Trauma and Emergency Care

Research Article

A validation study of the PAWPER XL tape: accurate estimation of both total and ideal body weight in children up to 16 years of age

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Abstract

Background: The PAWPER tape has proved to be one of the most accurate weight estimation systems available, but its reduced accuracy in obese children and relative shortness (153cm) limit its functioning. The PAWPER tape was redeveloped as the PAWPER XL tape, to provide additional capacity for estimating weight in obese children and taller children (for extra-length and extra-large children). The aim of this study was to evaluate the accuracy of the PAWPER XL tape in estimating total body weight (TBW) and ideal body weight (IBW) in a population with a high prevalence of underweight and obese children.

Methods: Estimations of TBW and IBW were obtained using the Broselow tape, the Mercy method, the original PAWPER tape and the new PAWPER XL tape in a convenience sample of 332 Emergency Department children. These predicted weights were compared to actual weight and calculated IBW.

Results: The percentage of TBW estimates within 10% of actual weight (PW10) for the PAWPER XL tape, the PAWPER tape, the Mercy method and the Broselow tape was 83.4%, 81.8%, 63.9% and 57.1% respectively. For IBW the PW10 for the PAWPER XL tape, the PAWPER tape and the Broselow tape was 87.9%, 86.7% and 80.0% respectively.

Conclusions: The PAWPER XL tape estimated both TBW and IBW extremely accurately, significantly better than the other weight estimation systems. The increased length and number of habitus score categories of the PAWPER XL tape enabled it to outperform the PAWPER tape in children >153cm in length and in severely obese children.

Abbreviations: Total body weight-TBW; Ideal body weight-IBW; Emergency Department-ED

Introduction

Obtaining an estimate of weight forms part of the emergency management of critically ill or injured children, as most drug doses, and many other interventions, are based on weight. The effectiveness and safety of treatment is ultimately dependent on the accuracy of weight estimation, as enough drug must be administered to ensure efficacy but not too much to cause toxic or unwanted side effects [1]. Although some drugs (such as opioids) can be titrated to effect, some drugs (such as anticonvulsants) require an accurate first-time administration to ensure optimum outcomes [2]. The most accurate weight-estimation systems available should therefore be used, and the continued use of weight estimation methods that are known to be inaccurate should be considered to be poor medical practice [3].

The need for a modification of the original PAWPER system became apparent from the results of local and international research [4-6]. While the PAWPER system still proved to be more accurate than other weight estimation systems in these studies, some limitations of the tape were identified. Firstly, the original PAWPER tape was too short at 153cm to provide weight estimations for some children. Studies on children "too tall for the tape" (referring primarily to the Broselow tape) showed that these children should not be treated as adults in terms of drug dosing [7]. Children as young as 9 or 10 years of age could fall beyond the length of the Broselow tape (145cm) and therefore put at risk of significant overdosing errors if dosed as adults, or underdoing if dosed according to the last Broselow weight. Although the original PAWPER tape is slightly longer than the Broselow tape, it still failed to provide weight estimations for some older children. We decided that it was essential that the PAWPER system be adapted to provide an accurate weight estimation in children up to the age of at least 16 years. Secondly, the original PAWPER system failed to provide accurate weight estimations for children who were severely obese. Two studies from populations in the USA with a high prevalence of obesity showed that the PAWPER tape underestimated weight in obese children [4,5]. This could lead to dosing errors in these children.

In order to avoid underestimation of weight in taller, obese and severely obese children, the PAWPER XL tape was developed for "extra-length" and "extra-large" children (see Figure 1). The major changes between the original PAWPER tape system and the new PAWPER XL tape system were: the length of the tape was increased from 153cm to 180cm; the number of habitus score categories was increased from five to seven, with HS6 and HS7 added for severely obese children (children on the 97th and 99th centiles of weight-for-length); changes were made

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Figure 1. The PAWPER XL tape. This tape is a 1800mmx40mm tape with 13 colour-zones and 34 weight divisions, from 3kg to 70kg. The lower panel shows the appearance of the 60kg and 65kg ideal body weight segments, which fall into the zebra-stripe and giraffe-spot colour-zones. The seven habitus score categories along with their predicted weights are shown. The ideal body weight is predicted by the habitus score 3 weights.

to HS1 and HS2 weights in shorter children and HS 4 and 5 weights in taller children to improve accuracy of weight estimations; and each weight segment of the PAWPER XL tape was labelled with the ideal body weight (IBW), which corresponded to the HS3 weight at that length. How the tape is used is shown in Figure 2.

With the increasing worldwide prevalence of obesity in children total body weight (TBW) may not be the best weight-descriptor for dose calculations for all drugs in all children [8]. The problem of potential overdosing of obese children poses challenges during dose calculations based on TBW for drugs with serious side-effects, such as analgesic, anti-convulsant or anti-arrhythmic drugs. For these drugs, a dosing scalar such as ideal body weight (IBW) is recommended instead of TBW during weight-based dose calculations [9,10]. The use of IBW as a weight-descriptor is usually most applicable in obese children when dosing hydrophilic medications with a small volume of distribution (e.g. adrenaline).

The aim of this study was to establish the accuracy of the PAWPER XL tape in estimating both TBW and IBW in a sample of children with a high prevalence of both underweight and obesity. The secondary objective was to compare the accuracy of the PAWPER XL tape with the original PAWPER tape, the Broselow tape and the Mercy method.

Methods

Study design and setting

This was a prospective, cross-sectional study conducted in the Emergency Department (ED) of a medium-sized, academically aligned private hospital in Johannesburg, South Africa, which provides service to approximately 6000 paediatric patients per year. Ethics approval was obtained from the institutional review board as well as from the Human Research Ethics Committee of the University of the Witwatersrand.

Selection of participants

A convenience sample of 332 children from one month to 16 years of age who presented to the ED or who were an in-patient at the study hospital between October 2014 and January 2015 were enrolled. Only children whose participation did not interfere with emergent medical treatment were eligible for inclusion. Written informed consent and assent (where applicable) was obtained for all participants.

Methods and measurements

Data was collected by one of the researchers (MW or LG) with the same procedure followed for each child. Basic demographic data was obtained and the children then changed into a hospital gown for the subsequent measurements. The child was positioned supine on the examination bed for weight estimation by the Broselow and original PAWPER tapes according to the directions on the tapes. Weight estimations for the PAWPER XL tape were generated from measurements of length and a visual assessment of body habitus. Basic anthropometric measurements were also obtained with the child in a supine position: length, mid-arm circumference (MAC) and humerus length. The child was finally weighed on a calibrated digital scale (Tanita SC-240 Body Composition Analyser).

The anthropometric measurements were used to calculate a number of additional measures. An estimation of TBW was obtained

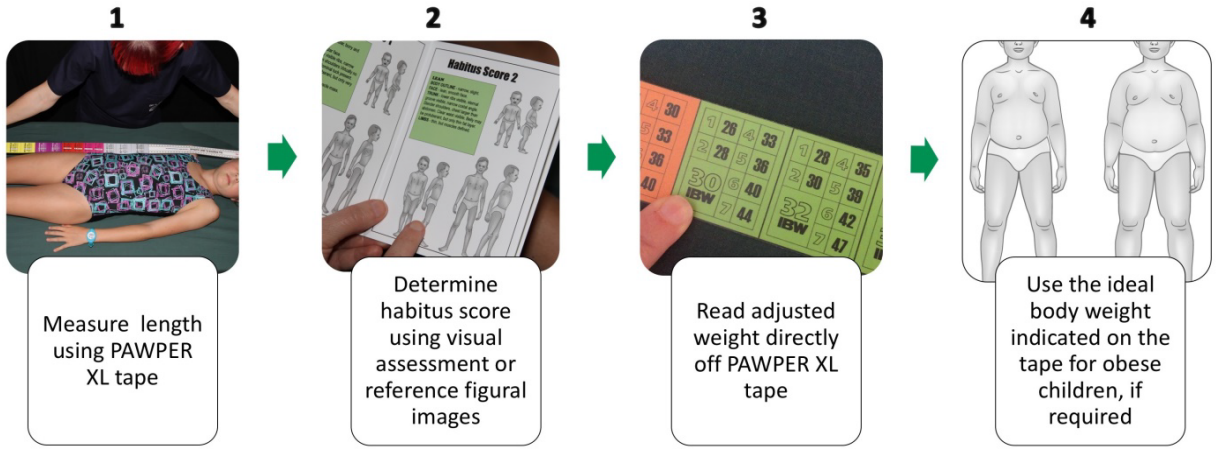

Figure 2. How to use the PAWPER XL tape. The steps required to use the PAWPER XL tape are shown. Both total body weight and ideal body weight can be read directly off the tape.

from the MAC and humerus-length data using the Mercy method [11]. Body mass index (BMI) and the corresponding BMI-for-age Z-scores were determined. An estimate of IBW was determined using the BMI50 method [12]. IBW estimation by the Broselow tape was considered to be the same as the TBW estimation; IBW estimation by the PAWPER XL tape was obtained using the HS3 weight at the child's length.

Analysis

Each weight-estimation system was compared with measured TBW and calculated IBW using both parametric and non-parametric statistical methods. Three primary statistical measures were used to assess performance: mean percentage error (MPE) was calculated to quantify the overall estimation bias; the 95% limits of agreement of the mean percentage error represented the estimation precision; and the percentage of weight estimations that fell within 10% (PW10) and 20% (PW20) of the measured weight-descriptor represented overall accuracy.

Subgroup analyses were performed in three weight categories (<10kg, 10 to 25kg and >25kg) and three habitus categories based on BMI-for-age Z-scores ("thin" children Z-score <-2.0, "overweight" children Z-score >+2.0 and "average" children in between). Subgroup analyses were also performed in children with a length >145cm and HS≥5.

The data was also graphically represented using a modified Bland-Altman plot. Comparisons of accuracy were made using the McNemar or Fisher exact tests. A $p < 0.05$ was considered to be significant for all statistical tests.

Outcome measures

The primary outcome measure was the performance of each of the weight-estimation models when compared to actual weight. A PW10 of >70% and a PW20>95% was regarded as an acceptable level of accuracy. This benchmark was derived from previously suggested criteria, as well as the level of accuracy commonly achieved by newer dual length- and habitus-based weight estimation systems [13]. This benchmark was also considered to indicate an acceptable accuracy of IBW estimation.

Results

Characteristics of study participants

A total of 332 children were included in the study. The basic demographic information is shown in Table 1. The BMI-for-age distribution showed a population with a sizeable number of underweight children (15.3%) and overweight or obese children (32.5%) in which to test the weight estimation systems. There was also a high prevalence of children (20.5%) whose TBW and IBW differed by more than 20%.

Main results

The performances of each of the weight-estimation systems against TBW and IBW are shown in Table 2. With regards to estimating TBW, the Broselow tape and the Mercy method achieved an intermediate degree of accuracy (PW10s of 57.1 and 63.9 respectively) while the PAWPER tape and PAWPER XL tape achieved an extremely high degree of accuracy (PW10 81.8% and 83.4% respectively). The modified Bland & Altman percentage error plots for each of the weight estimation systems are shown in Figure 3.

There were 43 children (13.0% of the sample) >145cm in length who were too tall for the Broselow tape and 24 children (7.2% of the sample) >153cm in length who were too tall for the PAWPER tape. Only the Mercy method and the PAWPER XL tape could provide weight estimations in these children, which were similar in accuracy to that in shorter children (PW10s of 70.3% and 83.3% respectively, Fisher exact test, $p<0.0001$).

There were 34 obese or severely obese children (10.2% of the sample) in whom the weight estimation by the original PAWPER system was handicapped because of the maximum habitus score limitation. The Mercy method and the PAWPER XL tape again were the best performers in these children, but with only a moderate degree of accuracy (PW10s of 53.3% each) while the Broselow tape and the original PAWPER tape had very low accuracy (PW10s of 0% and 16.7% respectively).

While the Broselow tape was substantially more accurate in average weight children than in underweight, overweight and obese children, the Mercy method, the PAWPER tape and the PAWPER XL tape had a more consistent performance across the spectrum of body-types and weight categories. The relatively poorer performance of all the systems in children <10kg was partly because of the high incidence of obesity and severe obesity in this group.

The Broselow tape, the original PAWPER tape and the PAWPER XL tape all predicted IBW extremely well in obese children (PW10 80.0, 86.7% and 87.9% respectively, Fisher exact test, $p<0.0001$ for comparison between Broselow tape and PAWPER tapes).

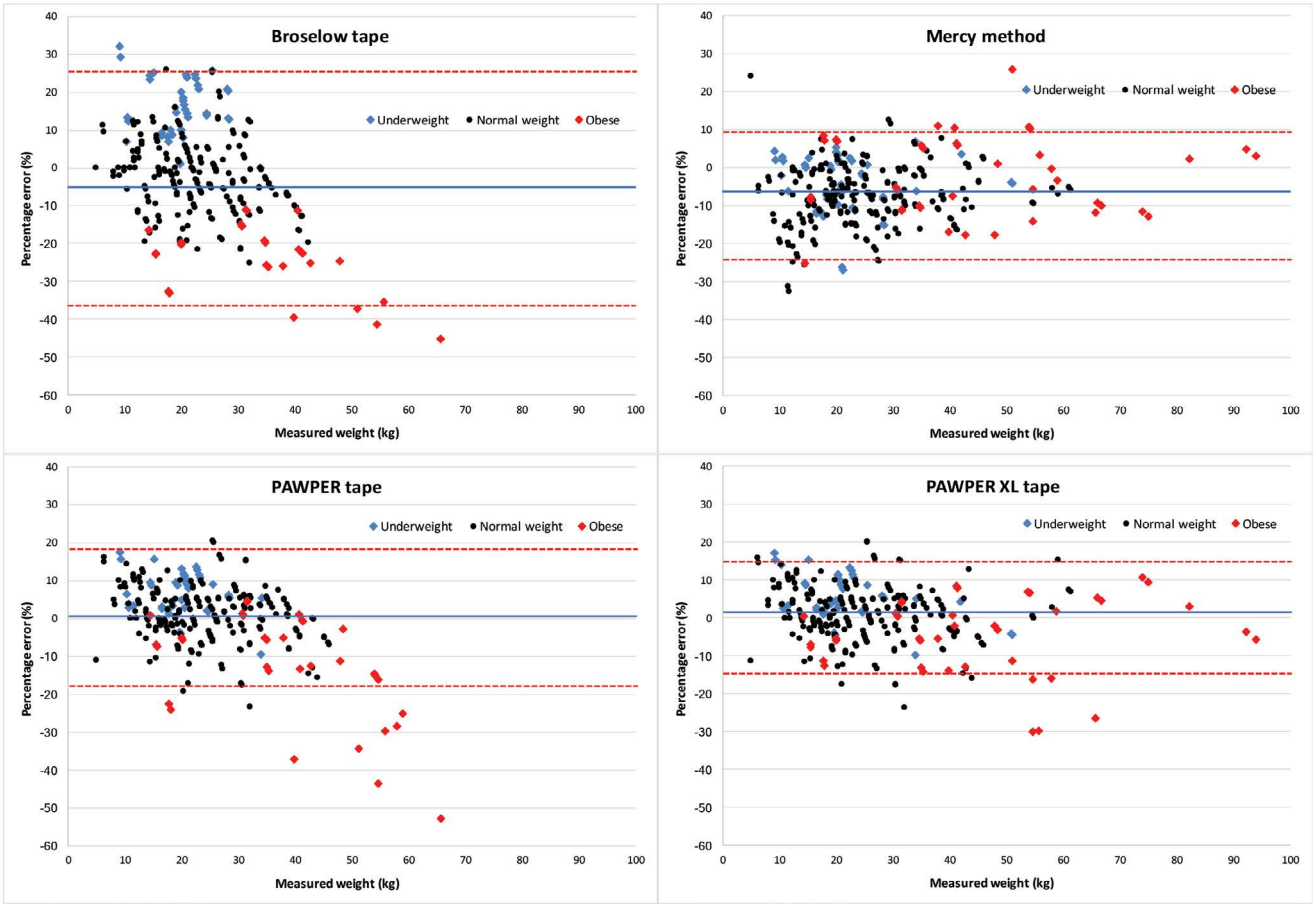

Figure 3. Modified Bland & Altman plots for each weight estimation system. A percentage error method was used rather than actual differences, because of the wide range of weights of participating children. The solid blue lines indicate the mean percentage error (MPE) while the dashed red lines indicate the 95% limits of agreement. Underweight children, normal weight and obese children are shown with different markers on the plot.

Table 1. Description of the study population: demographic information with body composition data. Subgroup data are provided using a body mass index (BMI) classification. Since body composition reference data have not been well established in children, and especially in younger children, most analyses in this study made use of pragmatic limits that might affect drug dosing decisions: children were considered to be significantly obese when their total body weight (TBW) was >120% of ideal body weight (IBW) (which roughly corresponds to a Z-score of +2) as this would require the use of IBW as a drug dosing descriptor for some drugs. Likewise, children were considered significantly underweight when their TBW was <80% IBW (which approximates a Z-score of -2) as the use of IBW would result in a critical overdosing error. Medians and interquartile ranges are shown.

	All	Underweight	Thin	Normal	Overweight	Obese	Severely obese
Number	332	18 (5.4)	33 (9.9)	173 (52.1)	74 (22.3)	20 (6.0)	14 (4.2)
Sex (male)	154 (46.4)	4 (22.2)	15 (45.5)	93 (53.7)	25 (33.8)	12 (60.0)	5 (35.7)
Age (years)	7.2 (4.5, 9.3)	6.4 (3.5, 8.0)	9.1 (5.7, 13.1)	7.3 (4.9, 10.1)	7.8 (5.0, 9.4)	6.7 (4.9, 10.0)	3.0 (1.7, 6.9)
BMI (kg/m²)	16.7 (15.2, 18.8)	13.2 (12.9, 13.4)	16.3 (15.6, 18.6)	16.2 (15.4, 17.3)	18.6 (17.8, 20.0)	19.9 (19.3, 26.6)	22.6 (20.5, 26.4)
BMI-for-age Z-score	0.4 (-0.5, 1.1)	-2.7 (-3.5, -2.2)	0.0 (0.0, 0.0)	0.3 (-0.3, 0.6)	1.4 (1.1, 1.6)	2.1 (2.0, 2.2)	2.9 (2.8, 3.5)
IBW (kg)	23.2 (17.7, 30.7)	22.2 (14.9, 23.5)	26.4 (21.2, 43.0)	22.8 (18.3, 31.5)	25.9 (18.9, 31.5)	23.7 (18.2, 35.9)	14.2 (11.3, 35.9)
IBW >120% TBW n (%)	10 (3.0)	9 (50.0)	1 (3.0)	-	-	-	-
TBW>120% IBW n (%)	58 (17.5)	-	-	1 (0.6)	25 (33.8)	18 (90.0)	14 (100)
HS	3 (3, 4)	2 (2, 2)	3 (3, 3.75)	3 (3, 4)	4 (4, 4.8)	4.5 (4, 5)	5 (5, 6)
TBW (kg)	23.4 (17.6, 33.8)	18.3 (12.3, 20.0)	26.6 (21.1, 43.1)	23.4 (18.4, 31.4)	30.6 (21.6, 38.8)	30.8 (21.3, 56.3)	19.0 (15.5, 39.3)

The results of the statistical comparisons between the weight estimation systems are shown in Table 3. The Broselow tape was statistically inferior to the other systems in virtually every analysis. The Mercy method was statistically inferior to the PAWPER tape and PAWPER XL tape in the overall sample, in children >10kg of weight and in children of average habitus, but was significantly superior to the PAWPER tape in obese children. The PAWPER XL tape outperformed the PAWPER tape in the subgroup of overweight and obese children.

Discussion

The performance of the weight estimation systems – TBW estimation

The PAWPER XL tape performed very well in this study and achieved the acceptable outcome criteria. It performed very well in every subgroup except for the group of severely obese children. Although there is no previous data from studies on the PAWPER

Table 2. Outcomes of the weight-estimation systems against total body weight (TBW) and ideal body weight (IBW). Subgroups by weight, thinness (IBW>120% TBW) and fatness (TBW > 120% IBW) are shown. The performance of estimations of IBW are only shown for obese children (in whom these descriptors might be used). To evaluate the performance of the PAWPER XL tape, the outcomes for each system are shown for comparison for children "too tall for the original tape" (>145cm) and those with habitus scores above the obese range (HS 6 and HS 7). A description of the terminology for outcomes is provided in the lowest panel.

Total body weight (TBW) estimation outcomes							
		N	**PW10**	**PW20**	**MPE**	**LLOA**	**ULOA**
Broselow tape	All	289	57.1	86.5	-1.9	-27.8	24.0
	<10kg	11	72.7	81.8	6.7	-18.1	31.4
	10-25kg	168	62.5	90.5	0.9	-21.9	23.7
	>25kg	110	47.3	80.9	-7.0	-34.2	20.2
	Thin	41	19.5	58.5	17.5	4.5	30.5
	Average	202	75.7	99.0	-1.5	-17.2	14.2
	Overweight	46	8.7	56.5	-20.9	-38.5	-3.2
	>145cm	43	-	-	-	-	-
	HS≥5	29	0	0	-36.4	-56.4	-16.4
Mercy method	All	332	63.9	94.3	-6.7	-23.1	9.6
	<10kg	11	54.5	90.9	-4.2	-27.4	19.0
	10-25kg	168	64.9	92.3	-7.5	-23.8	8.9
	>25kg	153	63.4	96.7	-6.1	-21.8	9.7
	Thin	46	78.3	93.5	-3.7	-19.9	12.5
	Average	218	62.3	94.7	-8.0	-22.6	6.6
	Overweight	58	58.6	93.1	-4.2	-24.6	16.2
	>145cm	43	70.8	100	-4.8	-18.4	8.7
	HS≥5	34	53.3	93.3	-1.1	-25.2	22.9
PAWPER tape	All	308	81.8	96.2	0.5	-17.9	18.9
	<10kg	11	54.5	100	8.7	-7.1	24.4
	10-25kg	168	85.7	98.8	1.9	-11.6	15.4
	>25kg	112	78.6	92.0	-2.4	-25.2	20.4
	Thin	41	58.5	97.6	9.2	-0.7	19.0
	Average	202	93.1	100	1.7	-9.4	12.7
	Overweight	48	54.2	79.2	-11.8	-36.7	13.1
	>153cm	24	-	-	-	-	-
	HS≥5	31	16.7	33.3	-24.6	-56.3	7.1
PAWPER XL tape	All	332	83.4	98.5	1.1	-13.9	16.1
	<10kg	11	54.5	100	8.7	-7.1	24.4
	10-25kg	168	86.3	100	2.0	-10.4	14.3
	>25kg	153	82.4	96.7	-0.4	-17.1	16.3
	Thin	46	70.4	97.8	7.8	-3.2	18.9
	Average	218	91.7	100	1.5	-10.0	13.1
	Overweight	58	70.8	93.1	-6.0	-24.5	12.5
	>145cm	43	83.3	97.9	-0.3	-16.8	16.2
	HS≥5	34	53.3	86.7	-6.2	-30.0	17.7
Ideal body weight (TBW) estimation outcomes							
		N	**PW10**	**PW20**	**MPE**	**LLOA**	**ULOA**
Broselow tape	Obese	30	80.0	100	-3.5	-26.2	19.3
PAWPER tape	Obese	30	86.7	100	4.5	-6.1	15.1
PAWPER XL tape	Obese	34	87.9	100	4.8	-4.5	14.1

Description of accuracy outcomes

PW10	**Descriptor**	**PW20**	**Descriptor**
<30%	Critically inaccurate	<80%	Very high critical error rate
30-40%	Very inaccurate	80-90%	High critical error rate
40-50%	Inaccurate		
50-60%	Moderately accurate	90-95%	Moderate critical error rate
60-70%	Accurate		
70-80%	Very accurate	>95%	Low critical error rate
80-90%	Extremely accurate		
>90%	Exceptionally accurate		

Table 3. Outcomes of the statistical tests between the weight estimation systems for the whole sample and for the indicated subgroups. The Fisher exact test was used. The abbreviations shown in the matrix indicate which system was more accurate in the paired tests. Abbreviations: BT – Broselow tape, MM – Mercy method; PT – original PAWPER tape, PTXL – PAWPER XL tape, NS – not significant.

All			
	Broselow tape	**Mercy method**	**PAWPER tape**
Mercy method	MM (p=0.0041)		
PAWPER tape	PT (p<0.0001)	PT (p<0.0001)	
PAWPER XL tape	PTXL (p<0.0001)	PTXL (p<0.0001)	NS
Weight <10kg			
	Broselow tape	**Mercy method**	**PAWPER tape**
Mercy method	NS		
PAWPER tape	NS	NS	
PAWPER XL tape	NS	NS	NS
Weight 10 to 25kg			
	Broselow tape	**Mercy method**	**PAWPER tape**
Mercy method	NS		
PAWPER tape	PT (p<0.0001)	PT (p<0.0001)	
PAWPER XL tape	PTXL (p<0.0001)	PTXL (p<0.0001)	NS
Weight >25kg			
	Broselow tape	**Mercy method**	**PAWPER tape**
Mercy method	MM (p<0.0001)		
PAWPER tape	PT (p<0.0001)	PT (p<0.0001)	
PAWPER XL tape	PTXL (p<0.0001)	PTXL (p<0.0001)	NS
Thin children			
	Broselow tape	**Mercy method**	**PAWPER tape**
Mercy method	MM (p<0.0001)		
PAWPER tape	PT (p<0.0001)	NS	
PAWPER XL tape	PTXL (p<0.0001)	NS	NS
Average children			
	Broselow tape	**Mercy method**	**PAWPER tape**
Mercy method	NS		
PAWPER tape	PT (p<0.0001)	PT (p<0.0001)	
PAWPER XL tape	PTXL (p<0.0001)	PTXL (p<0.0001)	NS
Overweight children			
	Broselow tape	**Mercy method**	**PAWPER tape**
Mercy method	MM (p<0.0001)		
PAWPER tape	PT (p<0.0001)	NS	
PAWPER XL tape	PTXL (p<0.0001)	NS	PTXL (p<0.0001)
Obese children			
	Broselow tape	**Mercy method**	**PAWPER tape**
Mercy method	MM (p<0.0001)		
PAWPER tape	PT (p<0.0001)	MM (p<0.0001)	
PAWPER XL tape	PTXL (p<0.0001)	NS	PTXL (p<0.0001)

XL tape, it performed better in obese children in this study than the original PAWPER tape did in obese populations in previous studies [4,5]. The use of figural reference images to increase the accuracy of habitus assessment may increase the performance of the PAWPER XL tape further.

The Broselow tape achieved moderate accuracy in this study but did not meet the acceptable outcome criteria. Although the Broselow tape accurately estimated weight in children of average habitus (those with a TBW similar to IBW), it was critically inaccurate in underweight and overweight children and failed to estimate weight within 20% of actual weight in every obese child in this study. This has been frequently reported previously, with potentially dangerous overestimation of weight in low- and middle-income countries and substantial underestimation of weight in high-income populations [14-18]. The accuracy was highest in the youngest children, falling off significantly in children >25kg. This is also a pattern repeatedly reported previously [19]. The Broselow tape was simply not accurate enough and could not provide a weight estimation in a substantial number of children who were too tall for the tape. Given its repeated failure to achieve acceptable accuracy in this study and many previous studies, the role of the Broselow tape as the gold standard of weight estimation in children needs to be reconsidered.

The Mercy method achieved a lower accuracy in this study than in many previous studies (PW10s generally above 70%) [11,20,21]. This is probably because children were measured supine in this study to simulate how the method would be used during emergency care. Differences in skill and experience in anthropometry may also have played a role, however, as has been previously noted in studies on the Mercy method [20,22]. Improving the performance of the Mercy method, when used by novices and ordinary clinicians, needs to be explored further. Its use during actual emergency care also needs to be evaluated.

The original PAWPER tape achieved an exceptionally high overall level of accuracy in this study sample, similar to that previously reported from non-obese populations [6,23,24]. The accuracy in obese children was poor, however, similar to previous findings from studies in populations with a high prevalence of obesity [4,5]. The possible explanations for poor accuracy are, probably, a failure of the users to visually assess habitus accurately, leading to an underestimation of a child's weight status; and an inherent inability of the tape to provide weight estimations for obese and severely obese children [25]. These shortcomings provided the motive to develop the PAWPER XL tape.

A comparison between the PAWPER XL tape and the other methods

The overall performance of the PAWPER systems was better than that of the Mercy method, which was better than that of the Broselow tape. These findings echo previous studies in which these three methods have been compared [5,6,23]. Given the consistently higher accuracy of the dual length- and habitus-based weight estimation systems (such as the Mercy method and the PAWPER tapes) when compared with length-only systems (such as the Broselow tape) it is hard to justify the continued use of the Broselow tape.

The PAWPER XL tape had the best performance of all the systems in every subgroup except the <10kg group. In this group, the Broselow tape performed best because it overestimated weight less than the other methods. The differences between the PAWPER XL tape and the PAWPER tape were small overall, but it was the areas of difference between the tapes that was of most interest: in the >145cm group and the obese and severely obese children. In taller children, even with a relatively small subgroup size, the PAWPER XL tape was extremely accurate and as accurate as in shorter children. The accuracy in the subgroup of obese children was significantly and substantially better than the Broselow tape and the PAWPER tape, but similar to the Mercy method. Since the PAWPER XL tape still underestimated the weight in obese children, it might be possible to recalibrate the system to further improve accuracy, but there was no clear indication of how the Mercy method could be improved.

Children "too tall for the tape" and "too fat for the tape"

One of the important measures of a weight estimation system is the restrictions to its use. The Broselow tape and the original PAWPER tape had a substantial number of "weight estimation orphans" for whom another method would have had to be used to estimate their weight in a clinical setting. The use of either adult weight for these children,

or the highest weight on the tape has been shown to be erroneous and potentially harmful [7]. The Mercy method and the PAWPER XL tape were able to provide weight estimations for all children in this study: both these systems are thus likely to work well in children up to approximately 16 years of age, making them useful beyond the restrictions of most other weight estimation systems.

The changes in the PAWPER XL tape, increased to a length of 180cm, showed excellent performance in the subgroup of taller children. With its habitus scores increased to seven from the original PAWPER tape's five, it showed reasonable performance in morbidly obese children but further assessment in a larger sample will still be required.

The performance of the weight estimation systems – IBW estimation

The Broselow tape, the original PAWPER tape and the PAWPER XL tape predicted IBW extremely accurately in obese children. Although it has previously been suggested that length-based methods could predict IBW, this is the first study to confirm that assumption [26]. The Mercy method, despite being accurate at predicting TBW, does not have a mechanism by which to estimate IBW: the use of humerus-length as a surrogate for recumbent length prevents easy, direct prediction of IBW.

The significance of IBW estimation

As the Pediatric Advanced Life Support (PALS) guidelines of the American Heart Association affirm, there is no clarity on whether drug doses must be adjusted during the resuscitation of obese children and there is no empirical evidence from which to create guidelines [27]. Their own guidelines are somewhat self-contradictory, however, as they regard the use of either actual body weight (TBW) or length-based weight estimations (IBW) for drug dosing as equivalent. It is clear from the findings of this study that TBW and IBW are not interchangeable: a fifth of the study population had more than a 20% difference between TBW and IBW. The use of IBW as a scalar will, therefore, result in medication overdoses in underweight children [28]. Similarly, the use of TBW in obese children will result in significant overdosing of hydrophilic medications. Although there is no clear evidence of harm from medication errors arising from the incorrect use of TBW or IBW as a dose scalar, there has been speculation that these errors may have led to poorer outcomes following cardiac arrest in obese children [29]. The theoretical considerations about the use of appropriate dose scalars in obese children must be given some credence, especially if both TBW and IBW can be rapidly and accurately estimated in an emergency [30].

Limitations

Although this was a preliminary study to evaluate the PAWPER XL tape, the subgroup sample sizes were quite small. Further research is still required in a sample with a greater number of obese children and taller children. Secondly, the process of assigning a habitus score using a visual assessment of habitus was subjective and may be a significant contributor to error, especially in obese children: this was not evaluated in this study. The use of more objective methods of habitus assessment, such as the use of figural reference images, need to be evaluated. Thirdly, the impact of inaccurate weight estimations on outcomes is not known, nor is the benefit of using IBW over TBW for appropriate drugs in obese children. This needs to be established to guide the stringency of further development of weight estimation systems.

Conclusions

The PAWPER XL tape was extremely accurate in this study and surpassed the acceptable accuracy benchmark. It was more accurate than the original PAWPER tape because of its expanded length and modified habitus score categories. Although the PAWPER XL tape was more accurate than the other systems in severely obese children, it did not achieve the acceptable outcome criteria in this subgroup. The Broselow tape performed poorly, as in multiple previous studies and was simply not accurate enough and not long enough. The continued use of the tape needs to be carefully reconsidered. The Mercy method was moderately accurate, but its accuracy appears to be dependent on patient positioning and the experience of its users. This also needs to be explored in future research. The Broselow tape, the PAWPER tape and the PAWPER XL tape predicted IBW with a high degree of accuracy. The significance and usefulness of an easily-determined IBW needs to be determined with some urgency, to ensure that emergency drug dosing in children is optimised and medication errors avoided.

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