WEIGHT ESTIMATION IN ADULTS DURING EMERGENCY CARE – A LENGTH BASED, HABITUS

Dr SMN Mason
MBChB (UP), DipPEC (SA)
Student number 0602474G

Weight estimation in adults during emergency care – a length based, habitus modified system

Dr SMN Mason

MBChB (UP), DipPEC (SA)

Student number 0602474G

Abstract

Background: Medical errors are a significant cause of morbidity and mortality, and a large portion of medical errors occur due to medication dose errors. Many drug doses are based on weight in adult patients and it is frequently difficult to weigh patients prior to emergency interventions. Doctors are notoriously poor at weight estimation. Much research has been devoted in the field of weight estimation in children and length-based tapes (e.g. PAWPER and Broselow tapes) have been shown to be effective at estimating weight in the emergency setting.

Objectives: To validate the accuracy of a length based, habitus modified system in weight estimation; to assess the accuracy of weight estimates by health care providers; and to assess the accuracy of weight estimates by patients.

Methods: This was a prospective study in which a convenience sample of 400 patients were enrolled. Researcher estimated patient weight. Patient estimated weight. Height, weight and body habitus recorded using tape measure, scale and observer estimate. Weight then estimated using pre-calculated formulae. The primary outcome measure for the study was PW20 within 20% for each estimate category- researcher estimate, participant estimate, and formula estimate. The secondary outcome measure for the study was PW10 for all of the abovementioned objectives.

Results: A total of 398 patients were eligible for study. For the group habitus <3, error within 10% was 43.8%, and error within 20% was 93.3%. For the Habitus 3, error within 10% was 22.3, and error within 20% was 48.5%. For habitus >3, error within 10% was 19.8% and error within 20% was 43.8%. Overall accuracy within 10% was 22.9% and within 20% was 50.3%. Researcher estimates overall error within 10% was 67.1%, and within 20% was 93.2%.

Conclusion: The height based, habitus modified system was shown to be inaccurate at estimating weight over the total study population, with the best accuracy achieved in the thin study population. Researcher and participant estimation was shown to be more accurate over the total study population.

Introduction

A man staggers into the Emergency Department (ED) with an ischaemic stroke[26-27] and collapses. How much thrombolytic does he need? How much is too much? How much is too little? In today's Emergency Medicine, standard, one-size-fits-all doses are no longer acceptable as weight-based dosing is becoming regarded as evidence-based care [2,5,9]

Medical errors are a daily occurrence, especially in the field of Emergency Medicine, where the emergency nature, as well as patient factors (e.g. uncooperative or unconscious patients, immobilised patients with severe trauma),[1,5,18] prohibit the rapid and accurate assessment of the patient's weight [2, 9, 15, 18] This leads to a significant proportion of weight-based drug errors, with patients often being significantly over- or under-dosed. Medications are often used in a 'stat', one size fits all dose that is not adjusted for weight or height of the patient.[9,15] This inevitably leads to significant morbidity and mortality, with patients not receiving the required dose of prophylactic antibiotics or receiving higher doses of potentially dangerous thrombolytics.

Emergency Medicine practitioners often rely on patient estimates, near relative best guesses, or health care provider estimates, none of which have been shown to be reliably accurate.[3, 13; 17-18] Patient guesses of their own weight approach nearly 80% accuracy (being within 20% of their actual weight), which is significantly better than health care provider estimates. Best guess estimates for health care providers ranged between 20 and 35% accuracy, with significant weight estimation errors of greater than 20% actual body weight occurring regularly.[19]

Methods have been developed using patient height to aid weight estimation, which have increased accuracy moderately (when compared with guessing alone), but have still proven significantly inaccurate, especially at the extremes of body habitus.[8,12,14] Formulae have been developed, relying on multiple variables to increase accuracy (e.g. waist circumference, calf circumference, triceps skin fold thickness).[11,13-14] These have increased the accuracy of weight estimation, but are difficult and time consuming to perform, while the formulas are not easily memorized and often require apps or calculators to use. This is not suited to the emergency environment, and these methods are better suited to a more stable setting.

The field of paediatrics has shown significant improvements in the field of emergency weight estimation, with the development of rapid calculation systems for estimating weight in children based on their ages (the APLS and Luscombe and Owens methods) as well as length based tapes (the Broselow and PAWPER tapes).[4,6-7,20] These methods have been shown to be rapid and reasonably easy to use, with moderate accuracy (better than the best weight estimate provided by the health care team) although the accuracy did vary with the different systems over the varying age categories for paediatric populations.

Literature research showed limited information or studies on the use of rapid, simple weight estimation methods in adults, despite the obvious need.[10] Due to the reasonable success of length-based, habitus modified systems in paediatric populations, we, the researchers, feel that this approach could potentially be modified for the use of such systems in adult populations.

There have been several studies using height based methods to estimate weight[10,13-14,19,21-22] , but none have been studied using height modified by body habitus.

The aims of the study were to assess the accuracy of weight estimates by health care providers, to assess the accuracy of weight estimates by patients and to validate the accuracy of a length-based, habitus modified system for weight estimation in a South African adult population.

Methods

Participants and Setting

The study took place between July and December 2016 in the Helen Joseph Hospital walk-in outpatient clinic. A convenience sample of 400 patients were enrolled in the study. All potential participants had to be older than 18 years of age, able to give consent, able to stand and not require emergency treatment. This research was approved was the Human Research Ethics Committee of the University of the Witwatersrand. All patients signed informed consent prior to participation.

Study protocol

The study was performed in the following sequence (see Figure 1):

- Participants were invited to participate
- Consent was obtained
- Each participant's weight was first estimated by the researcher
- Participants then provided an estimation their own weight
- Actual length was recorded using a tape measure
- Body habitus was estimated by the researcher using the Collins' figures as reference images
- Weight was calculated using the model developed for this study (see Figure 3).
- Finally, actual weight was measured on an electronic scale (Safeway electronic scale) to the nearest 0.1kg.

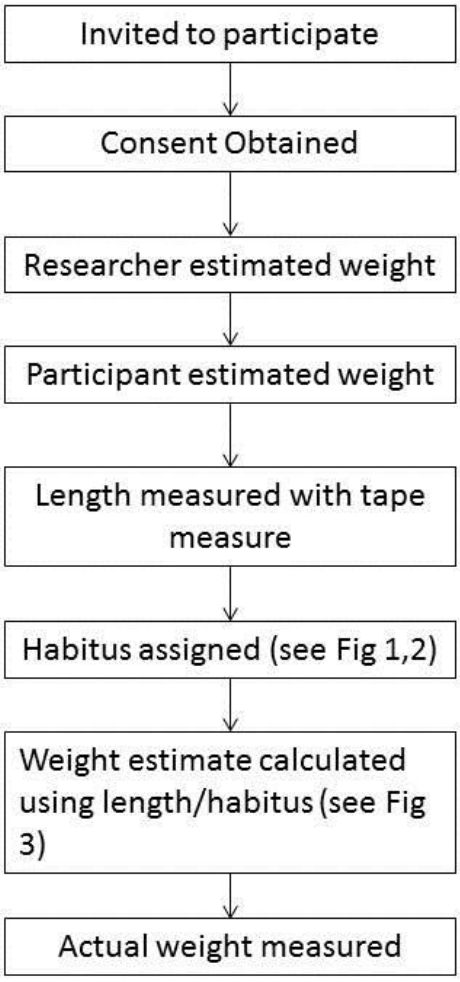

Figure 1 Diagram showing the study protocol

The weight estimation model

The novel model for weight estimation tested in this study was developed based on the principles of the PAWPER tape system [6]. It was a dual length- and habitus-based system. Pulvers' figures were employed to estimate body habitus. Habitus is separated into seven categories for both males and females, with 1 being very underweight, 3 being 'normal' and 7 being obese. The weights for adult patients were extrapolated (based on calculations performed by Prof M Wells) from the Centres for Disease Control weight-for-length growth charts. Weight was then estimated using height and the habitus corresponding to the reference Pulvers'

figures according to the estimation table (see Table 1 and Figures 2 and 3). Habitus scores 1-7 were used, although the Pulvers' extended to a habitus score of 9, due to the lower prevalence of massive obesity in the South African context.

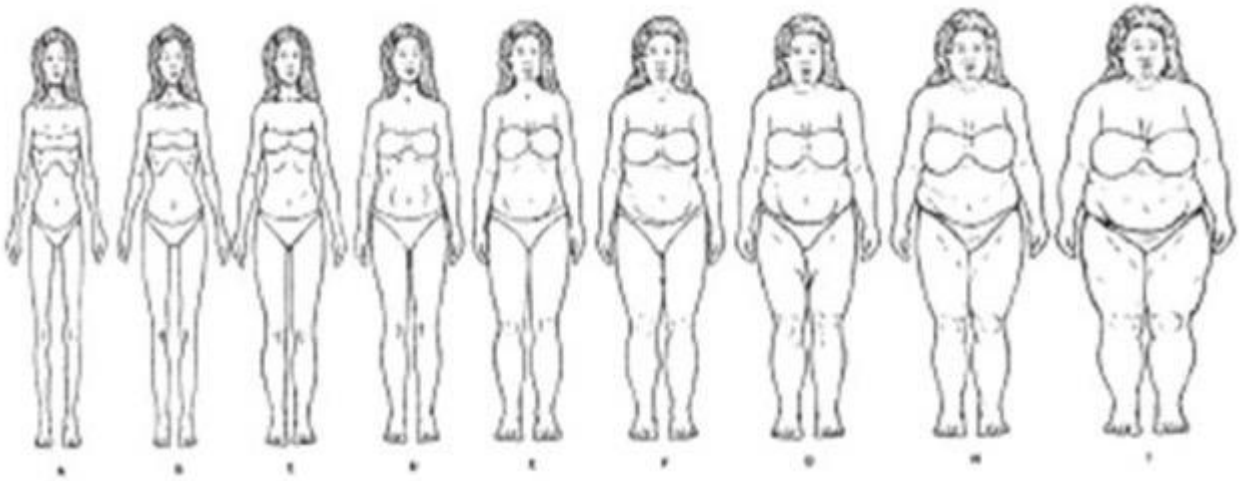

Fig 1 Pulvers figures Female [28]

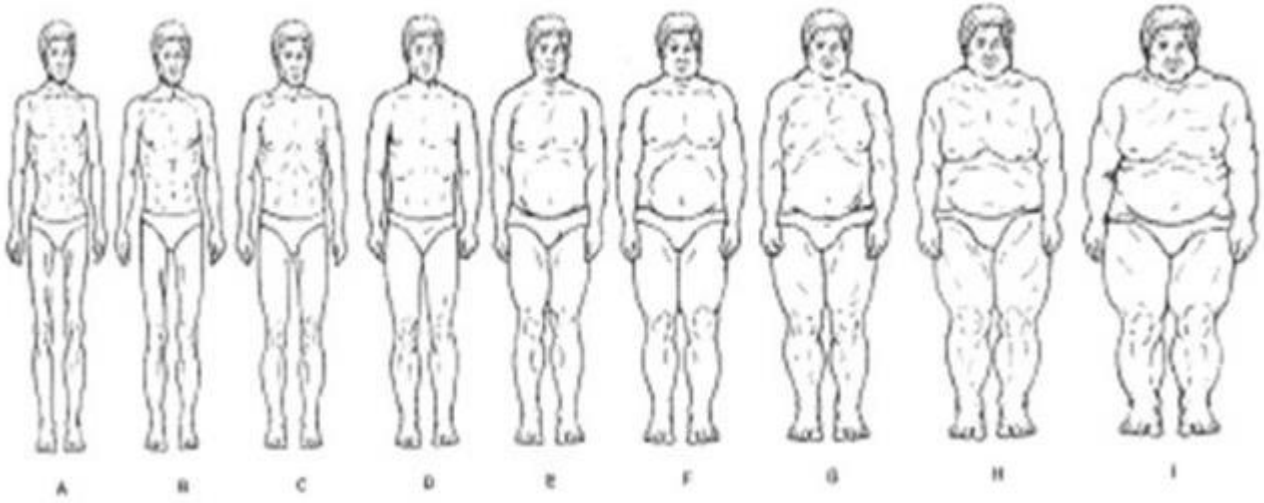

Fig 2 Pulvers figures Male [28]

LENGTH (mm)	BODY HABITUS SCORES with estimated weights (kg)						
	1	**2**	**3**	**4**	**5**	**6**	**7**
1433 to 1465	31	34	36	39	43	47	52
1466 to 1498	33	36	38	41	45	50	55
1499 to 1531	35	38	40	43	47	55	65
1532 to 1580	36	39	45	58	64	70	77
1581 to 1650	37	44	50	66	72	79	87
1651 to 1700	42	49	55	71	77	85	94
1701 to 1740	46	54	60	77	83	91	100
1741 to 1770	52	59	65	83	89	98	108
1771 to 1800	55	63	70	87	95	105	116
1801 to 1830	59	68	76	96	105	116	128
1831 to 1860	64	73	83	107	117	129	142
1861 to 1890	68	79	90	119	129	143	157
1891 to 1920	73	86	98	132	143	158	174
1921 to 1950	79	93	106	146	159	157	193

Table 1 Estimated weight for height and habitus devised for this study (based on prior calculations performed by Prof M Wells)

Data analysis

The habitus-modified estimate, researcher estimate and participant estimate were compared against the actual weight measured. There were several key outcome measures used:

- Mean percentage error for all three estimates and subgroups were calculated to represent bias (or trueness)
- Upper and lower limits of agreement of the percentage error were calculated to establish precision
- Percentage weight accuracy within 20% and within 10% (PW20 and PW10 respectively) were calculated for all estimates and subgroups to establish the overall accuracy of the estimates

Subgroup analysis was performed on groups based on habitus score: thin (habitus score 1 and 2), normal (habitus score 3 and 4) and obese (habitus score >4).

The primary outcome measure for the study was PW20 within 20% for each estimate category- researcher estimate, participant estimate, and formula estimate. The secondary outcome measure for the study was PW10 for all of the abovementioned objectives.

Results

Demographic information

A total of 398 patients were included, of which 146 participants were male (36.6%) and 252 (63.3%) were female. A total of 30 patients were included in the Thin (Habitus <3 group), 205 in the Normal (Habitus 3) group, and 162 in the obese group (Habitus >3 group).

Habitus	Number of participants
1	0
2	30
3	206
4	93
5	38
6	28
7	3

Table 2 Distribution of participants by habitus score

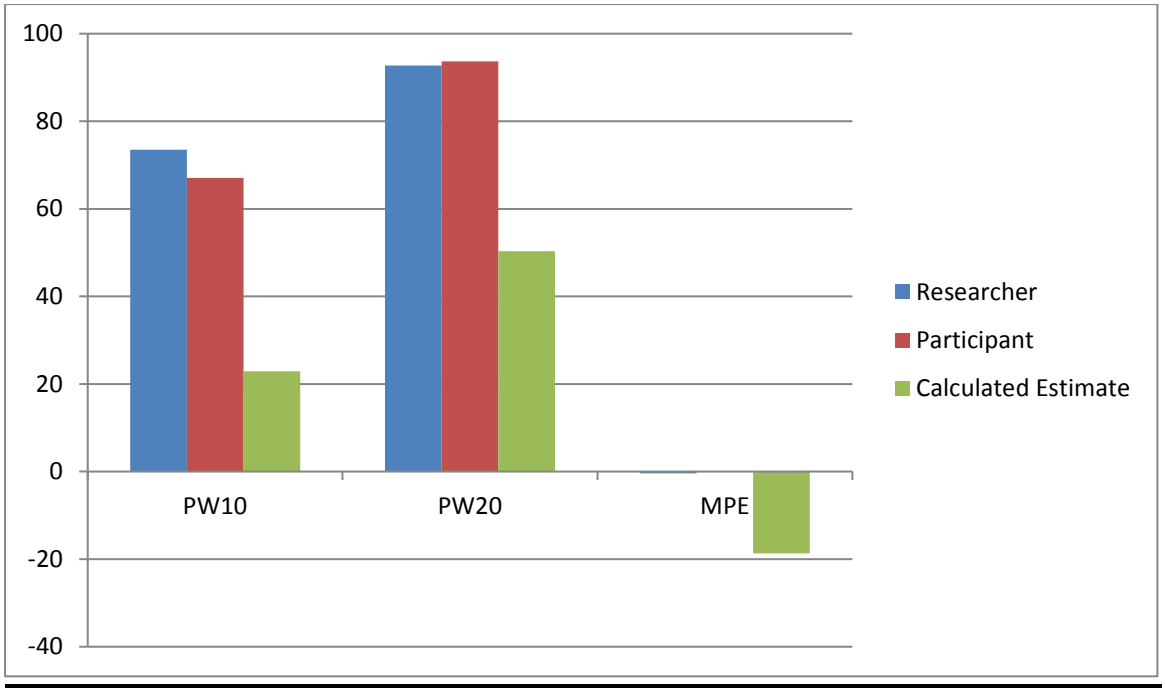

Figure 1: Bar chart showing PW20, PW10 and MPE for all three categories (MPE- Mean percentage error, PW20- Percentage weight within 20%. PW10- Percentage weight within 10%)

Table 3 Distribution of results for all participants and divided by category

	Analysis for all			**Thin**			**Normal**			**Large**		
	Researcher (%)	Participant (%)	Calculated Estimate(%)	Researcher (%)	Participant (%)	Calculated Estimate(%)	Researcher (%)	Participant (%)	Calculated Estimate(%)	Researcher (%)	Participant (%)	Calculated Estimate(%)
MPE	-0.4 (-21.5, 20.7)	0.1 (-22.3, 22.4)	-18.7 (-49.3, 11.8)	7.3 (-14.1, 28.8)	13.1 (-13.3, 39.4)	-5.3 (-28.1, 17.5)	0.5 (-18.9, 19.8)	1.5 (-19.5, 22.4)	-19.3 (-51.2, 12.7)	-2.8 (-24.4, 18.8)	-4.1 (-22.7, 14.6)	-21.8 (-56.2, 12.6)
ULOA	20.7	22.4	11.8	28.8	39.4	17.5	19.8	22.4	12.7	18.8	14.6	12.6
LLOA	-21.5	-22.3	-49.3	-14.1	-13.3	-28.1	-18.9	-19.5	-51.2	-24.4	-22.7	-56.2
PW10	73.5	67.1	22.9	62.1	36.7	43.3	76.1	72.8	22.3	72.2	65.4	19.8
PW20	92.7	93.2	50.3	86.2	70.0	93.3	95.1	94.2	48.5	90.7	96.3	43.8

(MPE- Mean percentage error, PW20- Percentage weight within 20%, PW10- Percentage weight within 10%, ULOA- Upper limits of agreement, LLOA- Lower limits of agreement)

Primary outcome of PW20 for the calculated estimates was 50.3%, with an accuracy of 93.3% in the thin group, 48.5% in the normal group and 43.8% in the large group. Secondary outcome of PW10 had an accuracy of 22.9% overall, with 43.3% for the thin group, 22.3% in the normal group and 19.8% in the large group. The healthcare provider estimates had an overall accuracy of PW20 of 92.7% and for the participants 93.2% (See Table 2, Figure 1).

Discussion

Calculated Estimates

The results showed that in the primary outcome of PW20, the calculated estimated performed with an accuracy of 50%, with a PW20 of greater than 90% in the thin group, but below 50% in the normal and fat groups. PW10 was below 50% in all groups, indicating that the system performed poorly when subjected to a PW10. MPE has consistently negative results, this indicates that the system consistently under-estimated the weights for all groups regardless of habitus, but with greater accuracy in the thin. Upper and lower limits of agreement were highly variable, indicating that there was a high degree of variability in the estimated results. LLOA for the large habitus group was -50%, indicating that participants were consistently underestimated. This could be due to the fact that there is a broad variability of weight in the larger habitus groups when compared to smaller habitus groups.

Researcher and Patient Estimates

Secondary outcomes of researcher/participant accuracy showed good accuracy, (MPE -0.4% and 0.1%; PW20 92.7% and 93.2%; and PW10 73.5% and 67.1% for researcher and participant respectively)

Both researcher and participant tended to overestimate the thinner group (ULOA 28.8% and 39.4% respectively), and underestimate the larger group (LLOA -24.4% and -22.7% respectively), with the researcher having better MPE overall for all groups (7.3%; 0.5% and -2.8%). Higher accuracy requirement (PW10) showed above average results for both the researcher and participant group, with the researcher having better accuracy over all the subsets of the analysis.

In comparison to previous studies [10,13-14,19,21-22] the length based, habitus modified system was shown to be comparably accurate to these methods in smaller habitus groups, but was less accurate as the habitus increased. These other methods tend to be more accurate due to the use of multiple factors considered and difficult to perform calculations based on the multiple factors. The studied method therefore requires further research into improving the weight estimates, considering the larger variation in weights among the larger habitus population.

Application

Clinically, this shows that the tape system would be an accurate method for estimating weight in smaller habitus adults, with little over- or under-estimating. However, for larger adults, care would have to be taken when interpreting the estimates.

Ultimately, the calculated estimates have been shown to be less accurate in adults than in paediatric populations (compared to PAWPER/Broselow systems). It has also been shown to be less accurate than the harder to perform calculation based estimation systems, although it is still significantly easier to perform.

Clinically this shows that the calculation estimate will significantly underdose in the large and normal population groups but will be reasonably accurate at estimating weight-based dosages in thinner population groups.

Comparison

Multiple studies have shown patient weight estimates by medical staff to have poor accuracy when it comes to estimation of weight, with variable results found in multiple studies. Patient weight estimates were shown to be more accurate than medical staff, but also not 100% accurate. Evidence has shown that where possible, patient estimate should be used over medical staff estimates. [12,19,23-26] However, participant and researcher accuracy in this study was shown to be more accurate than previous research. This could be due to multiple patient or researcher factors, such as patient level of literacy and researcher experience.

Overall, the assessed method has been shown to be less accurate when compared to rapid paediatric weight estimation techniques in estimating weight in patient

groups, particularly in the normal and obese groups. This is in comparison to researcher and participant guesses. However, patient and researcher estimation were shown to be better accurate than previous estimates.

Limitations

Body habitus, despite the use of Collins figures, is still a subjective measurement. It is therefore possible that habitus may have been over or under-estimated by the researcher in some cases. This would therefore lead to a significant error in weight estimate once the system was implemented.

Only one researcher was used for estimates, therefore this does not translate well to all researchers/health care providers, due to individual variations and experience with weight estimations.

Only one facility (and therefore local population) was used, therefore decreasing the variety of participants encountered.

Participants tended to be from a lower socio-economic background, and therefore educational background, which might influence their weight estimates due to a lack of knowledge of body habitus and weights.

The scale used originally was broken by a participant, with several readings being inaccurate after that. The scale was then replaced with a digital scale, but it is impossible to know the correlation and accuracy between the two scales. This might have affected weights prior or post the change.

Conclusions

In conclusion, the length based, habitus modified system is reasonably accurate when used in thinner habitus patients, and less accurate in larger habitus patients. Therefore, it is recommended that the calculations for the tape system be re-assessed to consider the greater variability in the larger habitus population.

Patient and researcher estimates were shown to be more accurate than in previous studies, with the researcher being significantly more accurate than previously shown.

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