Comparing the Usability of Paediatric Weight Estimation Methods:

a Simulation Study

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Abstract

Objective: Estimating weight is essential in order to prepare appropriate sized equipment and doses of resuscitation drugs in cases where children are critically ill or injured. Many methods exist with varying degrees of complexity and accuracy. The most recent version of the Advanced Paediatric Life Support (APLS) course has changed their teaching from an age based calculation method to the use of a reference table. We aimed to evaluate the potential implications of this change.

Method: Using a bespoke online simulation platform we assessed the ability of acute paediatric staff to apply different methods of weight estimation. Comparing the time taken, rate and magnitude of errors made using the APLS single and triple age based formulae, Best Guess, and reference table methods. To add urgency and an element of cognitive stress, a time based competitive component was included.

Results: 57 participants performed a total of 2240 estimates of weight. The reference table was the fastest (25(22-28) vs 35(31-38) to 48(43-51) seconds) and most preferred, but errors were made using all methods. There was no significant difference in the percentage accuracy between methods (93-97%) but the magnitude of errors made were significantly smaller using the three APLS formulae 10%(6.5-21) compared to reference table (69%(34-133)) mainly from month/year table confusion.

Conclusion: In this exploratory study under psychological stress none of the methods of weight estimation were free from error. Reference tables were the fastest method but also had the largest errors and should be designed to minimise the risk of picking errors.

INTRODUCTION

In acutely ill or injured children, estimates of weight are often used to calculate drug and fluid dosage, and select appropriately sized equipment. Many methods exist, attempting to optimise the balance between ease of use and accuracy. The most accurate are based on physical measurements such as length or mid-arm circumference,[1] but those commonly used in the UK are age-based; these are particularly applicable in Emergency Departments as with an ambulance pre-alert they allow preparations to be made prior to the arrival of a child. In 2011, the Advanced Paediatric Life Support (APLS) recommendations changed from using a single formula to three. However the UK Resuscitation Council maintained that complexity increases risks of error and advocated the use of a single formula.[2] The most recent revision of the APLS handbook moves away from traditional calculation methods, now advocating the use of a reference table.[3] However to date no studies have assessed the crucial human factors affecting ease of use or rates of error of these different approaches. This project aimed to pilot a technique for testing accuracy, speed and user preference (usability) of different methods.

METHODS

We developed an interactive game website (www.pemresearch.org) where participants estimated weights using APLS single and three formula, Best guess[4], and reference table methods (table 1) to a set range of ages. Questions were grouped by method with starting block and order of ages randomised for each attempt. All subjects answered the same sets of questions estimating the weight of 6 months, 1, 5, 7, 10, 13 and 15 year olds; with the relevant formulae/table of the method being tested visible for reference at the time.

To replicate some of the human factors which may influence a resuscitation situation, psychological stress was generated by a large visible running timer – participants were made aware of a leader-board competition (which allowed repeated entries and a prize incentive) prior to starting. Nurses,

medical students and doctors were recruited through word of mouth and social media. Pre-test

participants were asked their usual method of weight estimation and after the test which of the four

methods they preferred.   As the study was a maths quiz open to anyone to enter, following the

Health Research Authority guidance ethical approval was not required and so was not sought. As a

pilot study no power calculation was performed.

Inter-method variability of speed and accuracy were analysed for normally distributed data using

one way repeated measures ANOVA with post hoc pairwise t-tests, and for non-parametric data we

used Kruskal and Dunn tests. P-values were adjusted for multiple testing using the Holm method.

Analysis was done using R.[5] Comparing the responses to the expected answers we categorised

errors into simple arithmetical, data entry or month/year confusion. Answers were considered an

error if not equal to the result generated by the formulae/table for the current age being assessed

and were analysed as rates, absolute and percentage difference from correct answer. Errors more

than ten times larger or smaller than the correct answer were deemed input errors and excluded

from the accuracy analyses.

RESULTS

57 acute paediatric staff (table 2) completed the test with a median of 1.4 attempts each (range 1-6). In practice 71% reported routinely using the single formula APLS method. Post-test 69% reported a preference for the reference table method, finding it easiest to use.

Comparing the total time taken to complete the tests, the reference table method was significantly quicker to use than other methods (p<0.001). (Table 3) Comparing the accuracy of the methods, there were significantly more errors made using the single formula APLS compared to using the reference table (p=0.002). However most errors using the single formula APLS occurred when it was applied to 6 month olds; as the formula is only recommended between the ages of 1-10 years we repeated the analysis excluding the 6 month task. This demonstrated no significant difference in accuracy between these methods (Table 4). Across the 2240 answers provided there were only 10 errors classified as input type.

The magnitude of errors made using the triple formulae APLS method was significantly less than the other methods (p=0.02, 0.02 0.05), with a median percentage error of 10% of bodyweight compared to 22-65% using other methods. Whilst overall the table method had the lowest frequency of errors, a proportion of these were disproportionately large; mainly due to month/year confusion.

DISCUSSION

Our novel method of assessing usability found significant differences in the speed of use of different age based methods of weight estimation. Using this as a proxy for task difficulty suggests that the use of single formula or a reference table are easier tasks to carry out than the other methods. However speed did not automatically correlate with accuracy of application. Whilst reference tables were faster and there was a non-significant trend to more frequent correct usage, the magnitude of errors were significantly smaller using the three formulae APLS method.

Many studies have examined the predicted accuracy of estimation methods against a population's true weight with no consensus of the ideal method[6], but few studies have examined their practical application in real world settings. Age based calculations tend to underestimate true weight but instead predict an ideal bodyweight which, due to the pharmacological properties of most resuscitation drugs, may be more suitable.[7] The only other study comparable to ours applied both age and length based methods to a cohort of 80 children in the USA, and found a 5% error of application rate, with device based methods (e.g. tapes) having the highest rate of application errors (25%).[8]

The additional choices and calculation inherent in paediatric resuscitation increase cognitive loading.[9] An alternative method to avoid weight estimation altogether by having pre-assigned equipment and drawn up medications in broad age based categories.[10] Although conceptually simpler this requires dedicated colour coded equipment and leads to improvement but not abolition of error.[11] With an increasing move in medicine to checklists for cognitive unloading, the use of a pre-populated table of weights, drug doses and equipment sizes for age is highly appealing and would seem to facilitate the optimum balance of usability and accuracy. We seem to have come full circle as these were first described in the 1980s,[12] but with concerns over their accuracy [13] they fell out of favour in preference for the APLS calculation methods. Whilst technological innovations including device applications promise the potential for more complex calculations, the practicalities of touch-screens, blood and latex gloves represent significant barriers in high pressure clinical scenarios. With critically unwell or injured children we feel the paradigm must be avoidance of errors through simplification. Poor design in aviation[14] and anaesthesia[15] cognitive aids has been linked to harmful effects. Our data suggest that reference tables should also be designed in a way to minimise potential picking errors.

As with all clinical medicine we have to be pragmatic; estimated weight will rarely be as accurate as true weight. Many would argue that simple estimates provide a safe starting point and that effect

should be guided by response. More accurate methods bring with them more complexity, even before considerations of body composition are taken into account. But we should remember that the evidence base for paediatric dosing in general is limited and there are practical limitations around the accuracy of small volume doses of many drugs (for example. adrenaline) that can be administered. We would hope that in a team situation other members would identify and challenge implausible weights, although this identification would become less likely with increasingly uncommon interventions - there may be less recognition of a reasonable value for e.g. defibrillation. With the initial identification of weight such a crucial component of the resuscitation perhaps there should be a formalised second person check as is commonplace during the preparation of drug doses.

CONCLUSION

In summary, our study which stress tested individuals applying methods of weight estimation under time pressure revealed significant differences in task difficulty and identified unexpected sources of error. With significant mistakes still made in 5-10% of cases we feel usability must be an important consideration in the development of future methods of emergency decision making. Simply providing a list of weight values is not enough to avoid errors, with design and layout important factors that require assessment before clinical use. We feel our simple tool provides a method of rapid evaluation to identify and prevent uncommon but potentially significant errors.

What is known about this topic:

- There are many methods of weight estimation of children balancing complexity and accuracy.

- The use of checklists helps cognitive unloading during stressful tasks.

- The Advance Paediatric Life Support course is moving away from calculations in favour of reference tables.

What this study adds:

- Weight look-up tables are faster to use and preferred by clinicians over calculations

- Their design can introduce un-anticipated large errors through month/year confusion.

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Table 1: Methods of weight estimation compared in the study.

	Method	
	Age range	**Formula**
Single formula APLS (APLS1)	1-10 years	weight = (age + 4) x 2
Three formulae APLS (APLS3)	<12 months	weight = (0.5 x age in months) + 4
	1-5 years	weight = (2 x age) + 8
	6-12 years	weight = (3 x age) +7
Modified Best Guess Method (BGM)	<12 months	weight = (age in months +9) / 2
	1-9 years	weight = (2 x age) +10
	10-14 years	weight = (4 x age)
Reference table* Derived from UK-WHO growth charts[16]	0-16 years	weight = 50th centile for age

(*reference table as provided to participants available as online supplement)

Table 2: Grade and speciality of respondents

Paediatrician						Foundation Trainee	Adult EM ST4+	Anaesthetics ST4+	Paramedic
ST1-3	ST 4+	EM Grid	EM Cons	Nurse	Intensivist				
5 (9%)	15 (26%)	16 (28%	8 (14%)	6 (11%)	1 (2%)	2 (4%)	2 (4%)	1 (2%)	1 (2%)

Table 3 – Results of estimation estimates for each method.

	Method of weight estimation			
	APLS1	APLS3	BGM	Table
Total time taken (s) (95% CI)	45(*) (40-49)	55(*) (49-58)	48(*) (42-53)	30(*) (28-33)
Accuracy (%) (95% CI)	90(†) (87-92)	94 (91-95)	94 (92-96)	96(†) (93-97)
Median % error (95% CI)	22% (11-33)	10%(*) (7-21)	39% (17-42)	66% (8-132)
Correct answers (n)	504	524	527	536
Error type (%)				
Arithmetic	55 (98%)	34 (94%)	27 (82%)	7 (29%)
Input	1 (2%)	1 (3%)	6 (18%)	2 (8%)
month/year	0	1 (3%)	0	15 (63%)

Comparing each method by pairwise analysis, (*) denotes that a result is significantly different from the three others methods ($p<0.05$). Pairs of results marked with (†) are significantly different from each other ($p<0.05$), but not significantly different from the unmarked methods.

Table 4 - Results of estimation estimates for each method - excluding the 6m old task.

	Method of weight estimation			
	APLS1	**APLS3**	**BGM**	**Table**
Total time taken (s) (95% CI)	35(*) (31-38)	48(*) (43-51)	38(*) (34-42	25(*) (22-28)
Accuracy (%) (95% CI)	95 (92-97)	93 (90-95)	94 (92-96)	96 (94-98)
Median % error (95% CI)	24% (10-60)	10%(†) (7.0-21)	32% (17-67)	70%(†) (34-133)
Correct answers (n)	455	444	453	461
Error type				
Arithmetic	25 (100%)	34 (94%)	21 (78%)	3 (16%)
Input	0	1 (3%)	6 (22%)	1 (5%)
month/year	0	1 (3%)	0	15 (79%)

Comparing the result of each method to one another by pairwise analysis, (*) denotes that a result is significantly different from the three others methods (p<0.05). Pairs of results marked with (†) are significantly different from each other (p<0.05), but not significantly different from those that remain unmarked.