and a weight estimation App, under realistic simulated resuscitation scenarios. We also aimed to establish whether patient factors, including patient positioning and patient cooperation, and participant human error factors, including individual variations in competency, had a substantial impact on the accuracy of the weight estimation.

Methods

This study was a prospective, simulation study conducted in the Emergency Centre of a tertiary, academic hospital in Johannesburg, South Africa. Emergency medicine registrars, emergency medicine consultants, and senior advanced life support paramedics invited to participate in the study. All participants had at least five years' postgraduate experience. Permission to conduct the study was obtained from the Human Research Ethics Committee of the University of the Witwatersrand. All participants signed an informed consent form. An estimated sample size of 30 participants was required to detect a 10% difference in accuracy between the methods based on the McNemar test, powered to 80% at a 0.05 significance level and assuming a baseline accuracy of 70%.

Eight simulation stations were prepared, each recreating a commonplace emergency scenario, with a child volunteer who simulated the medical condition, patient position, and degree of cooperation specified for the scenario (Table 1). The scenarios were chosen to recreate a spectrum of common realistic medical circumstances in which children might not be supine and not cooperative. Some children were fully cooperative, some simulated actively uncooperative patients, such as with a seizure, and some were passively uncooperative, such as during a cardiac arrest. The children were positioned in clinically realistic positions, for example, a supine position for a child in cardiac arrest and a sitting position for a child in respiratory distress.

All participants attended a formal one-hour training session with the weight estimation methods and had an opportunity to practice to their satisfaction before starting the simulation. At each station, every participant used all four techniques to estimate weight. The sequence of methods used was different in each station, based on a randomised, predetermined order. The participants were instructed to obtain each weight estimate independently, not taking the results of the other methods into account. They were informed that the estimations might not be the same between the different methods. They were blinded to the measured weight of the children and the weight estimates of other participants. The time taken to estimate the weights was recorded by a time-keeper.

Upon completion of the six minutes allocated for each station, the participants rotated to the next station until all eight stations were completed. The participants then completed a questionnaire on their experiences with the different systems. Finally, the investigators, experts in the use of the weight-estimation methods, used each system in each child model, now fully cooperative, to provide control data for weight estimation accuracy under ideal circumstances.

Four weight estimation methods were tested in this study (Fig. 1): the PAWPER XL tape [2,17], the Broselow tape 2011 edition A, the Mercy method [15] and the *Emergency Drug Dosing 4 Children* mobile phone App.

Table 1
Details of simulation scenarios, simulated patients and the demographic characteristics of the participants.

Station number	Characteristics of simulated patient	Clinical scenario including position of child and cooperation	Order of weight estimation methods
1	Age: 9 years Weight: 22.5 kg Length: 130 cm HS: 1 (very underweight)	***Cardiac arrest*** Supine on bed Floppy, no cooperation or resistance	PTXL, APP, MM, BT
2	Age: 12 years Weight: 39.6 kg Length:151 cm HS: 4 (overweight)	***Status epilepticus*** Lateral position on bed Arms and legs jerking, no cooperation	APP, MM, BT, PTXL
3	Age: 11 years Weight: 34.2 kg Length: 145 cm HS: 3 (average)	***Respiratory distress – severe asthma*** Sitting on bed. Will not lie down Anxious, semi-cooperative	BT, PTXL, APP, MM
4	Age: 13 years Weight: 55.8 kg Length: 156 cm HS: 5 (obese)	***Major trauma with abdominal injuries*** Immobilised supine on stretcher Cooperative	MM, PTXL, BT, APP
5	Age: 16 years Weight: 61.2 kg Length: 174 cm HS: 3 (average)	***Major trauma with head injury GCS 10/15*** Supine on spine board Uncooperative, irritable	MM, BT, PTXL, APP
6	Age: 1 year Weight: 11.7 kg Length: 80 cm HS: 4 (overweight)	Severe gastroenteritis with hyperkalaemia Sitting on mom's lap Not cooperative	APP, MM, BT, PTXL
7	Age: 8 years Weight: 31.2 kg Length: 132 cm HS: 4 (overweight)	***Unstable supraventricular tachycardia*** Semi-recumbent on bed Fully cooperative	PTXL, MM, APP, BT
8	Age: 7 years Weight: 26.4 kg Length: 131 cm HS: 2 (underweight)	***Severe pneumonia with hypoglycaemia*** Sitting down. Floppy. Semi-cooperative	BT, APP, PTXL, MM

Characteristics of participants

Qualification	N	Sex – male n (%)	Experience Years median (LQ, UQ)	Confidence with children score median (LQ, UQ)
All	32	21 (65.6)	5.5 (3.0, 11.5)	6 (4, 7)
Emergency medicine registrars	21	14 (66.7)	5.0 (4.0, 6.8)	6 (4, 7)
Emergency medicine consultants	5	1 (20.0)	9.0 (7.5, 9.8)	7 (7, 7)
Senior advanced life support paramedics	6	6 (100)	12.5 (11.3, 15.3)	7 (7, 8)

HS, habitus score; PTXL, PAWPER XL tape; MM, Mercy method; BT, Broselow tape; LQ, lower quartile; UQ, upper quartile.