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COMPARISON OF WEIGHT ESTIMATION FORMULAE IN PAEDIATRIC PATIENTS AT CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

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A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Medicine in the branch of Anaesthesiology

Johannesburg, 2017

DECLARATION

I, Zakiyya Soni, declare that this research report is my own, unaided work. It is being submitted for the degree of Master of Medicine in the branch of Anaesthesiology at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

Signature

Signed at: University of the Witwatersrand, Johannesburg

On this date:

ABSTRACT

Background

Accurate weight determination is essential in providing optimal care to the paediatric population, as both over- and under-estimation can be detrimental.

This study aimed to compare the accuracy and precision of three paediatric weight estimation formulae, the Advanced Paediatric Life support (APLS), the formula used by anaesthetists in academic hospitals affiliated to the University of Witwatersrand (Wits-A), and the Luscombe and Owens (LO) formula, to the measured weight of children at the Chris Hani Baragwanath Academic Hospital (CHBAH) outpatient department.

Methods

A prospective, contextual, descriptive study design was used with quota sampling. Four hundred children aged 1 - 10 years were recruited for the study. Age, gender, ethnicity, weight and height were recorded.

Results

On average the APLS formula performed the best with 49 % of estimates within 10% of the actual measured weight (PW10), the lowest mean percentage difference (MPD) of +0.7% and the narrowest 95% limits of agreement. The Wits-A formula followed with a PW10 of 41% and a MPD of -5.2% while the LO formula had a PW10 of 24% and a MPD of -19.4%.

Conclusion

An accurate and precise weight estimation technique remains elusive and the gold standard is a measured weight. The APLS formula was however found to be the most accurate in the CHBAH population and should be used over the Wits-A formula if a formula has to be used.

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Table of Contents

DECLARATION ii
ABSTRACT iii
Background iii
Methods iii
Results iii
Conclusion iii
ACKNOWLEDGEMENTS iv
LIST OF FIGURES vii
LIST OF TABLES viii
LIST OF ABBREVIATIONS ix
SECTION 1: LITERATURE REVIEW AND BACKGROUND 1
1.1 SIGNIFICANCE OF WEIGHT ESTIMATION IN THE PAEDIATRIC POPULATION 1
1.2 WEIGHT ESTIMATION TECHNIQUES 2
1.2.1 Broselow tape technique 6
1.2.2 APLS formula 9
1.2.3 Argall formula 11
1.2.4 Luscombe and Owens formula 11
1.2.5 Best Guess formulae 13
1.2.6 Parents', nurses', and doctors' estimations 14
1.3 STUDIES EVALUATING MORE THAN ONE WEIGHT ESTIMATION TECHNIQUE 15
1.4 FORMULA USED BY ANAESTHETISTS AT ACADEMIC HOSPITALS AFFILIATED TO WITS 17
1.5 THE SOUTH AFRICAN STUDIES 19
1.6 GLOBAL OBESITY EPIDEMIC 20
1.7 DEFINING AND CLASSIFYING OVERWEIGHT AND OBESITY 20
1.8 DEFINING AND CLASSIFYING BMI 21
1.8.1 CDC recommendations 22
1.8.2 WHO and CDC combined recommendations 22
1.8.3 IOTF recommendations 23
1.9 THE SOUTH AFRICAN POPULATION 23
1.10 SUMMARY 24
References 25
SECTION 2: JOURNAL GUIDELINE TO AUTHOR 30

SECTION 3: DRAFT ARTICLE 36
Abstract 38
Introduction 39
Methods 41
Results 43
Discussion 47
Conclusion 49
Acknowledgements 49
Conflict of Interest 49
References 50
Section 4: APPENDICES 54
SECTION 5: PROPOSAL 57
5.1 INTRODUCTION 58
5.2 PROBLEM STATEMENT 60
5.3 AIM 60
5.4 OBJECTIVES 61
5.5 RESEARCH ASSUMPTIONS 61
5.6 DEMARCATION OF STUDY FIELD 62
5.7 ETHICAL CONSIDERATIONS 62
5.8 RESEARCH METHODOLOGY 63
5.8.1 Study design 63
5.8.2 Study population 63
5.8.3 Study sample 64
5.8.4 Data collection 64
5.8.5 Data analysis 65
5.9 SIGNIFICANCE OF STUDY 67
5.10 VALIDITY AND RELAIBILITY 68
5.11 POTENTIAL LIMITATIONS 68
5.12 PROJECT OUTLINE 69
References 70

LIST OF FIGURES

Figure 1. Mean measured weights for each age category, and the estimated weight using the 3 different formulae 44
Figure 2. Bland Altman plots for each weight estimation formula 45
Figure 3. BMI-for-age (Girls) 46
Figure 4. BMI-for-age (Boys) 47

LIST OF TABLES

Table 1. Advantages and disadvantages of height based versus age based weight estimation methods 3
Table 2. Weight estimation techniques and their age or height parameters 4
Table 3. Broselow tape studies reviewed by world economic status 8
Table 4. APLS studies reviewed by world economic status 10
Table I. Calculation of weight estimation formulae and BMI as well as their age parameters 42
Table II. Interpretation of BMI for children 42
Table III. Weight and height and BMI for gender per age category 43
Table IV. Mean percentage difference (MPD), standard deviation (SD), 95% limits of agreement (LOA) and PW10 for each weight estimation formulae 44

LIST OF ABBREVIATIONS

APLS	Advanced Paediatric Life Support
CHBAH	Chris Hani Baragwanath Academic Hospital
Wits	University of the Witwatersrand
BMI	Body mass index
DWEM	Derived Weight - Estimating Method
MPD	Mean percentage difference
NCHS	National Centre for Health Statistics
USA	United States of America
UK	United Kingdom
GNI	Gross National Income
PAWPER	Paediatric Advanced Weight Prediction in the Emergency Room
WHO	World Health Organisation
IOTF	International Obesity Taskforce
CDC	Centres for Disease Control and Prevention
LO	Luscombe and Owens
SD	Standard Deviation
LOA	Limits of Agreement
POPD	Paediatric Outpatient Department

SECTION 1: LITERATURE REVIEW AND BACKGROUND

A detailed review on paediatric weight estimation techniques is discussed in this section.

The introduction focuses on the importance of accurate weight determination, the consequences of inaccuracies, especially in the emergency setting, and reasons why it may be impossible or impractical to weigh a child.

Secondly the various techniques developed to aid clinicians with paediatric weight estimation will be reviewed. A detailed discussion of each method follows: where and when it was developed, the population on whom it was studied and the subsequent studies validating it. The techniques discussed in detail are the Broselow tape, Advanced Paediatric Life Support (APLS) formulae (original and updated), Argall formula, Luscombe and Owens formula, Best Guess formulae and Shann formula. The advantages and disadvantages of height based versus age based weight estimation techniques are also tabulated.

Next the combined studies evaluating more than one technique are discussed. Comparisons and conclusions are drawn from these. Thereafter the three studies identified from South Africa which compared weight estimation techniques are discussed. The history, or lack thereof, of the formula used by anaesthetists at Chris Hani Baragwanath Academic Hospital (CHBAH) and other academic hospitals affiliated to the University of the Witwatersrand (Wits) is then explored.

Lastly, the second important component of the study, the relevance of body mass index (BMI) in the paediatric population, the global childhood obesity epidemic (including the definition, and controversy around the evaluation of overweight and obesity), and the particular challenges faced by the South African population is addressed.

1.1 SIGNIFICANCE OF WEIGHT ESTIMATION IN THE PAEDIATRIC POPULATION

Accurate weight assessment is crucial both in the emergency and elective setting. Most medication dosages in children, airway device sizes and resuscitative

interventions such as defibrillation energy selections, are calculated according to weight (1).

With regards to medication dosing, an overdose may result in lethal toxicity, especially with drugs with a narrow therapeutic index, whereas an underdose may not meet therapeutic requirements (2). It is therefore crucial to determine the weight as accurately as possible to reduce the margin for error.

To date the gold standard is still a measured weight (3). However, this may be impossible in a critically ill child requiring immediate resuscitation or in settings where calibrated, working scales may be scarce.

At the time of this research no validated universal technique for the estimation of paediatric weight has been validated, with particular concern over the applicability of developed country techniques in developing country populations (1). This highlights the importance of this study, and the need for a technique applicable to different populations.

1.2 WEIGHT ESTIMATION TECHNIQUES

Numerous techniques have been described in order to assist clinicians with paediatric weight estimation, the majority of these being age based formulae. Table 1 is an unabridged version of the advantages and disadvantages of height based versus age based weight estimation techniques from the APLS Guidelines (4).

Table 1. Advantages and disadvantages of height based versus age based weight estimation methods (4)

	Height based weight estimation method (e.g. Broselow tape)	**Age based weight estimation method (e.g. APLS and Luscombe and Owens formulae)**
Advantages	Simple to use	Simple to use
	Reduces cognitive load of remembering formulae	Does not require measuring tapes or tables
	Can be used with a system of pre-packaged equipment	Can be used in any environment
	Useful when age not known	No equipment cost
	Reasonably accurate	Allows preparation of equipment and medication doses in patients who are notified by the ambulance personnel prior to arrival to the hospital
Disadvantages	May not be readily available (e.g. pre-hospital setting)	Need to remember and calculate the formula
	Limited to weight 3 − 36 kg and height 46 − 147 cm	Limited to age 1 − 10 years
	Cost of Broselow tape	Tends to underestimate or overestimate

Table 2 gives an overview of the various techniques, when they were developed, and their age or height parameters.

Table 2. Weight estimation techniques and their age or height parameters

Weight estimation Technique	Date derived	Technique (table, tape or formula)	Age or height parameters
Traub-Johnson formula (5)	1980	2.05 x *e* (to the power of 0.02 x height in cm)	1 − 18 years
Traub-Kitchen formula (6)	1980	2.396 x 1.0188 (to the power of height in cm)	1 − 17 years and height over 74 cm
Derived Weight - Estimating Method (DWEM) table (7)	1986	Weight from table	50 − 175 cm
Oakley chart (8)	1988	Weight from chart	50 − 160 cm
Broselow tape (9)	1988	As per height	46 − 147 cm or 3 − 36 kg
Original (APLS) formula (4)	1988	(Age in years + 4) x 2	1 − 10 years
Updated Advanced Paediatric Life Support (updated APLS) formulae (10)	2011	(Age in months x 0.5) + 4 (Age in years x 2) + 8 (Age in years x 3) + 7	1 − 11 months 1 − 5 years 6 − 10 years
Argall formula (11)	2003	(Age in years + 2) x 3	1 − 10 years
Nelson formulae (12)	2004	(Age in months + 9) / 2 (Age in years × 2) + 8 (Age in years × 7 − 5) / 2	Infants 3 − 11 months 1 − 6 years 7 − 12 years
Luscombe and Owens Formula (13)	2007	(Age in years x 3) + 7	1 − 10 years
Best Guess formula (14)	2007	(Age in months + 9) / 2 (Age in years + 5) x 2 Age in years x 4	Infants < 12 months 1 − 4 years 5 − 14 years
Wits Anaesthesiology formula (Wits-A) (15)		(Age in years x 2) + 9	Not Specified
Shann Formula*	Unknown	(Age in years x 2) + 9 Age in years x 9	1 − 9 years 10 years

* Derivation and validation studies could not be identified

A review of each technique, in chronological sequence from the earliest to the most recently developed follows. Techniques prior to the year 2000 have not been discussed in detail except for the Broselow tape and APLS formula. Both of these techniques were derived from the same data set, are the earliest and most commonly employed as a benchmark against which other techniques are measured. Each technique is discussed in the same sequence, where and by whom it was developed and the subsequent studies validating it. Once they have all been discussed in totality, individual studies evaluating more than one technique, are discussed. To conclude this aspect of the chapter, doctors', nurses' and parents' estimates are reviewed.

Concerning evaluation of the various techniques, there is very little agreement with regards to the ideal assessment in the literature. The statistical analyses vary between the various studies (16, 17). However, the best single reflection of performance is probably the proportion of children whose weights are estimated to be within 10% of their actual weights. Most authorities seem to agree on an error limit within 10%, however there is disagreement as to the proportion of children's weights within this proportion. Some researchers have viewed 60% as a poor indicator (18) while others have suggested this to be too strict a limit (19). However, a limit of 60% seems to be the lowest acceptable value (17).

The other measure described for evaluation of the performance of the various techniques is the mean percentage difference (MPD). This is calculated as:

(True weight – estimated weight) / true weight x 100.

A positive value indicates an underestimation of weights on average, while a negative value would conversely imply an overestimation. The mean bias is also reported in some studies. This is calculated as:

(True weight – estimated weight) / true weight.

The majority of the techniques or formulae discussed are evaluated using either one of these parameters.

With regards to the older techniques, the Traub-Johnson and Traub-Kitchen formulae have possibly not gained favour due to their complexity. Both require the

use of a scientific calculator which may be expensive and impractical in a resource poor setting.

The Oakley chart and the DWEM, have also been poorly accepted. Of the studies identified, two studies looked at the Oakley chart (16, 20) and three at the DWEM (7, 20, 21) subsequent to their description in the early 1980's. The Oakley chart is a reference chart based on either weight or height. To the left of the age for weight chart, the length and depth of endotracheal tubes, corresponding to age (y-axis), are tabulated. Below the table various emergency drug doses and initial defibrillation settings are recorded. These correspond to weight (x-axis) (8). The DWEM involves weighing a child, assessing body habitus and then reading off the corresponding weight on the table (7). Both techniques seem valuable, however, the limited number of studies regarding their comparison or validation to other techniques prevents an exact assessment of their accuracy from being made.

1.2.1 Broselow tape technique

In 1979, the National Centre for Health Statistics (NCHS) published a new set of growth curves for children in the United States of America (USA) using data collected by the NCHS between 1963 and 1975. A nationwide sample group of 20 000 children were chosen by the NCHS and the United States Bureau of Census. Using this data, Broselow then determined the 50th percentile weight for the various lengths or height. This was translated to a colour coded measuring tape (9).

The Broselow tape technique is only applicable to children who are 46 − 147 cm in height or 3 − 36 kg in weight. It involves measuring the child from head to toe, and using height, a specific weight class is assigned. The "usefulness of the tape extends beyond weight estimation, as the colour coded weight classes also list dosages of commonly used resuscitation drugs and the sizes of resuscitation equipment" (such as endotracheal tubes and suction catheters) (3).This is particularly helpful in emergency situations as it simplifies the cognitive workload placed on the clinician and thus reduces the margin of error (3).

In addition to the tape, Broselow also developed a paediatric resuscitation trolley. The colours on the tape correspond to those on the trolley drawers, and used in conjunction with one another, it may be more effective in an emergency situation.

Only one study could be found regarding the efficiency of the trolley, as most of the studies focus on the accuracy of the Broselow tape as a weight estimation technique (22). Argall et al (23) found that use of the Broselow paediatric trolley resulted in a significantly faster location of intubation instruments compared to standard trolleys. Only 10% of participants had prior experience with the Broselow trolley (23).

In 1988, the first study was undertaken to evaluate the accuracy of weight estimation by this technique. Lubitz et al (9) used a prototype of the Broselow tape. It was compared to weight estimates made by doctors' and nurses', the most commonly used technique at the time, and found to be significantly more accurate. According to the results, 59.7% of the Broselow tape estimations were within 10% of the measured weight, and 79% within 15%.

Even in 1988, the accuracy of the Broselow tape technique estimation was shown to decrease in children weighing more than 25 kg. This was explained by a change in body habitus in older children, and it was suggested that a possible variation would be the inclusion of a body habitus variable (9). Numerous subsequent studies have shown that the Broselow tape is unreliable at higher weights (24-27), yet the modification has not yet been put to print.

Table 3 provides a summary of the identified studies regarding the Broselow tape technique reviewed according to world economic status.

World economic status is classified by the World Bank (28) as high, upper middle-, lower middle- or low income economies. The high income group are then regarded as developed countries while the other three groups are collectively grouped as developing countries. Gross National Income (GNI) per person, the purchasing power of a citizen, is often used as the main criterion. Other variables are also considered such as geographical region and external debt. There are limitations, however, as the classification by income may not necessarily reflect the development status of a country. Certain countries with a biased income distribution may have a relatively high per-capita GNI despite most of its citizens having a relatively low level of income. Economies are re-evaluated on 1 July every year (28).

Table 3. Broselow tape studies reviewed by world economic status

Author	Year	Location	Sample size	Author conclusions
Developed countries				
Lubitz et al (9)	1988	USA	937	Accurate
Hofer et al (24)	2002	Switzerland	585	Accurate
Black et al (20)	2002	Australia	339	Accurate
Argall et al (11)	2003	United Kingdom (UK)	300	Accurate
Theron et al (16)	2005	New Zealand	909	Underestimate
Nieman et al (18)	2006	USA	7 813	Accurate
Krieser et al (26)	2007	Australia	41	Accurate
DuBois et al (21)	2007	USA	300	Accurate
Jang et al (25)	2007	Republic of Korea	665	Accurate
So et al (27)	2009	USA	1 011	Accurate
Casey and Borland (29)	2010	Australia	1 028	Accurate
Bourdeau et al (30)	2011	Canada	243	Underestimate
Rosenberg et al (3)	2011	USA	372	Underestimate
Park et al (31)	2012	Republic of Korea	124 094	Accurate
Sinha et al (32)	2012	USA	118	Underestimate
Ken Milne et al (33)	2012	Canada	6 361	Underestimate
Heyming et al (34)	2012	USA	572	Accurate
Loo et al (35)	2013	Singapore	875	Accurate
Britnell and Koziol-Mclain (36)	2015	New Zealand	376	Accurate
Skrobo and Kelleher (37)	2017	Ireland	3 155	Underestimate
Developing countries				
Varghese et al (38)	2006	India	500	Accurate
Ramarajan et al (39)	2008	India	548	Overestimate
Geduld et al (1)	2011	South Africa	2 832	Accurate
House et al (40)	2012	Kenya	967	Accurate
Shah and Bavdekar (41)	2017	India	210	Overestimate

The findings of underestimation, overestimation or accuracy are as defined by the authors of the respective articles. The Broselow tape may still under- or over-estimate and be recorded as accurate. This applies to all of the studies discussed.

The studies which also compare other weight estimation techniques are discussed separately under the relevant subheadings.

1.2.2 APLS formula

One of the most frequently used techniques for estimating weight is that taught by the APLS course (4). This formula, like the Broselow tape, was also derived from the 1977 NCHS USA data (1). It was recommended for children aged 1 − 10 years, and based on age in completed years. It is calculated as follows:

$$\text{Weight (kg)} = (\text{age in years} + 4) \times 2$$

In 2011 the original APLS formula was revised. Three new formulae were proposed; for infants 1 to 11 months, children aged 1 − 5 years and children aged 6 − 12 years. The formula for 1 − 5 year olds is equivalent to the original APLS formula and that used for 6 − 12 years is the same as the Luscombe and Owens formula (10).

The original formula is still used in the European Paediatric Life Support course. In reviewing the literature, it became evident that even studies after 2011 referred to the original and not updated APLS formula. Likewise, in this review the APLS formula refers to the original formula.

Table 4 presents a summary of all the studies identified comparing this formula to measured weight, or to other weight estimation techniques. Of all the studies identified, it is evident that the APLS formula consistently underestimates weight in developed countries (13, 14, 16, 20, 35, 42-44). Five studies were identified from the developing countries, and their findings are contradictory. Two studies found the APLS formula overestimated weight (38, 45), two studies found it accurate in predicting children's weight (1, 40) and one study found it to underestimate weight (46).

Table 4. APLS studies reviewed by world economic status

Author	Year	Location	Sample size	Author Conclusions
Developed countries				
Black et al (20)	2002	Australia	376	Underestimate
Argall et al (11)	2003	UK	300	Accurate
Theron et al (16)	2005	New Zealand	909	Underestimate
Luscombe and Owens (13)	2007	UK	17 244	Underestimate
Tinning and Acworth (14)	2007	Australia	67 363	Underestimate
Sandell and Charman (44)	2009	UK	544	Underestimate
Luscombe et al (43)	2010	UK	93 827	Underestimate
Loo et al (35)	2013	Singapore	875	Underestimate
Britnell and Koziol-McLain (36)	2015	New Zealand	376	Underestimate
Ali et al (42)	2012	Trinidad and Tobago	1723	Underestimate
Developing Countries				
Varghese et al (38)	2006	India	500	Overestimate
Geduld et al (1)	2011	South Africa	2832	Accurate
House et al (40)	2012	Kenya	967	Accurate
Georgoulas and Wells (46)	2016	South Africa	300	Underestimate
Bowen et al (45)	2017	Zambia	1381	Overestimate

Being one of the earliest and most common age based techniques employed, the original APLS formula is often used as a gold standard against which other formulae were derived or validated. These studies will be discussed either under the relevant formula or under combination studies, if more than one formula was evaluated.

1.2.3 Argall formula

In 2003, Argall et al (11) compared the Broselow tape technique and APLS formula to the measured weight. The study included 300 children attending an emergency department in the UK. They concluded that although the study confirmed that both methods of estimation correlated well with actual weight, there were significant outliers, and that with increasing age and weight they became more inaccurate. Once again, this was explained by the increasing trend of overweight and obesity in the developed country populations. The Argall formula was then derived using the same dataset:

$$\text{Weight (kg)} = (\text{age in years} + 2) \times 3.$$

A subsequent study by Nguyen et al (47) failed to validate the formula. Even though the study was conducted in Australia, also classified as part of the developed country population, the formula underestimated weight with a mean bias of −1.66 kg, compared to only −0.52 kg in the derivation study. The sample population is stated as a limitation, however this is a limitation of every study attempting to validate or compare weight estimation techniques.

No other studies purely validating the Argall formula were identified.

1.2.4 Luscombe and Owens formula

In 2007 Luscombe and Owens (13) collected data on the ages and weights of 17 244 children aged 1 − 10 years. The sample was taken from a large emergency department in a major city in the UK. The aim was to compare the data with the APLS formula, and if a significant difference was found, a more accurate formula would then be derived using the same data set.

A sample size calculation was carried out to establish the minimum number of children needed to provide adequate data to allow individual age group analysis. This was determined to be 400 per age group. Data were collected from 17 244 children, aged 1 − 10 years of age (13).

The APLS formula was found to underestimate weight by a mean percentage difference of 18.8%, attributed to the rising trend of overweight and obesity in the

studied population. A new formula, the Luscombe and Owens formula, was then derived:

$$\text{Weight (kg)} = (\text{age in years} \times 3) + 7.$$

This formula was found to be the most accurate with a mean percentage underestimate of only 2.5%. It was the same as the APLS formula at age one, but more accurate at all other ages (13).

The authors did conclude that the use of two formulae would be more accurate than one, given the change in the age-weight relationship at approximately six years of age. However, they found that in the stressful environment the use of one formula is more appropriate, as it decreases the potential for error (13).

In 2010, Luscombe et al (43) attempted to validate the formula described in their earlier study. The sample population of 93 827 children was also from a city in the UK and showed similar results to their previous study. They found that the APLS formula underestimated children's weights by a mean percentage difference of 33.4% over the age range 1 − 16 years, compared to a mean percentage underestimate of only 6.9% using the formula derived in their earlier study (43).

In 2011, Kelly et al (48) collected data from 410 Australian children. Their primary objective was validation of weight estimated by the Luscombe and Owens formula, to measured weight. Their secondary objective was a comparison to three other weight estimation formulae: The Argall, APLS and Best Guess formulae. It was found that 46% of the Luscombe and Owens formula estimates were within 10% of measured weight. Accuracy deteriorated at higher measured weight. The performance of the Luscombe and Owens formula was similar to the Best Guess formulae and better than the Argall formula and the APLS formula (48).

In 2012, Ali et al (42) attempted to primarily validate the original APLS formula which was commonly used in the Trinidadian population for children aged 1 – 5 years. Its validity was being questioned in developed countries with the Luscombe and Owens being shown to be a better estimate in these populations. A 'best fit' formula was derived from linear regression analysis of the measured weights and also compared to the above two formulae. The precision and accuracy of the three formulae were not significantly different from each other. The percentage estimates within 10% of

actual weight for the APLS, Luscombe and Owens and 'Best fit' formulae were 46%, 42% and 48% respectively. A recommendation was made to continue using the APLS formula as it was well known, simple and widely taught in their setting (42).

Skrobo and Kelleher (37) compared the Luscombe and Owens to the original APLS formula, their motivation being the increased incidence of obesity in their population. Data were collected from 3155 Irish children aged 1 – 15 in 2013. Their findings confirmed their suspicion of underestimation. The APLS underestimated weight by a mean of 20 % while the Luscombe and Owens showed a mean underestimation of 4% (37).

1.2.5 Best Guess formulae

In 2007 the Best Guess formulae were derived in Australia. With a substantial increase in children either classified as overweight or obese in developed countries, Tinning et al (14) identified the need for a revised formula. A study group of 67 363 was utilised in order to derive formulae that reflected the relationship between age and weight for each of three different age groups. According to the authors, a single formula could not be used to accurately estimate weight across a wide age range due to the different growth profiles throughout different age groups. The data were subsequently divided into three age groups. These were based on three social milestones in children corresponding to changes in growth velocity (14). The formulae are described as:

For infants <12 months: Weight (kg) = (age in months + 9) x 2

For children aged 1 − 4 years: Weight (kg) = (age in years + 5) x 2

For children aged 5 − 14 years: Weight (kg) = age in years x 4.

Later in 2007, the formulae were externally validated by Kelly et al (49). The study was carried out in a single multi-ethnic Australian population and included 410 children (11 years and younger). They found that the Best Guess formulae were accurate to within 20% of measured weight on more than 75% of the time in the 1 - 4 year group, and more than 60% of the time in the 5 − 11 year group (49). Comparatively, the Best Guess formula performed moderately well, but had a tendency to overestimate weight particularly in children with a lower BMI (49). The

differences however could be accounted for by the different sample population as the derivation study population were all Caucasian, whereas the study by Kelly et al had 25% non-Caucasian children who were found to be leaner (49).

No other studies exclusively validating the Best Guess formulae were identified.

1.2.6 Parents', nurses', and doctors' estimations

Four studies evaluating parents, nurses or doctors' estimates were identified since 1999, three from the USA and one from Australia.

In 1999 Harris et al (50) demonstrated that parents, nurses and physicians were all unable to accurately estimate paediatric patient weights, and that all three groups were comparably inaccurate. Twenty nine percent of doctors' estimates, 40% of nurses' estimates and 16% of parents' estimates differed from the actual weight by more than 15% (50).

Krieser et al (26), in 2007, compared parent estimates and five weight estimation techniques (Broselow tape technique and four age based formulae) with measured weight. In this study of 410 Australian children, parents were the most accurate, with 78% of estimates within 10% of measured weight (26).

A 2009 study by Partridge et al (51) concluded that parents were more accurate at estimating children's weights than nurses, and were 79% of the time within 10% of the measured weight. Nurse estimates were far more inaccurate with only 55% within 10% of the measured weight. The sample population included 812 children from the emergency department of a children's hospital in Washington.

Also in 2009, Rosenberg et al (3) demonstrated that the Broselow tape technique was more accurate than doctors' estimations except in obese children. The reason for the discrepancy is uncertain. Sixty three percent of the Broselow tape technique estimations, compared to only 43% of doctors' estimates, were within 10% of measured weight.

From the limited number of studies, doctors (3, 50) and nurses (50) are unable to reliably estimate the weight of children, whereas with parents', the results are conflicting, two studies concluding accuracy (26, 51) and the other not (50). It may however not be possible to rely on parents' estimates exclusively, as parents may

not be available, or unable to recall or estimate weight in an emergency situation (3). In some instances, the primary caregiver may not be the person accompanying the child. This may be particularly true in the South African context. These variables have not been studied and therefore estimates would have to be used in conjunction with another weight estimation technique, the one chosen being most appropriate for that population.

1.3 STUDIES EVALUATING MORE THAN ONE WEIGHT ESTIMATION TECHNIQUE

An attempt has been made to group the studies in a logical order, however this is challenging as individual studies not only compare different techniques, but also report results using different parameters of bias, precision and accuracy, some studies only reporting a mean percentage difference and others only the proportion of estimates within 10%, 20% or even 30% of the actual weight.

The following two studies evaluate the Broselow tape, APLS formula, and one of two recently derived formulae: The Best Guess formulae in the case of the first study and the Luscombe and Owens formula in the second.

In 2010, Casey and Borland (29) recruited 1235 children, aged 0 − 14 years, presenting to an emergency department in Australia. Of the three techniques evaluated, the Broselow tape was found to be the most precise across all age groups. The Best Guess formulae were found to be accurate, particularly in the 1 − 4 year age group, with a tendency to moderately overestimate weight in other age groups. The APLS formula had the lowest accuracy and precision, underestimating weight in all age groups.

In 2013, Loo et al (35) recruited 875 Asian children, aged 1 – 10 years, in a paediatric emergency department in Singapore. Of the three techniques evaluated, the Broselow tape was again found to be the most accurate only marginally underestimating weight with a MPD of 0.6%, while the APLS and Luscombe and Owens formulae, underestimated and overestimated weight with a MPD of 7.6% and 7.4% respectively. With regards to the percentage estimates within 10% of actual weight the Broselow tape, APLS and Luscombe and Owens were 60%, 46%, and

36% respectively. The Broselow tape was found to be the most accurate and precise method of weight estimation (35).

The following two studies identified considered Nelson's age based formulae from Nelson's Textbook of Paediatrics (12). Both studies are from developing countries, where the formulae still seem to be widely accepted, quiet contrary to developed countries. No studies validating only Nelson's formulae could be identified.

The formulae are:

For infants aged 3 − 12 months: (age in months + 9) / 2

For children aged 1 − 6 years: (age in years × 2) + 8

For children aged 7 − 12 years: (age in years × 7 - 5) / 2.

The first is a study from 2006 by Varghese et al (38). The primary objective of this study was to validate the Broselow tape in an Indian population. The secondary objective was to validate three of the most commonly employed weight estimation formulae (APLS, Argall, and Nelson's formulae) for emergency needs (adrenaline dose, fluid bolus and endotracheal tube size). The authors questioned these techniques as they were all derived in the western population, and it was suspected they would overestimate the weight of Indian children. The Broselow tape was found to be the most accurate, and of the formulae, they all were found to overestimate weight.

The second is a study from 2012 by House et al (40). This study aimed to validate the Broselow tape in a Kenyan population by comparing it to the APLS and Nelson's formulae. The Broselow tape and APLS formula were found to be most accurate (however still overestimating weight) in determining weight with a MPD of – 2.2% and – 5.2% respectively, while the Nelson's formulae overestimated weight with a MPD of – 10%.

Thus, both studies from the developing countries showed a consistent overestimation with Nelson's formulae.

One of the first studies evaluating the updated APLS was in 2014 by Graves et al (52). They compared the actual recorded weights of Australian children to the

predicted weights using the original and updated APLS, Luscombe and Owens, Best Guess formulae and the Broselow tape. They found the Best Guess Formulae to be the most accurate for children over the age of 1 year and the updated APLS more accurate in children less than 1 year of age (52).

One other study comparing the original and updated APLS formulae was identified. This study is discussed in the next subsection as it incorporated the Shann formulae (45).

1.4 FORMULA USED BY ANAESTHETISTS AT ACADEMIC HOSPITALS AFFILIATED TO WITS

The formula used by anaesthetists in the Department of Anaesthesiology, Wits, has not, to the researcher's knowledge, been validated in the South African population. In fact, there is very little information with regards to this formula. It is suggested from a prescribed textbook, Clinical Anaesthesiology (15), with no reference to its derivation or evidence for use. Only in compiling the literature review, did it become evident that this formula is the same as the Shann formula for children aged 1 − 9 years, despite not being referred to as such in the text. Henceforth this formula will be referred to as the Wits anaesthesiology formula (Wits-A).

Five studies were identified evaluating the Shann formulae. Both PubMed and Google were searched for a derivation study with no success. In two (16, 31) of the three articles the formula is referenced to the same textbook, Emergency Medicine at your fingertips, second edition. The other articles also reference the formula to textbooks (36, 45, 53). The author was unable to access the texts online. A brief summary of each study will follow.

The first is a study from 2005 by Theron et al (16). Five weight estimation techniques (Broselow tape, Oakley chart, APLS, Leffler and Shann formulae) were evaluated in 909 Pacific Island and Maori children in New Zealand. These children are usually on the 95th centile on the NCHS standard for weight. The results for this study were separately reported for four different ethnicities (Maori, Pacific, European and Asian/Indian children). All of the techniques were found to underestimate weight, and a new weight chart was derived (16).

The second is a study by Park et al (31) in 2012. They aimed to derive a new formula in the Korean population, validate it and then compare it to the Broselow tape and four other formulae, the Shann formulae being one of them. The sample size included 124 094 children. The new formula was found to be accurate while all the other techniques underestimated weight in the Korean population (31).

In 2013, Hegazy and Taher (53) aimed to validate a new formula for Egyptian paediatric cancer patients against the APLS and Shann formulae. This is a different population group to the population presenting to the outpatient department where studies are usually conducted. Some children may be of normal weight, some may be underweight or malnourished from cachexia while others may be overweight, with the large bulk of the weight being a tumour or oedema. Both the APLS and Shann formulae underestimated weight in the paediatric cancer patients, while the new formula was found to be accurate with a slight tendency to overestimate (53).

The fourth is a study by Britnell and Koziol-Mclain (36) where they intended to determine the accuracy of paediatric weight estimation techniques used in New Zealand. The Broselow tape and three other formulae (APLS, Shann and Theron) were evaluated for children aged 5 – 10 years at five Auckland schools. The Broselow tape was found to be the most accurate method of weight estimation (73% of estimates within 10% of actual weight) with poor performance by the age based formulae (proportion of weight estimates ranging from 28 – 46%) (36).

In 2017 Bowen et al (45) evaluated the Broselow tape and 14 weight estimation formulae (including the original and revised APLS, Luscombe and Owens, and Shann formulae). The Broselow tape was found to be the most precise and accurate weight estimation technique with a mean percentage overestimation of 4.3 and 47% of estimates within 10% of actual weight. With regards to the age based formulae the original APLS was found to be most accurate with a mean percentage overestimation of 8.1% and 38% of estimates within 10% of actual weight. All the formulae overestimated weight. This was attributed to the fact that 8% of the population were severely malnourished. Zambia is classified as a lower middle-income country whereas South Africa is classified as upper middle-income by the World Bank (28) and although both are developing countries the results of one study may be significantly different to the other.

1.5 THE SOUTH AFRICAN STUDIES

Three studies were identified, two of which evaluated both height and age based techniques, and one which attempted to validate a technique developed in South Africa.

In 2011 Geduld et al (1) evaluated four weight estimation techniques (Broselow tape, APLS, Luscombe and Owens and Best Guess formulae) in order to determine which were most accurate for children in the Western Cape, South Africa. They included 2832 children aged 1 − 10 years. Although ethnicity was not recorded, the same population was previously described as having the following ethnic distribution: Black 56%, Coloured 30%, Asian 8%, White 4%, and other 2%. The Broselow tape and APLS formula were found to be the most accurate with overall mean percentage underestimation of 0.9% and 3.3% respectively. The Luscombe and Owens and Best Guess formulae both overestimated weight with mean percentage differences of −12.4% and −15.4% respectively. In terms of percentage of estimates within 10% of measured weight, the Broselow tape and APLS formulae performed similarly with estimates of 64% and 57% respectively, while the Luscombe and Owens and Best Guess formulae were only accurate 34% and 31% respectively (1).

The authors emphasised the need to validate the Broselow tape and APLS formula for the South African paediatric population across all socioeconomic and ethnic groups, and the necessity to repeat the study every few decades with changing growth patterns (1).

The second study from South Africa, attempted to validate the Paediatric Advanced Weight Prediction in the Emergency Room (PAWPER) tape in the emergency departments of two Johannesburg private hospitals. The PAWPER tape is a length based weight estimation technique developed by Wells in 2007. A baseline weight estimation is first made by measuring length after which this value is adjusted according to the child's body habitus. Its accuracy was compared to that of the Broselow tape. The mean percentage error for the Broselow tape and PAWPER tape was −3.8 % and 0% respectively. The Broselow tape predicted weight to within 10% of actual weight in 63.6% of children and the PAWPER tape in 89.2%. The difference between weight prediction between the two tape measures were more inaccurate in children greater than 20 kg, and in children above or below average weight-for-

length. The addition of a measure of body habitus proved to have increased the accuracy of weight estimation. In this study it out performed the Broselow tape in terms of accuracy and affordability (17).

Lastly Georgoulas and Wells (46) compared the performance of the Broselow tape, PAWPER tape, two other length based techniques, and three weight estimation formulae (Original APLS, Updated APLS and the best Guess formulae). A total of 300 children were included in the study from an outpatient department serviced by Rahima Moosa Mother and Child Hospital, another hospital in the Gauteng region affiliated to Wits. Ethnicity was not recorded. The percentage of estimates within 10% for the PAWPER tape was 88% compared to 54% for the Broselow tape, 45% for the original APLS, 37% for the updated APLS and 20% for the Best Guess Formulae. The findings regarding the PAWPER tape mirrored the previous study by Wells et al (17) with similar accuracy and precision even though the sample populations were very different. The median BMI-for-age centile was 30 in this study whereas it was 50 in the original PAWPER tape study. The author suggested that the Broselow tape and the age based formulae were very poor weight estimation techniques and should no longer be used (46).

1.6 GLOBAL OBESITY EPIDEMIC

Childhood obesity is a global epidemic and gradually affecting many more low- and middle-income countries. In the last 15 years, the prevalence has increased quiet drastically. “Globally in 2010, the number of overweight children under the age of five, was estimated to be over 42 million. Close to 35 million were believed to be from developing countries. By 2020, if the current epidemic continues, nine percent of all children less than five will be overweight or obese, nearly 60 million children. The WHO has reported that the fastest overweight and obesity growth rates are in Africa with the number almost doubling from 1990 to 2010” (54).

1.7 DEFINING AND CLASSIFYING OVERWEIGHT AND OBESITY

According to the WHO overweight and obesity are defined as “abnormal or excessive fat accumulation to the extent that it may have adverse effects on the health and well-being of the patient” (55).

Numerous measures have been employed to evaluate overweight and obesity. Some of these include clinical assessment, skinfold thickness, weight-for-age growth curves, and BMI. By far the most common is a BMI (54). BMI-for-age is not used before 2 years of age as at younger ages there is a weak association with adolescent or adult obesity. The measurement of BMI is a screening not a diagnostic tool (56). It only identifies children and adults with increased body weight, this could be increased adiposity or muscle bulk. However, at present, it is the best measure available in terms of cost and convenience (57).

1.8 DEFINING AND CLASSIFYING BMI

BMI is defined as the weight divided by the height squared. Unlike adults, in children, the classification of nutritional status based on BMI is slightly more complex, and to date there is still no consensus. This is because adiposity varies with age and gender during childhood and adolescence, and therefore BMI is age and gender specific (56).

Three different classification systems are used to interpret BMI in children. These include reference sets by the International Obesity Taskforce (IOTF), the Centres for Disease Control and Prevention (CDC) and the WHO. However, these charts have been compiled with data from developed countries ,and therefore pose the same problem as weight estimation techniques, there are no normative values for developing countries (54).

In 2008, Quak et al (58) suggested the following as a guideline:

- “for epidemiological studies, the definition introduced by the IOTF (59) should be used to define overweight and obesity in children and adolescents aged 2 - 18 years. This definition allows international comparison of trends in overweight and obesity.
- for clinical use, BMI for age charts should be used. The decision as to which particular reference chart should be used has to be considered individually by the different national groups” (58).

A brief discussion on the development and guidelines recommended by the CDC, WHO and IOTF will follow.

1.8.1 CDC recommendations

The CDC Growth Charts were released in May 2000. They include revised versions of the growth charts developed by the NCHS in 1977 and the addition of the new BMI-for-age charts (56). The data used to construct the new charts differ from the 1977 NCHS charts in that they are based on a nationally representative reference population. The 1977 Growth Charts were based on a sample that consisted primarily of white middle-class children from south-western Ohio (56).

The interpretation is as follows for children of the same age and sex:

- “underweight is defined as a BMI less than the 5th percentile
- healthy weight is defined as a BMI from the 5th percentile to less than the 85th percentile
- overweight is defined as a BMI at or above the 85th percentile and lower than the 95th percentile
- obesity is defined as a BMI at or above the 95th percentile” (56) .

The rationale for the use of these criteria is that a BMI at the 95th percentile in the USA population corresponds to a BMI of 30 in adults, which is the value used to define obesity (56). A BMI at the 85th percentile corresponds to a BMI of 25, which is the value corresponding to the upper limit of normal weight (56).

1.8.2 WHO and CDC combined recommendations

In 2006, the WHO published new international growth charts for children aged 0 − 59 months. In the same year the CDC, the National Institutes of Health, and the American Academy of Paediatrics assembled a professional panel to review the evidence and discuss the possible use of the new WHO Growth Charts in clinical settings in the USA. It was recommended that clinicians in the USA use the 2006 WHO International Growth Charts for children aged less than 24 months, and the CDC growth charts for children and adolescents aged 2 − 19 years (60).

The reason for using the WHO Growth Charts in children less than 24 months is that infants who are breastfed are the standard by which all children should ideally be compared to, and in deriving the WHO Growth Charts, every child in the sample was breastfed for at least 12 months (60).

1.8.3 IOTF recommendations

In 2000 the IOTF suggested an international definition for childhood obesity. This was based on data from 192 727 children from six countries (USA, UK, Hong Kong, Brazil, Singapore and the Netherlands) (59).

In 2012 Cole and Lobstein (61) revised the existing IOTF and thinness references. The revised IOTF cut-offs correspond to the following BMI cut-offs at 18 years (61):

- “16 thinness grade 3
- 17 thinness grade 2
- 18.5 thinness grade 1
- 23 overweight (unofficial Asian cut-off)
- 25 overweight
- 27 obesity (unofficial Asian cut-off)
- 30 obesity
- 35 morbid obesity” (61).

The IOTF tables provide cut-offs at one month intervals from age 2 − 18 years. Separate charts are available for boys and girls (61).

1.9 THE SOUTH AFRICAN POPULATION

South Africa is considered as a rapidly developing country with a mixture of ethnicities and socioeconomic classes (1). In 2011, 50.5 million people were censored. Of these 80.2 % were Black, 8.4 % were White, 8.8 % Coloured, 2.5% Asian (Indian) and 0.5% other (62).

The incidence of overweight and obesity in South Africa parallels that seen in developed countries more than a decade ago (54). In a review article published in 2012, Rossouw et al (54) highlighted the results of all major studies on the prevalence of overweight and obesity in South African children and adolescents. The more recent studies demonstrated a mean prevalence of just over 15% for overweight and obesity combined, higher in girls than boys.

South Africa faces the so-called double burden of disease, paralleled by other low- and middle-income countries. This is described as the co-existence of obesity and malnutrition in the same individual, in the same family or the same population (54).

This compounds the problem even further, emphasising the need for further research to assess the South African population with regards to nutritional status and institute appropriate interventions or preventative measures.

1.10 SUMMARY

In summary, a detailed review on weight estimation techniques, the rising trend of overweight and obesity and the assessment of BMI has been reviewed. The concerns regarding the South African population both with regards to weight estimation techniques and BMI have been highlighted.

References

1. Geduld H, Hodkinson PW, Wallis LA. Validation of weight estimation by age and length based methods in the Western Cape, South Africa population. Emerg Med J. 2011 Oct;28(10):856-60. Epub 2010/10/15. Eng.10.1136/emj.2010.098640

2. Anglemyer BL, Hernandez C, Brice JH, Zou B. The accuracy of visual estimation of body weight in the ED. Am J Emerg Med. 2004 Nov;22(7):526-9. PubMed PMID: 15666254. Epub 2005/01/25. Eng

3. Rosenberg M, Greenberger S, Rawal A, Latimer-Pierson J, Thundiyil J. Comparison of Broselow tape measurements versus physician estimations of pediatric weights. Am J Emerg Med. 2011 Jun;29(5):482-8. Epub 2010/09/10. Eng.10.1016/j.ajem.2009.12.002

4. Advanced Paediatric Life Support. 3rd ed. London: BMJ Publishing Group; 2003.

5. Traub SL, Johnson CE. Comparison of methods of estimating creatinine clearance in children. Am J Hosp Pharm. 1980 Feb;37(2):195-201. PubMed PMID: 7361791. Epub 1980/02/01. Eng

6. Traub SL, Kichen L. Estimating ideal body mass in children. Am J Hosp Pharm. 1983 Jan;40(1):107-10. PubMed PMID: 6823980. Epub 1983/01/01. Eng

7. Garland JS, Kishaba RG, Nelson DB, Losek JD, Sobocinski KA. A rapid and accurate method of estimating body weight. Am J Emerg Med. 1986 Sep;4(5):390-3. PubMed PMID: 3741556. Epub 1986/09/01. Eng

8. Oakley PA. Inaccuracy and delay in decision making in paediatric resuscitation, and a proposed reference chart to reduce error. BMJ. 1988 Oct 1;297(6652):817-9. PubMed PMID: 2460172. Pubmed Central PMCID: PMC1834608. Epub 1988/10/01. Eng

9. Lubitz DS, Seidel JS, Chameides L, Luten RC, Zaritsky AL, Campbell FW. A rapid method for estimating weight and resuscitation drug dosages from length in the pediatric age group. Ann Emerg Med. 1988 Jun;17(6):576-81. PubMed PMID: 3377285. Epub 1988/06/01. Eng

10. Advanced paediatric life support: the practical approach. 5th ed: Chichester: John Wiley & Sons Ltd; 2011.

11. Argall JA, Wright N, Mackway-Jones K, Jackson R. A comparison of two commonly used methods of weight estimation. Arch Dis Child. 2003 Sep;88(9):789-90. PubMed PMID: 12937099. Epub 2003/08/26. Eng

12. Keon V, Barhman. Nelson's Textbook of paediatrics. 18 ed2007

13. Luscombe M, Owens B. Weight estimation in resuscitation: is the current formula still valid? Arch Dis Child. 2007 May;92(5):412-5. Pubmed Central PMCID: PMC2083737. Epub 2007/01/11. Eng.10.1136/adc.2006.107284

14. Tinning K, Acworth J. Make your Best Guess: an updated method for paediatric weight estimation in emergencies. Emerg Med Australas. 2007 Dec;19(6):528-34. Epub 2007/11/21. Eng.10.1111/j.1742-6723.2007.01026.x

15. Morgan G, Mikail M, Murray M. Clinical Anesthesiology Fourth Edition: McGraw-Hill Medical Publishing Division; 2006.

16. Theron L, Adams A, Jansen K, Robinson E. Emergency weight estimation in Pacific Island and Maori children who are large-for-age. Emerg Med Australas. 2005 Jun;17(3):238-43. Epub 2005/06/15. Eng.10.1111/j.1742-6723.2005.00729.x

17. Wells M, Coovadia A, Kramer E, Goldstein L. The PAWPER tape: A new concept tape-based device that increases the accuracy of weight estimation in children through the inclusion of a modifier based on body habitus. Resuscitation. 2013 Feb;84(2):227-32. Epub 2012/07/17. eng.10.1016/j.resuscitation.2012.05.028

18. Nieman CT, Manacci CF, Super DM, Mancuso C, Fallon WF, Jr. Use of the Broselow tape may result in the underresuscitation of children. Acad Emerg Med. 2006 Oct;13(10):1011-9. Epub 2006/10/04. Eng.10.1197/j.aem.2006.06.042

19. Luten RC, Zaritsky A, Wears R, Broselow J. The use of the Broselow tape in pediatric resuscitation. Acad Emerg Med. 2007 May;14(5):500-1; author reply 1-2. Epub 2007/04/26. Eng.10.1197/j.aem.2007.02.015

20. Black K, Barnett P, Wolfe R, Young S. Are methods used to estimate weight in children accurate? Emerg Med (Fremantle). 2002 Jun;14(2):160-5. PubMed PMID: 12147113. Epub 2002/07/31. Eng

21. DuBois D, Baldwin S, King WD. Accuracy of weight estimation methods for children. Pediatr Emerg Care. 2007 Apr;23(4):227-30. Epub 2007/04/18. Eng.10.1097/PEC.0b013e31803f5aca

22. Meguerdichian MJ, Clapper TC. The Broselow tape as an effective medication dosing instrument: a review of the literature. J Pediatr Nurs. 2012 Aug;27(4):416-20. Epub 2012/05/15. Eng.10.1016/j.pedn.2012.04.009

23. Agarwal S, Swanson S, Murphy A, Yaeger K, Sharek P, Halamek LP. Comparing the utility of a standard pediatric resuscitation cart with a pediatric resuscitation cart based on the Broselow tape: a randomized, controlled, crossover trial involving simulated resuscitation scenarios. Pediatrics. 2005 Sep;116(3):e326-33. Epub 2005/08/03. Eng.10.1542/peds.2005-0320

24. Hofer CK, Ganter M, Tucci M, Klaghofer R, Zollinger A. How reliable is length-based determination of body weight and tracheal tube size in the paediatric age group? The Broselow tape reconsidered. Br J Anaesth. 2002 Feb;88(2):283-5. PubMed PMID: 11878662. Epub 2002/03/07. Eng

25. Jang HY, Shin SD, Kwak YH. Can the Broselow tape be used to estimate weight and endotracheal tube size in Korean children? Acad Emerg Med. 2007 May;14(5):489-91. Epub 2007/03/27. Eng.10.1197/j.aem.2006.12.014

26. Krieser D, Nguyen K, Kerr D, Jolley D, Clooney M, Kelly AM. Parental weight estimation of their child's weight is more accurate than other weight estimation methods for determining children's weight in an emergency department? Emerg Med J. 2007 Nov;24(11):756-9. Pubmed Central PMCID: PMC2658317. Epub 2007/10/24. Eng.10.1136/emj.2007.047993

27. So TY, Farrington E, Absher RK. Evaluation of the accuracy of different methods used to estimate weights in the pediatric population. Pediatrics. 2009 Jun;123(6):e1045-51. Epub 2009/06/02. Eng.10.1542/peds.2008-1968

28. The World Bank. How does the World Bank classify countries? [cited 2017 09/09/2017]. Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries.

29. Casey J, Borland M. Best Guess method: a further external validation study and comparison with other methods. Emerg Med Australas. 2010 Feb;22(1):68-74. Epub 2010/02/16. Eng.10.1111/j.1742-6723.2009.01258.x

30. Bourdeau S, Copeland J, Milne WK. Accuracy of the Broselow tape in estimating the weight of First Nations children. Can J Rural Med. 2011 Fall;16(4):121-5. PubMed PMID: 21955338. Epub 2011/10/01. Eng

31. Park J, Kwak YH, Kim do K, Jung JY, Lee JH, Jang HY, et al. A new age-based formula for estimating weight of Korean children. Resuscitation. 2012 Sep;83(9):1129-34. Epub 2012/02/01. Eng.10.1016/j.resuscitation.2012.01.023

32. Sinha M, Lezine MW, Frechette A, Foster KN. Weighing the pediatric patient during trauma resuscitation and its concordance with estimated weight using Broselow Luten Emergency Tape. Pediatr Emerg Care. 2012 Jun;28(6):544-7. Epub 2012/06/02. Eng.10.1097/PEC.0b013e318258ac2e

33. Ken Milne W, Yasin A, Knight J, Noel D, Lubell R, Filler G. Ontario children have outgrown the Broselow tape. CJEM. 2012 Jan;14(1):25-30. PubMed PMID: 22417954. Epub 2012/03/16. Eng

34. Heyming T, Bosson N, Kurobe A, Kaji AH, Gausche-Hill M. Accuracy of paramedic Broselow tape use in the prehospital setting. Prehosp Emerg Care. 2012 Jul-Sep;16(3):374-80. Epub 2012/03/27. Eng.10.3109/10903127.2012.664247

35. Loo PY, Chong SL, Lek N, Bautista D, Ng KC. Evaluation of three paediatric weight estimation methods in Singapore. J Paediatr Child Health. 2013 Apr;49(4):E311-6. Epub 2013/03/16. Eng.10.1111/jpc.12141

36. Britnell S, Koziol-McLain J. Weight estimation in paediatric resuscitation: A hefty issue in New Zealand. Emerg Med Australas. 2015 Jun;27(3):251-6. Epub 2015/04/08. eng.10.1111/1742-6723.12389

37. Skrobo D, Kelleher G. CORKSCREW 2013 CORK study of children's realistic estimation of weight. Emerg Med J. 2015 Jan;32(1):32-5. Epub 2014/02/21. eng.10.1136/emermed-2013-203352

38. Varghese A, Vasudevan VK, Lewin S, Indumathi CK, Dinakar C, Rao SD. Do the length-based (Broselow) Tape, APLS, Argall and Nelson's formulae accurately estimate weight of Indian children? Indian Pediatr. 2006 Oct;43(10):889-94. PubMed PMID: 17079832. Epub 2006/11/03. Eng

39. Ramarajan N, Krishnamoorthi R, Strehlow M, Quinn J, Mahadevan SV. Internationalizing the Broselow tape: how reliable is weight estimation in Indian children. Acad Emerg Med. 2008 May;15(5):431-6. Epub 2008/04/29. Eng.10.1111/j.1553-2712.2008.00081.x

40. House DR, Ngetich E, Vreeman RC, Rusyniak DE. Estimating the weight of children in Kenya: do the Broselow tape and age-based formulas measure up? Ann Emerg Med. 2013 Jan;61(1):1-8. Epub 2012/09/04. Eng.10.1016/j.annemergmed.2012.07.110

41. Shah V, Bavdekar SB. Validity of Broselow tape for estimating weight of Indian children. Indian J Med Res. 2017 Mar;145(3):339-46. Pubmed Central PMCID: PMC5555062. Epub 2017/07/28. eng.10.4103/ijmr.IJMR_837_14

42. Ali K, Sammy I, Nunes P. Is the APLS formula used to calculate weight-for-age applicable to a Trinidadian population? BMC Emerg Med. 2012;12:9. Epub 2012/08/04. Eng.10.1186/1471-227x-12-9

43. Luscombe MD, Owens BD, Burke D. Weight estimation in paediatrics: a comparison of the APLS formula and the formula 'Weight=3(age)+7'. Emerg Med J. 2010 Jul;28(7):590-3. Epub 2010/07/28. Eng.10.1136/emj.2009.087288

44. Sandell JM, Charman SC. Can age-based estimates of weight be safely used when resuscitating children? Emerg Med J. 2009 Jan;26(1):43-7. Epub 2008/12/24. Eng.10.1136/emj.2008.061119

45. Bowen L, Zyambo M, Snell D, Kinnear J, Bould MD. Evaluation of the accuracy of common weight estimation formulae in a Zambian paediatric surgical population. Anaesthesia. 2017 Apr;72(4):470-8. Epub 2016/12/28. eng.10.1111/anae.13780

46. Georgoulas VG, Wells M. The PAWPER tape and the Mercy method outperform other methods of weight estimation in children at a public hospital in South Africa. S Afr Med J. 2016 Aug 07;106(9):933-9. Epub 2016/09/08. eng.10.7196/SAMJ.2016.v106i9.10572

47. Nguyen K, Krieser D, Kerr D, Jolley D, Clooney M, Kelly AM. Failed validation of the Argall weight formula for estimating children's weight in an Australian emergency department. Acad Emerg Med. 2007 May;14(5):486-8. Epub 2007/03/27. Eng.10.1197/j.aem.2006.12.009

48. Kelly AM, Nguyen K, Krieser D. Validation of the Luscombe weight formula for estimating children's weight. Emerg Med Australas. 2011 Feb;23(1):59-62. Epub 2010/12/08. Eng.10.1111/j.1742-6723.2010.01351.x

49. Kelly AM, Kerr D, Clooney M, Krieser D, Nguyen K. External validation of the Best Guess formulae for paediatric weight estimation. Emerg Med Australas. 2007 Dec;19(6):543-6. Epub 2007/11/21. Eng.10.1111/j.1742-6723.2007.01025.x

50. Harris M, Patterson J, Morse J. Doctors, nurses, and parents are equally poor at estimating pediatric weights. Pediatr Emerg Care. 1999 Feb;15(1):17-8. PubMed PMID: 10069305. Epub 1999/03/09. Eng

51. Partridge RL, Abramo TJ, Haggarty KA, Hearn R, Sutton KL, An AQ, et al. Analysis of parental and nurse weight estimates of children in the pediatric emergency department. Pediatr Emerg Care. 2009 Dec;25(12):816-8. Epub 2009/12/18. Eng.10.1097/PEC.0b013e3181c32eb6

52. Graves L, Chayen G, Peat J, O'Leary F. A comparison of actual to estimated weights in Australian children attending a tertiary children's' hospital, using the original and updated APLS, Luscombe and Owens, Best Guess formulae and the Broselow tape. Resuscitation. 2014 Mar;85(3):392-6. Epub 2013/12/11. eng.10.1016/j.resuscitation.2013.11.024

53. Hegazy M, Taher E. Validating a new formula for weight estimation in pediatric cancer patients. Int J Med Med Sci. February 21 2013;1:34-9.

54. Rossouw A, Grant C, Viljoen M. Overweight and obesity in children and adolescents: The South African problem. South African Journal of Science. 2012.

55. World Health Organisation. Obesity and Overweight.: WHO; 2013. Available from: www.who.int/mediacentre/factsheets/fs311.

56. Centres for Disease Control and Prevetion. Using the BMI-for-Age Growth Charts. In: Prevention CfDCa, editor. 2010.

57. Flegal KM, Ogden CL. Childhood obesity: are we all speaking the same language? Adv Nutr. 2011 Mar;2(2):159S-66S. Pubmed Central PMCID: PMC3065752. Epub 2012/02/15. Eng.10.3945/an.111.000307

58. Quak SH, Furnes R, Lavine J, Baur LA. Obesity in children and adolescents. J Pediatr Gastroenterol Nutr. 2008 Aug;47(2):254-9. Epub 2008/07/31. Eng.10.1097/MPG.0b013e318181b2cd

59. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ. 2000 May 6;320(7244):1240-3. PubMed PMID: 10797032. Epub 2000/05/08. Eng

60. Laurence M G-S, Chris R, Nancy F K. Use of World Health Organization and CDC Growth Charts for Children Aged 0--59 Months in the United States. 2010.

61. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes. 2012 Aug;7(4):284-94. Epub 2012/06/21. eng.10.1111/j.2047-6310.2012.00064.x

62. Statistics South Africa. Census 2011 [cited 2017 09/09/2017]. Available from: http://mobi.statssa.gov.za/census2011/index.html#home.

SECTION 2: JOURNAL GUIDELINE TO AUTHOR

This section highlights the guidelines that the author has followed with regards to the length and formatting of the research article.

The guidelines followed in creating the draft article were those of the Southern African Journal of Anaesthesia and Analgesia, which is the intended journal of publication.

Southern African Journal of Anaesthesia and Analgesia guidelines to authors

Article sections and lengths

The following contributions are accepted (word counts exclude abstracts, tables and references):

Original research (2800 – 3200 words/ 4-5 pages)

Title page

All articles must have a title page with the following information and in this particular order: Title of the article; surname, initials, qualifications and affiliation of each author; The name, postal address, e-mail address and telephonic contact details of the corresponding author and at least 5 keywords.

Abstract

All articles should include an abstract. The structured abstract for an Original Research article should be between 200 and 230 words and should consist of four paragraphs labelled Background, Methods, Results, and Conclusions. It should briefly describe the problem or issue being addressed in the study, how the study was performed, the major results, and what the authors conclude from these results. The abstracts for other types of articles should be no longer than 230 words and need not follow the structured abstract format.

Keywords

All articles should include keywords. Up to five words or short phrases should be used. Use terms from the Medical Subject Headings (MeSH) of Index Medicus when available and appropriate. Key words are used to index the article and may be published with the abstract.

Acknowledgements

In a separate section, acknowledge any financial support received or possible conflict of interest. This section may also be used to acknowledge substantial contributions to the research or preparation of the manuscript made by persons other than the authors.

References

Cite references in numerical order in the text, in superscript format (Format> Font> Click superscript). Please do not use brackets or do not use the foot note function of MS Word.

In the References section, references must be typed double-spaced and numbered consecutively in the order in which they are cited, not alphabetically.

The style for references should follow the format set forth in the Uniform Requirements for Manuscripts Submitted to Biomedical Journals (http://www.icmje.org) prepared by the International Committee of Medical Journal Editors. Abbreviations for journal titles should follow Index Medicus format. Authors are responsible for the accuracy of all references. Personal communications and unpublished data should not be referenced. If essential, such material should be incorporated in the appropriate place in the text.

List all authors when there are six or fewer; when there are seven or more, list the first three, then ";et al."; When citing URLs to web documents, place in the reference list, and use the following format: Authors of document (if available). Title of document (if available). URL. (Accessed [date]).

The following are sample references:

1.Jun BC, Song SW, Park CS, Lee DH, Cho KJ, Cho JH. The analysis of maxillary sinus aeration according to aging process: volume assessment by 3-dimensional reconstruction by high-resolutional CT scanning. Otolaryngol Head Neck Surg. 2005 Mar;132(3):429-34.

2.2. Polgreen PM, Diekema DJ, Vandeberg J, Wiblin RT, Chen YY, David S, et al. Risk factors for groin wound infection after femoral artery catheterization: a case-control study. Infect Control Hosp Epidemiol [Internet]. 2006 Jan [cited 2007 Jan 5];27(1):34-7. Available from: http://www.journals.uchicago.edu/ICHE/journal/issues/v27n1/2004069/2004069.web.pdf.

More sample references can be found at: http://www.nlm.nih.gov/bsd/uniform_requirements.html"

Tables

Tables should be self-explanatory, clearly organised, and supplemental to the text of the manuscript. Each table should include a clear descriptive title on top and numbered in Roman numerals (I, II, etc) in order of its appearance as called out in text. Tables must be inserted in the correct position in the text. Authors should place explanatory matter in footnotes, not in the heading. Explain in footnotes all non-standard abbreviations.

For footnotes use the following symbols, in sequence:*,†,‡,§,||,**,††,‡‡

Figures

All figures must be inserted in the appropriate position of the electronic document. Symbols, lettering, and numbering (in Arabic numerals e.g. 1, 2, etc. in order of

appearance in the text) should be placed below the figure, clear and large enough to remain legible after the figure has been reduced. Figures must have clear descriptive titles.

Photographs and images

If photographs of patients are used, either the subject should not be identifiable or use of the picture should be authorised by an enclosed written permission from the subject. The position of photographs and images should be clearly indicated in the text. Electronic images should be saved as either jpeg or gif files. All photographs should be scanned at a high resolution (300dpi, print optimised). Please number the images appropriately.

Permission

Permission should be obtained from the author and publisher for the use of quotes, illustrations, tables, and other materials taken from previously published works, which are not in the public domain. The author is responsible for the payment of any copyright fee(s) if these have not been waived. The letters of permission should accompany the manuscript. The original source(s) should be mentioned in the figure legend or as a footnote to a table.

Review and action

Manuscripts are initially examined by the editorial staff and are usually sent to independent reviewers who are not informed of the identity of the author(s). When publication in its original form is not recommended, the reviewers' comments (without the identity of the reviewer being disclosed) may be passed to the first author and may include suggested revisions. Manuscripts not approved for publication will not be returned.

Ethical considerations

Papers based on original research must adhere to the Declaration of Helsinki on "Ethical Principles for Medical Research Involving Human Subjects"; and must specify from which recognised ethics committee approval for the research was obtained.

Conflict of interest

Authors must declare all financial contributions to their work or other forms of conflict of interest, which may prevent them from executing and publishing unbiased research. [Conflict of interest exists when an author (or the author's institution), has financial or personal relationships with other persons or organizations that inappropriately influence (bias) his or her opinions or actions.]* *Modified from: Davidoff F, et al. Sponsorship, Authorship, and Accountability. (Editorial) JAMA 2001: 286(10) The following declaration may be used if appropriate: ";I declare that I

have no financial or personal relationship(s) which may have inappropriately influenced me in writing this paper."

Submissions and correspondence

All submissions must be made online at www.sajaa.co.za and correspondence regarding manuscripts should be addressed to:

The Editor, SAJAA, E-mail: toc@sajaa.co.za

Note: Ensure that the article ID [reference] number is included in the subject of your email correspondence.

Electronic submissions by post or via email

Authors with no e-mail or internet connection can mail their submissions on a CD to: SAJAA, PO Box 14804, Lyttelton Manor, 0140, Gauteng, South Africa.

All manuscripts will be processed online. Submissions by post or by e-mail must be accompanied by a signed copy of the following indemnity and copyright form.

Tips on Preparing your manuscript

1.Please consult the “Uniform requirements for manuscripts submitted to biomedical journals” at www.icmje.org

2.Please consult the guide on Vancouver referencing methods at: http://www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=citmed.TOC&depth=2

3.The submission must be in UK English, typed in Microsoft Word or RTF with no double spaces after the full stops, double paragraph spacing, font size 10 and font type: Times New Roman.

4.All author details (Full names, Qualifications and affiliation) must be provided.

5.The full contact details of corresponding author (Tel, fax, e-mail, postal address) must be on the manuscript.

6.There must be an abstract and keywords.

7.References must strictly be in Vancouver format. (Reference numbers must be strictly numerical and be typed in superscript, not be in brackets and must be placed AFTER the full stop or comma.)

8.It must be clear where every figure and table should be placed in the text. If possible, tables and figures must be placed in the text where appropriate. If too large or impractical, they may be featured at the end of the manuscript or uploaded as separate supplementary files.

9.All photographs must be at 300dpi and clearly marked according to the figure numbers in the text. (Figure 1, Table II, etc.)

10.All numbers below ten, without percentages or units, must be written in words.

11.Figure numbers: Arabic, table numbers: Roman

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Submission Preparation Checklist

As part of the submission process, authors are required to check off their submission's compliance with all of the following items, and submissions may be returned to authors that do not adhere to these guidelines.

1.This manuscript has currently only been submitted to SAJAA and has not been published previously.

2.This work is original and all third party contributions (images, ideas and results) have been duly attributed to the originator(s).

3.Permission to publish licensed material (tables, figures, graphs) has been obtained and the letter of approval and proof of payment for royalties have been submitted as supplementary files.

4.The submitting/corresponding author is duly authorised to herewith assign copyright to the South African Society of Anaesthesiologists (SASA).

5.All co-authors have made significant contributions to the manuscript to qualify as co-authors.

6.Ethics committee approval has been obtained for original studies and is clearly stated in the methodology.

7.A conflict of interest statement has been included where appropriate.

8.The submission adheres to the instructions to authors in terms of all technical aspects of the manuscript.

9.Plagiarism

The submitting author acknowledges that the Editorial Board reserves the right to use plagiarism detection software on any submitted material.

SECTION 3: DRAFT ARTICLE

This section presents the draft article in the format specified by the Southern African Journal of Anaesthesia and Analgesia, which is the intended journal of publication. The font and references are therefore different to the other sections presented.

COMPARISON OF WEIGHT ESTIMATION FORMULAE IN PAEDIATRIC PATIENTS AT CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

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Keywords

Paediatric weight estimation, APLS formula, Luscombe and Owens formula, Shann formula, BMI

Abstract

Background

Accurate weight determination is essential in providing optimal care to the paediatric population, as both over- and under-estimation can be detrimental. This study aimed to compare the accuracy and precision of three paediatric weight estimation formulae, the Advanced Paediatric Life support (APLS), the formula used by anaesthetists in academic hospitals affiliated to the University of Witswatersrand (Wits-A), and the Luscombe and Owens (LO) formula, to the measured weight of children at the Chris Hani Baragwanath Academic Hospital (CHBAH) paediatric outpatient department (POPD).

Methods

A prospective, contextual, descriptive study design was used with quota sampling. Four hundred children aged 1 − 10 years were recruited for the study. Age, gender, ethnicity, weight and height were recorded.

Results

On average the APLS formula performed the best with 49 % of estimates within 10% of the actual measured weight (PW10), the lowest mean percentage difference (MPD) of 0.7% and the narrowest 95% limits of agreement. The Wits-A formula followed with a PW10 of 41% and a MPD of -5.2% while the LO formula had a PW10 of 24% and a MPD of -19.4%.

Conclusion

An accurate and precise weight estimation technique remains elusive and the gold standard is a measured weight. The APLS formula was however found to be the most accurate in the CHBAH population and should be used over the Wits-A formula if a formula has to be used.

Introduction

Accurate weight determination is essential in providing optimal care to the paediatric population. Prescribed fluid volumes, most drug dosages, defibrillation energy selections, ventilator tidal volumes and airway device sizes, are calculated or estimated utilising body weight. Both overestimation and underestimation of a child's weight may lead to suboptimal care and related morbidity or mortality. [1] To date the gold standard is still a measured weight. [2] However, this may be impossible in a critically ill child requiring immediate resuscitation or in settings where calibrated, working scales may be scarce.

Numerous techniques have been derived in order to help with paediatric weight estimation. These techniques are either height based or age based. The Broselow tape is one of the most commonly employed height based techniques. The age based calculation formulae include the original and updated Advanced Paediatric Life Support (APLS) formulae, the Argall formula, LO formula, and Best Guess formulae. [3, 4] The advantages of height based techniques are that they are simple to use and reduce the cognitive load of recalling formulae. Advantages of age based formulae are that they can be used in any environment, allow pre-preparation of equipment and medication and there is no equipment cost. [5]

The Broselow tape technique and the original APLS formula are two of the earliest methods described. The Broselow tape technique has been validated in several studies both in developed and developing countries. [1, 6-9] However, its usefulness in populations where obesity rates have increased has been questioned. [8] Similar findings of underestimation regarding the APLS formula have also been shown. [4, 6, 10] The subsequent formulae were all developed in an attempt to address the issue of an increasing number of children either classified as overweight or obese in the developed world. The Broselow tape, the APLS and all the subsequent age based formulae have been derived and mostly validated in countries; defined by the World Bank as developed. [11, 12] The utilisation of these methods in developing countries where malnutrition is prevalent is not well studied. [8]

The original APLS formula, was revised in 2011. Three new formulae were proposed, for infants 1 − 11 months, children aged 1 – 5 years and children aged 6 − 12 years. The formula for children aged 1 − 5 years is equivalent to the current APLS formula, whereas the formula used for 6 – 12 years is the same as the LO formula. [13, 14] The original formula is, however, still being used in the European Paediatric Life Support course. In reviewing the literature, it became evident that even studies after 2011 referred to the original APLS formula.

The formula used by anaesthetists in the Department of Anaesthesiology, University of the Witwatersrand (Wits), has not, to the authors' knowledge, been validated in the South African population. In fact, there is very little information with regards to this formula. It is suggested from a prescribed textbook, Clinical Anaesthesiology with no reference to its derivation or evidence for use. [15] Henceforth is will be referred to as the Wits Anaesthesiology (Wits-A) formula. Only when reviewing the literature, did it become evident that this formula is the same as the Shann formula for children aged 1 – 9 years, despite not being referred to as such in the text. A limited number of studies were identified regarding the Shann formula and no derivation study could be found. It is referenced to two New Zealand textbooks which the author was unable to access. [16, 17]

Doctors, nurses and parents' estimates have also been evaluated. From the limited number of studies, doctors [2, 18] and nurses [18] are unable to reliably estimate the weight of children, whereas with parents', the results are conflicting, two studies concluding accuracy [3, 10] and the other not. [18] It may, however not be possible to rely on parents' estimates exclusively, as parents may not be available, or unable to recall or estimate weight in an emergency situation. [2] In some instances, the primary caregiver may not be the person accompanying the child. This may be particularly true in the South African context.

There is limited literature regarding the use of the most appropriate technique for the South African population, and to date only three studies have been identified. [19-21] The results from these studies, however, may not be able to be extrapolated to all regions of South Africa due to the diversity of the population, both in terms of ethnic and socioeconomic distribution. Determinants of weight are complex and are influenced by gender, genetics, and ethnicity in addition to age and height/length. Therefore, there is a need to determine the most appropriate technique for the South African, and specifically the CHBAH paediatric population.

We therefore undertook a study with the aim of comparing three paediatric weight estimation formulae; the original APLS, the Wits-A, and the LO formulae, to the measured weight of children at the CHBAH POPD. The original APLS was selected over the updated APLS formulae as the original APLS is more widely used by clinicians in the Wits circuit. This formula is still shown to be accurate in developing countries while the Luscombe and Owens has been shown to be more accurate in developed countries. The results of the study would give an indication as to which of the formulae is most accurate in our population.

The body habitus of the CHBAH paediatric population using the Body Mass Index (BMI) as an anthropometric index would also be described. BMI-for-age is not used before 2 years of age as at younger ages there is a weak association with adolescent or adult obesity. [22]

Methods

A prospective, contextual, descriptive study design was used. Approval to proceed with this study was obtained from the Human Research Ethics Committee (Medical), Wits, and other relevant authorities. Patient confidentiality was maintained as there was no documentation regarding the individual patient's identity.

With the assistance of a biostatistician, a sample size of 40 children (20 males and 20 females) per age group (1 − 10 years) was found to constitute an adequate sample size to provide sufficient data for individual age group analysis. This was calculated based on a maximum allowable difference of 0.00485 between the weight estimation formulae and actual weight, with a power of 80% and a significance level 0.05. In total 400 children were included in the study. The research was conducted at the CHBAH paediatric outpatient department (POPD). CHBAH is a Wits affiliated central hospital in Johannesburg, Gauteng. It services one of the largest populations in the southern hemisphere and is the referral centre for a number of smaller, regional hospitals. The clinic operates every day of the week and approximately 100 children are consulted per day.

Caregivers (parents, guardians or caregivers) and their children were invited to participate in the study as they arrived in the department. Following agreement, an information letter was given to them, and parents were asked to sign informed consent while children eight years and older were asked to sign an assent form. All children aged 1 – 10 years (inclusive) presenting to the POPD were screened except critically ill children requiring immediate intervention or resuscitation, chronically ill children known to a specialist clinic and children who were oedematous or had severe joint contractures.

Weight and height are routinely measured on arrival in the POPD, prior to joining the queue. The nursing staff were approached to allow the author (ZS) to do the routine measurements. Data were collected in a summer month of 2014, until the sample size was reached. Age, gender, ethnicity, weight and height were recorded. Age was rounded down to the last completed year. Ethnicity was recorded as Black, White, Coloured, Indian or Asian. Weight was rounded to the nearest 0.1 kg. Standardisation was achieved by use of a calibrated, standing scale (Seca medical scale) and each child was weighed with light clothing and no shoes. Height was rounded to the nearest 0.1 cm and measured using a stadiometre attached to the wall. Children stood upright, backs and heels against the back bar of the stadiometre, arms to the side with palms facing inwards.

The raw data were captured on a Microsoft Excel ® 2007 spread sheet. The formulae used to estimate weight based on age, as well as the formula used to calculate BMI were pre-programmed into this spread sheet. Table I

summarises these calculations. The data were analysed using the software programme (Graphpad Prism©), in consultation with a biostatistician. Age, gender, ethnicity, weight, height and BMI were reported using descriptive statistics. Normally distributed data were analysed using the means and standard deviations, whilst skewed data were analysed using the medians and interquartile ranges.

Table I. Calculation of weight estimation formulae and BMI as well as their age parameters

Formulae	**Calculation**	**Parameters**
Original APLS formula [5]	(Age in years + 4) x 2	1 – 10 years
Wits-A formula [15]	(Age in years x 2) + 9	Not specified
LO Formula[23]	(Age in years x 3) + 7	1 – 10 years
BMI	(Weight in kg) / (height in m)^2	2 – 20 years

The assessment of accuracy for weight estimation techniques necessitated two analyses. The first was whether the technique on average calculated the correct answer. The second was the degree of variability in a technique when applied to many children of almost identical weight. These two analyses were, respectively, measurement bias and precision. [7] The bias was determined from the mean percentage difference (MPD). The standard deviation of the MPD was used to estimate the precision of the formulae in approximating the true weight. The Bland-Altman plot is a graphical representation of the measurement bias and precision. An analysis of the number of estimates within 10% of the measured weight (PW10) was also performed for each technique. This is a further indication and the most accepted evaluation of accuracy. The suggested minimum requirement for accuracy is 60% of estimates to be within 10% of actual weight. [20]

BMI was graphically represented on gender specific BMI-for-age growth charts developed by the Centres for Disease Control and Prevention (CDC). [22] Table II summarises the interpretation of BMI for children of the same age and gender.

Table II. Interpretation of BMI for children [22]

BMI	**Interpretation**
BMI less than the 5th percentile	Underweight
BMI from the 5th percentile to less than the 85th percentile	Healthy weight
BMI at or above the 85th percentile and lower than the 95th percentile	Overweight
BMI at or above the 95th percentile	Obese

Results

A total of 497 children were screened of which 400 were recruited for the study. Of the 97 children who did not fulfil the inclusion criteria, 80 of these children were outside the specified age cut-offs, two children above the age of 8 refused to participate, and 7 children were critically ill and immediately transferred for resuscitation. There were 20 boys and 20 girls in each age group with a total of 200 boys and 200 girls. The sample population consisted of the following ethnic distribution: Black (97%), Indian (1%), and Coloured (2%).

Weight and height for each age category is reflected in Table III as is the BMI for girls and boys aged 2 − 10 years. Combined male and female results are presented, as separate gender analysis was not statistically significant and yielded similar conclusions. Figure 1 illustrates the mean measured weights for each age category and the estimated weight using the three different formulae.

Table III. Weight and height and BMI for gender per age category

Age (years)	Weight (kg) mean (SD)	Height (cm) mean (SD)	Girls BMI mean (SD)	Boys BMI mean (SD)
1	9 (1)	76 (6)		
2	11 (2)	84 (5)	16.3 (2.1)	16.0 (1.8)
3	14 (2)	94 (5)	15.6 (1.1)	16.9 (2.1)
4	16 (4)	100 (6)	16.4 (2.9)	16.1 (1.4)
5	19 (4)	110 (7)	15.7 (2.1)	15.6 (2.1)
6	21 (4)	114 (6)	15.4 (1.5)	16.2 (2.0)
7	23 (5)	120 (6)	15.1 (2.1)	16.4 (2.8)
8	26 (5)	125 (6)	17.1 (2.8)	16.2 (3.3)
9	27 (5)	131 (8)	16.0 (1.6)	16.2 (2.8)
10	33 (6)	137 (9)	17.3 (3.1)	17.6 (2.5)

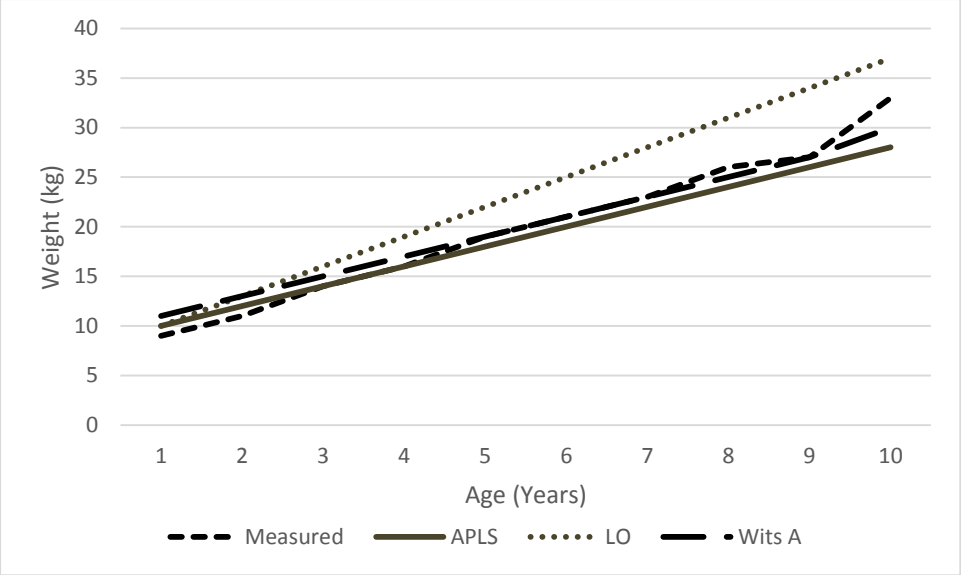


Figure 1. Mean measured weights for each age category, and the estimated weight using the 3 different formulae

The APLS formula underestimated the weight in all age groups. Both the Wits-A and LO formulae overestimated weight. This is reflected in Table IV.

Table IV. Mean percentage difference (MPD), standard deviation (SD), 95% limits of agreement (LOA) and PW10 for each weight estimation formulae

	MPD	SD	95% LOA	PW10
APLS	0.7	16.8	-0.9 to 2.5	49%
Wits-A	-5.2	18.4	-7.1 to -3.4	41%
LO	-19.4	20.4	-21.7 to -17.7	24%

With regards to the Bland-Altman plots, the three techniques consistently demonstrate an agreement in the lower weight groups (approximately < 20kg) with decreasing accuracy in the higher weight groups (approximately ≥ 20kg). The outliers reflect those children who were either extremely under- or over-weight for a particular age group. This is shown in Figure 2.

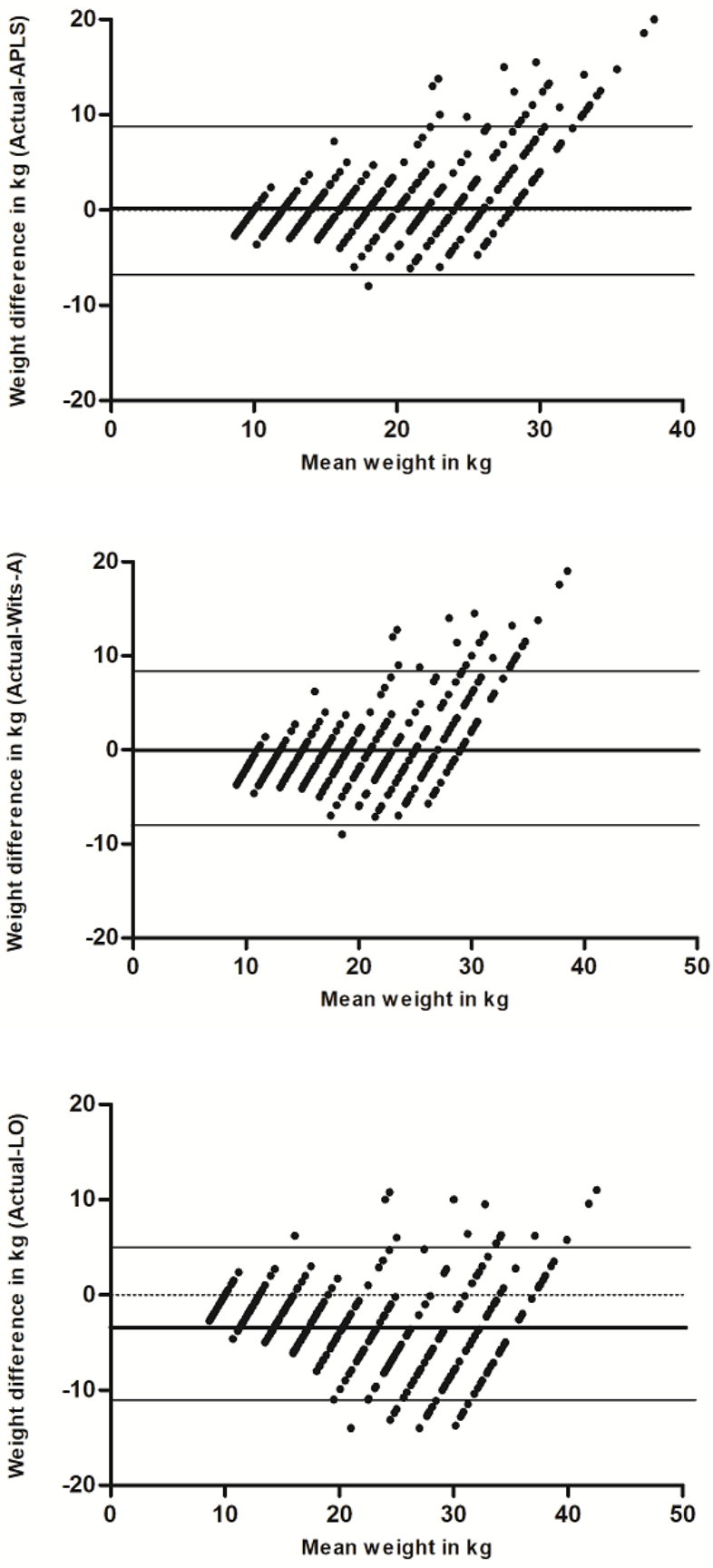


Figure 2. Bland Altman plots for each weight estimation formula

On average the APLS formula performed the best with 49% of estimates within 10% of the actual measured weight. The Wits-A formula followed with 41% while the LO formula only estimated 24% of weights to within 10% of the actual weight. These results are reflected in Table IV.

BMI is represented on gender specific BMI- for- age growth charts in Figure 3 and Figure 4. The BMI of our study population, both for girls and boys, was found to be between the 25th and 75th percentile.

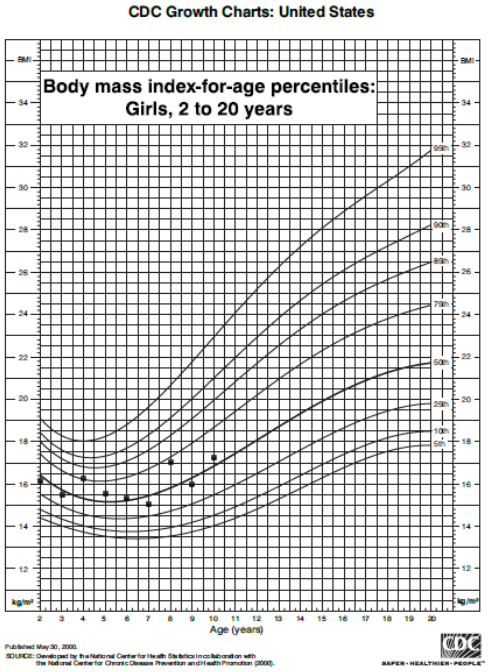


Figure 3. BMI-for-age (Girls)

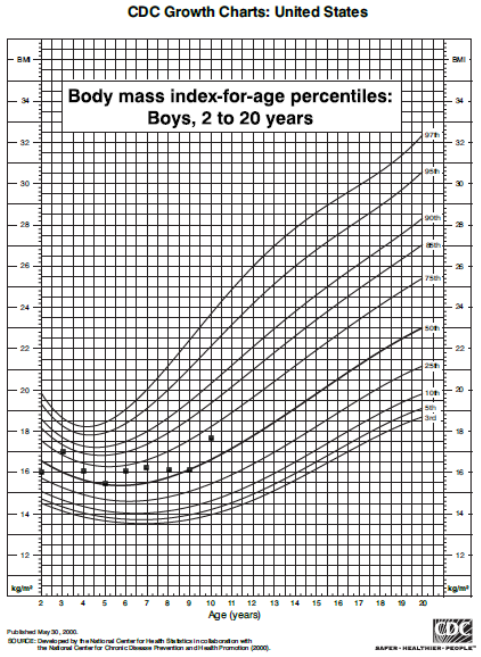


Figure 4. BMI-for-age (Boys)

Discussion

There are many techniques available to estimate the weight of children, the majority of these being age based formulae. However, the applicability of techniques derived in the developed countries to the developing countries is not well established. [19]

South Africa is regarded as a rapidly developing country facing the so-called double burden of disease, paralleled by other low- and middle-income countries. This is described as the co-existence of obesity and malnutrition in the same individual, in the same family or the same population. [24] Not only is it difficult to extrapolate findings from other developing countries but there are also regional socioeconomic differences within the South African population. Of concern is the global epidemic of obesity, where once thought to be isolated to the developing world, is increasingly affecting many low- and middle-income countries. The WHO has reported that the fastest overweight and obesity growth rates are in Africa with the number almost doubling from 1990 to 2010. [24] The BMI, both for girls and boys in this study, demonstrated a healthy weight. The girls and boys were both between the 25th and 75th percentile BMI for CDC growth charts.

The sample was, however, taken from one hospital in the Gauteng region, and although CHBAH is one of the largest hospitals in the southern hemisphere, it services a specific population in terms of ethnicity and socioeconomic status. The sample is therefore only reflective of this population and may not be generalizable to

other regions of the country. The sample was also taken in the paediatric outpatient department, and therefore excluded children attending specialist clinics, those with chronic conditions, and the critically ill.

In this study, the APLS formula performed the best in terms of bias, precision and overall accuracy (MPD 0,7%, SD 16.8% and 49%). This was followed by the Wits-A (MPD -5.2%, SD 18.4% and 41%), and lastly the LO formula (MPD -19.4%, SD 20.4% and 24%). No other identified studies have compared the same weight estimation formulae combination as in our study. Therefore, the results of the three formulae will be discussed separately. The findings of underestimation, overestimation or accuracy are as defined by the authors of the respective articles. This implies that a weight estimation technique may still under- or over-estimate and be recorded as accurate.

Being one of the earliest and most common age based techniques employed, the original APLS formula is often used as a gold standard against which other formulae were derived or validated. In this study the APLS formula marginally underestimated weight with a MPD of 0.7%, but a PW10 of 49% thus not meeting the suggested minimum requirement for accuracy (60% of estimates within 10% of actual weight). The APLS formula has been shown in previous studies to be more inaccurate at weights greater than 20 kg. [19, 25] This finding was also observed in our study potentially accounting for the above findings. The APLS formula has consistently been shown to underestimate weight in the developed world [1, 4, 7, 17, 26-28]. The findings in the developing world are contradictory with three studies, from India [29] , Zambia [11] and Kenya [8], reporting overestimation, and the SA studies [19, 21] reporting an underestimation. This discrepancy can be explained by the World Bank Classification of economic status according to income level as developing countries are further subdivided into upper middle-, lower middle-, and low income countries. SA is classified as upper middle-income, India and Kenya as lower middle-income, and Zambia as low income. The underweight and malnutrition rates are very different in an upper middle-income country compared to a low income country. [12] With regards to the other SA studies, the findings regarding the APLS formula were paralleled by Geduld et al [19] and Georgoulas and Wells. [21] In both studies, despite outperforming the other weight estimation formulae evaluated, the APLS formula did not meet the minimum requirement for accuracy. The PW10 for this study, Geduld et al [19] and the study by Georgoulas and Wells [21] were respectively 49%, 57% and 45%.

The Wits-A formula which is the same as the Shann formula for children aged 1 − 9 years overestimated weight in this study. This is in keeping with the only study identified from a developing country. [11] The Shann formula underestimated weight in all of the studies identified from developed countries. [16, 17, 26]

The LO formula, derived in order to address the problem of increasing rates of overweight and obesity [23] overestimated weight in this study. This is consistent with studies from other developing countries. [11, 19, 21] The children in this study were of normal weight. The LO formula has been shown to be accurate in the developed world, only marginally underestimating actual weight. [4, 30-32]

From the results of this study, it has become evident that a weight estimation technique in the elective or semi-emergency setting is suboptimal. These children should be weighed with a calibrated scale. In an emergency situation where it may be difficult to weigh a child, the existence of a validated weight estimation technique can offer the clinician a baseline from which to work. However to improve accuracy and eliminate confounders, the incorporation of both length (which correlates more significantly with weight than age [7, 19]) and an adjustment for body habitus would have to be included. In this regard the South African Paediatric Advanced Weight Prediction in the Emergency Room (PAWPER) tape seems to be the most promising weight estimation technique as it fulfils both these requirements in addition to providing emergency drug doses thus further reducing cognitive error. [20] It would have to be further evaluated in our population before a firm recommendation can be made.

Conclusion

An accurate and precise weight estimation technique remains elusive and the gold standard is still an actual weight. With regards to the CHBAH population the original APLS formula was found to be the most accurate of the three formulae evaluated, despite not meeting the minimum requirement for accuracy. This formula is easily memorised and still widely taught and used despite having been updated. The author suggests the use of this formula over the Wits-A formula if a formula has to be used.

Acknowledgements

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Conflict of Interest

The authors declare that they had no financial or personal relationships, which may have inappropriately influenced the writing of this paper.

References

1. Loo PY, Chong SL, Lek N, Bautista D, Ng KC. Evaluation of three paediatric weight estimation methods in Singapore. J Paediatr Child Health. 2013 Apr;49(4):E311-6. Epub 2013/03/16. Eng.10.1111/jpc.12141

2. Rosenberg M, Greenberger S, Rawal A, Latimer-Pierson J, Thundiyil J. Comparison of Broselow tape measurements versus physician estimations of pediatric weights. Am J Emerg Med. 2011 Jun;29(5):482-8. Epub 2010/09/10. Eng.10.1016/j.ajem.2009.12.002

3. Krieser D, Nguyen K, Kerr D, Jolley D, Clooney M, Kelly AM. Parental weight estimation of their child's weight is more accurate than other weight estimation methods for determining children's weight in an emergency department? Emerg Med J. 2007 Nov;24(11):756-9. Pubmed Central PMCID: PMC2658317. Epub 2007/10/24. Eng.10.1136/emj.2007.047993

4. Luscombe MD, Owens BD, Burke D. Weight estimation in paediatrics: a comparison of the APLS formula and the formula 'Weight=3(age)+7'. Emerg Med J. 2010 Jul;28(7):590-3. Epub 2010/07/28. Eng.10.1136/emj.2009.087288

5. Advanced Paediatric Life Support. 3rd ed. London: BMJ Publishing Group; 2003.

6. Argall JA, Wright N, Mackway-Jones K, Jackson R. A comparison of two commonly used methods of weight estimation. Arch Dis Child. 2003 Sep;88(9):789-90. PubMed PMID: 12937099. Epub 2003/08/26. Eng

7. Black K, Barnett P, Wolfe R, Young S. Are methods used to estimate weight in children accurate? Emerg Med (Fremantle). 2002 Jun;14(2):160-5. PubMed PMID: 12147113. Epub 2002/07/31. Eng

8. House DR, Ngetich E, Vreeman RC, Rusyniak DE. Estimating the weight of children in Kenya: do the Broselow tape and age-based formulas measure up? Ann Emerg Med. 2013 Jan;61(1):1-8. Epub 2012/09/04. Eng.10.1016/j.annemergmed.2012.07.110

9. So TY, Farrington E, Absher RK. Evaluation of the accuracy of different methods used to estimate weights in the pediatric population. Pediatrics. 2009 Jun;123(6):e1045-51. Epub 2009/06/02. Eng.10.1542/peds.2008-1968

10. Partridge RL, Abramo TJ, Haggarty KA, Hearn R, Sutton KL, An AQ, et al. Analysis of parental and nurse weight estimates of children in the pediatric emergency department. Pediatr Emerg Care. 2009 Dec;25(12):816-8. Epub 2009/12/18. Eng.10.1097/PEC.0b013e3181c32eb6

11. Bowen L, Zyambo M, Snell D, Kinnear J, Bould MD. Evaluation of the accuracy of common weight estimation formulae in a Zambian paediatric surgical population. Anaesthesia. 2017 Apr;72(4):470-8. Epub 2016/12/28. eng.10.1111/anae.13780

12. The World Bank. How does the World Bank classify countries? [cited 2017 09/09/2017]. Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/378834-how-does-the-world-bank-classify-countries.

13. Advanced paediatric life support: the practical approach. 5th ed: Chichester: John Wiley & Sons Ltd; 2011.

14. Marikar D, Varshneya K, Wahid A, Apakama O. Just too many things to remember? A survey of paediatric trainees' recall of Advanced Paediatric Life Support (APLS) weight estimation formulae. Arch Dis Child. 2013 Nov;98(11):921. Epub 2013/08/24. eng.10.1136/archdischild-2013-304360

15. Morgan G, Mikail M, Murray M. Clinical Anesthesiology Fourth Edition: McGraw-Hill Medical Publishing Division; 2006.

16. Park J, Kwak YH, Kim do K, Jung JY, Lee JH, Jang HY, et al. A new age-based formula for estimating weight of Korean children. Resuscitation. 2012 Sep;83(9):1129-34. Epub 2012/02/01. Eng.10.1016/j.resuscitation.2012.01.023

17. Theron L, Adams A, Jansen K, Robinson E. Emergency weight estimation in Pacific Island and Maori children who are large-for-age. Emerg Med Australas. 2005 Jun;17(3):238-43. Epub 2005/06/15. Eng.10.1111/j.1742-6723.2005.00729.x

18. Harris M, Patterson J, Morse J. Doctors, nurses, and parents are equally poor at estimating pediatric weights. Pediatr Emerg Care. 1999 Feb;15(1):17-8. PubMed PMID: 10069305. Epub 1999/03/09. Eng

19. Geduld H, Hodkinson PW, Wallis LA. Validation of weight estimation by age and length based methods in the Western Cape, South Africa population. Emerg Med J. 2011 Oct;28(10):856-60. Epub 2010/10/15. Eng.10.1136/emj.2010.098640

20. Wells M, Coovadia A, Kramer E, Goldstein L. The PAWPER tape: A new concept tape-based device that increases the accuracy of weight estimation in children through the inclusion of a modifier based on body habitus. Resuscitation. 2013 Feb;84(2):227-32. Epub 2012/07/17. eng.10.1016/j.resuscitation.2012.05.028

21. Georgoulas VG, Wells M. The PAWPER tape and the Mercy method outperform other methods of weight estimation in children at a public hospital in South Africa. S Afr Med J. 2016 Aug 07;106(9):933-9. Epub 2016/09/08. eng.10.7196/SAMJ.2016.v106i9.10572

22. Centres for Disease Control and Prevetion. Using the BMI-for-Age Growth Charts. In: Prevention CfDCa, editor. 2010.

23. Luscombe M, Owens B. Weight estimation in resuscitation: is the current formula still valid? Arch Dis Child. 2007 May;92(5):412-5. Pubmed Central PMCID: PMC2083737. Epub 2007/01/11. Eng.10.1136/adc.2006.107284

24. Rossouw A, Grant C, Viljoen M. Overweight and obesity in children and adolescents: The South African problem. South African Journal of Science. 2012.

25. Kelly AM, Kerr D, Clooney M, Krieser D, Nguyen K. External validation of the Best Guess formulae for paediatric weight estimation. Emerg Med Australas. 2007 Dec;19(6):543-6. Epub 2007/11/21. Eng.10.1111/j.1742-6723.2007.01025.x

26. Britnell S, Koziol-McLain J. Weight estimation in paediatric resuscitation: A hefty issue in New Zealand. Emerg Med Australas. 2015 Jun;27(3):251-6. Epub 2015/04/08. eng.10.1111/1742-6723.12389

27. Sandell JM, Charman SC. Can age-based estimates of weight be safely used when resuscitating children? Emerg Med J. 2009 Jan;26(1):43-7. Epub 2008/12/24. Eng.10.1136/emj.2008.061119

28. Tinning K, Acworth J. Make your Best Guess: an updated method for paediatric weight estimation in emergencies. Emerg Med Australas. 2007 Dec;19(6):528-34. Epub 2007/11/21. Eng.10.1111/j.1742-6723.2007.01026.x

29. Varghese A, Vasudevan VK, Lewin S, Indumathi CK, Dinakar C, Rao SD. Do the length-based (Broselow) Tape, APLS, Argall and Nelson's formulae accurately estimate weight of Indian children? Indian Pediatr. 2006 Oct;43(10):889-94. PubMed PMID: 17079832. Epub 2006/11/03. Eng

30. Ali K, Sammy I, Nunes P. Is the APLS formula used to calculate weight-for-age applicable to a Trinidadian population? BMC Emerg Med. 2012;12:9. Epub 2012/08/04. Eng.10.1186/1471-227x-12-9

31. Kelly AM, Nguyen K, Krieser D. Validation of the Luscombe weight formula for estimating children's weight. Emerg Med Australas. 2011 Feb;23(1):59-62. Epub 2010/12/08. Eng.10.1111/j.1742-6723.2010.01351.x

32. Skrobo D, Kelleher G. CORKSCREW 2013 CORK study of children's realistic estimation of weight. Emerg Med J. 2015 Jan;32(1):32-5. Epub 2014/02/21. eng.10.1136/emermed-2013-203352

Section 4: APPENDICES

Appendix A – Graduate Studies Committee Approval

UNIVERSITY OF THE
WITWATERSRAND
JOHANNESBURG

Private Bag 3 Wits, 2050
Fax: 027117172119
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Reference: Ms Thokozile Nhlapo
E-mail: thokozile.nhlapo@wits.ac.za

09 January 2015
Person No: 0300765N
PAG

Dr Z Soni
P O Box 96099
Brixton
2019
South Africa

Dear Dr Soni

Master of Medicine: Approval of Title

We have pleasure in advising that your proposal entitled *A comparison of weight estimation formulae in paediatric patients at Chris Hani Baragwanath Academic Hospital.* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

Appendix B – Ethics approval

R14/49 Dr Zakiyya Soni & Dr Estie Mostert

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M130704

NAME: (Principal Investigator)	Dr Zakiyya Soni & Dr Estie Mostert
DEPARTMENT:	Anaesthesiology Chris Hani Baragwanath Academic Hospital
PROJECT TITLE:	Comparison of Weight Estimation Formulae in Paediatric Patients at Chris Hani Baragwanath Academic Hospital
DATE CONSIDERED:	26/07/2013
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Ms Helen Perrie
APPROVED BY:	pp _____ Professor PE Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	10/01/2014

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report.**

_____ _____

Principal Investigator Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix C – Approval from the Head of the Paediatric Outpatient Department

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

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UNIVERSITY OF THE WITWATERSRAND
JOHANNESBURG

6th November 2013

Professor Y. Jeenah
Protocol Review Committee
Chris Hani Baragwanath Academic Hospital
Soweto

Dear Prof Jeenah,

I would like to inform you that Dr Zakiyya Soni has been given permission to conduct her research in the Department of Paediatrics at Chris Hani Baragwanath Academic Hospital. The title of her study is, 'Comparison of weight estimation formulae in paediatric patients at Chris Hani Baragwanath Academic Hospital.' She will be conducting her study in the Paediatric Outpatient Department.

Yours Sincerely,

Professor Sithembiso Velaphi
Head of Department of Paediatrics
Chris Hani Baragwanath Academic Hospital

SECTION 5: PROPOSAL

COMPARISON OF WEIGHT ESTIMATION FORMULAE IN PAEDIATRIC PATIENTS AT CHRIS HANI BARAGWANATH ACADEMIC HOSPITAL

Zakiyya Soni

Student number: 0300765N

Supervisor: Ms H Perrie (MSc)

Department of Anaesthesiology

University of the Witwatersrand

Co-supervisor: Dr E Mostert MBChB(Pret), DA(SA), FCA, MMed(Anaes)

Department of Anaesthesiology

University of the Witwatersrand

5.1 INTRODUCTION

Accurate weight determination is essential in providing optimal care to the paediatric population. Prescribed fluid volumes, most drug dosages, ventilator tidal volumes and airway device sizes, are calculated or estimated utilising body weight. Both overestimation and underestimation of a child's weight may lead to suboptimal care and related morbidity or mortality (1). In the emergency setting it is often impossible to weigh a child prior to intervention, and in other instances there may be no resources, such as a working, calibrated scale.

Numerous techniques have been derived in order to help with paediatric weight estimation. These techniques are either height based or age based. The Broselow tape is one of the most commonly employed height based techniques. The age based calculation formulae include the original and updated Advanced Paediatric Life Support (APLS) formula, the Argall formula, Luscombe and Owens formula, and Best Guess formulae (2, 3).

The Broselow tape technique has been validated in several studies both in developed and developing countries (1, 4-7). However, its usefulness in populations where obesity rates have increased has been questioned (6). Similar findings of underestimation regarding the original APLS formula have also been shown (3, 4, 8). The Broselow tape technique and the original APLS formula are two of the earliest methods described.

The subsequent formulae (Argall, Best Guess, Luscombe and Owens, and updated APLS) were all developed in an attempt to address the issue of an increasing number of children either classified as overweight or obese, in the developed world. Conversely, the utility of these methods in developing countries where malnutrition is prevalent is not well studied (6).

Parent and health care workers' estimations have also been evaluated. From the limited number of studies, doctors (9, 10) and nurses (9) are unable to reliably estimate the weight of children, whereas with parents', the results are conflicting, two studies concluding accuracy (2, 8) and the other not (9). It may however not be possible to rely on parents' estimates exclusively, as parents may not be available, or unable to recall or estimate weight in an emergency situation (10). In some

instances, the primary caregiver may not be the person accompanying the child. This may be particularly true in the South African context.

Three studies were identified from South Africa, two of which evaluated both height and age based techniques (11, 12), and one which attempted to validate a technique developed in South Africa (13).

In 2011 Geduld et al (11) evaluated four paediatric weight estimation techniques in the Western Cape population. They found that the Broselow tape and APLS formula were accurate for children aged 10 years and younger whereas the Luscombe and Owens and Best Guess formulae, both based on recent developed country data, overestimated weight in all age groups (11).

The second study attempted to validate the PAWPER tape in the emergency departments of two Johannesburg private hospitals. The PAWPER tape is a length based weight estimation technique which was developed in South Africa in 2007, and its accuracy was compared to that of the Broselow tape. The addition of a measure of body habitus proved to have increased the accuracy of weight estimation. In this study it outperformed the Broselow tape both in terms of accuracy and affordability (13).

Lastly Georgoulas and Wells (12) compared the performance of the Broselow tape, PAWPER tape, two other length based techniques, and three weight estimation formulae (Original APLS, Updated APLS and the best Guess formulae) in children recruited from Rahima Moosa Mother and Child Hospital, a public hospital in Johannesburg affiliated to Wits. The PAWPER tape outperformed the other techniques and the authors suggested that the Broselow tape and the age based formulae were very poor weight estimation techniques and should no longer be used. The findings regarding the PAWPER tape were mirrored in the study by Wells et al (13) with similar accuracy and precision even though the sample populations were very different. The median BMI-for-age centile was 30 in the study by Georgoulas whereas it was 50 in the original PAWPER tape study (12).

5.2 PROBLEM STATEMENT

There are many techniques available to estimate the weight of children, the majority of these being age based formulae. However, the applicability of techniques derived in developed countries, to developing countries is not well established.

With regards to the South African population, there is limited literature regarding the use of the most appropriate technique. The results from the available studies, however, may not be able to be extrapolated to all regions of South Africa due to of the diversity of the population, both in terms of ethnic and socioeconomic distribution.

Secondly, the formula used by anaesthetists in the Department of Anaesthesiology, University of the Witwatersrand (Wits), has not, to the researcher's knowledge, been validated in the South African population. In fact, there is very little information with regards to this formula. It is suggested from a prescribed textbook, Clinical Anaesthesiology, with no reference to its derivation or evidence for use (14). Henceforth this formula will be referred to as the Wits anaesthesiology formula (Wits-A).

Only in compiling the literature review, did it become evident that this formula is the same as the Shann formula for children aged 1 − 9 years, despite not being referred to as such in the text. A limited number of studies were identified evaluating the Shann formulae (15-19),and both PubMed and Google were searched for a derivation study with no success. In two (18, 19) of the three articles the formula is referenced to the same textbook, Emergency Medicine at your fingertips, second edition. The other articles also reference the formula to textbooks (16, 20). The author was unable to access these texts online.

5.3 AIM

The aim of the study is to compare three paediatric weight estimation formulae, the original APLS, Wits-A, and the Luscombe and Owens formulae, to the measured weight of children at the Chris Hani Baragwanath Academic Hospital (CHBAH) outpatient department.

5.4 OBJECTIVES

The objectives are to:

- document the actual height of each child
- document the actual measured weight of each child
- calculate the estimated weight using the original APLS formula
- calculate the estimated weight using the Wits-A
- calculate the estimated weight using the Luscombe and Owens formula
- compare the actual measured weight to each of the estimated weight formulae
- describe the body habitus of the CHBAH paediatric population using the body mass index (BMI) as an anthropometric index.

5.5 RESEARCH ASSUMPTIONS

The following definitions are used in this study.

Children: study participants aged one year up to and including 10 years of age.

Age: age in years rounded down to last completed year.

Measured weight: child is weighed in kilograms (with light clothing and no shoes) using a standardised, calibrated scale, and rounded to the nearest 0.1 kg.

Estimated weight: weight is calculated in kilograms using one of the formulae described below, and rounded to the nearest 0.1 cm.

Body mass index (BMI): an anthropometric index of weight and height that is defined as body weight in kilograms divided by height in meters squared. BMI-for-age is not used before two years of age as at younger ages there is a weak association with adolescent or adult obesity (21).

Original Advanced Paediatric Life Support (APLS) formula (22):

Applicable to children aged 1 − 10 years

Weight (kg) = (Age in years + 4) x 2.

Wits anaesthesiology formula (Wits-A) (14):

Applicable to children aged 1 − 10 years

Weight (kg) = (Age in years x 2) + 9.

Luscombe and Owens formula (23):

Applicable to children aged 1 − 10 years

Weight (kg) = (Age in years x 3) + 7.

Caregivers: Parent, guardian or caregiver looking after the child.

5.6 DEMARCATION OF STUDY FIELD

The research will be conducted at the CHBAH paediatric outpatient department. This clinic operates every day of the week and approximately 100 children are consulted per day.

CHBAH is a central hospital in Johannesburg, Gauteng, and is affiliated to the University of the Witwatersrand. It services one of the largest populations in the southern hemisphere and is the referral centre for a number of smaller, regional hospitals.

5.7 ETHICAL CONSIDERATIONS

Approval to proceed with this study will be obtained from the Graduate Studies Committee and the Human Research Ethics Committee (Medical), of Wits. At CHBAH permission will be obtained from the Medical Advisory Committee prior to the commencement of the study (Appendix A).

Written consent will be obtained from the Head of the CHBAH paediatric outpatient clinic (Appendix B). The Matron in charge of the clinic will also be informed of the study.

Patient confidentiality will be maintained as there will be no documentation regarding the individual patient's identity.

Parents' and children will be invited to participate in the study. Following agreement from parents', an information letter will be given to them and they will be asked to sign informed consent. Children eight years and older will be asked to sign an assent form after a verbal explanation of the information letter (Appendix C). It is anticipated that a significant number of patients will be accompanied to the clinic by their guardians or caregivers. Therefore, the Human Research Ethics Committee (Medical) will be asked to consider allowing guardians and care givers to give informed consent, as this study does not involve any invasive interventions. Collected data will be stored for 6 years.

The study will be conducted by adhering to the South African Good Clinical Practice Guidelines (24) and the Declaration of Helsinki (25).

5.8 RESEARCH METHODOLOGY

5.8.1 Study design

A prospective, contextual, descriptive study design will be used.

A prospective study design is one in which the variables are measured as the study is taking place. The cohort, or group of individuals are selected and followed over a period of time (26). This study is prospective as the variables (age and weight) are collected or measured over a period of time until the sample size is achieved.

A contextual study occurs in a specific location or area (27). This study will be contextually conducted at CHBAH paediatric outpatient department.

A descriptive study design is used to gain more information about certain characteristics within a particular field of study. There is no intention of establishing causality. This study design assists in acquiring knowledge in an area where limited literature has been published (28). For the reasons mentioned above, this is the most appropriate study design for this study.

5.8.2 Study population

The study population will include all children presenting to the CHBAH paediatric outpatient department.

5.8.3 Study sample

Sample size

With the assistance of a biostatistician, a sample size of 40 children per age group (20 males and 20 females) would constitute an adequate sample size to provide sufficient data for individual age group analysis. In total there will be 400 children included in the study.

Sample method

A quota sampling method will be followed in this study.

Quota sampling uses a convenience sampling technique with an additional strategy to ensure adequate representation of patients in each stratum for the planned statistical analysis. (29)

Inclusion and exclusion criteria

Inclusion criteria for this study are:

- all children aged 1 − 10 years (inclusive) presenting to the CHBAH paediatric outpatient department
- children of caregivers who have agreed to the participation of their child in the study.

Exclusion criteria for this study are:

- critically ill children requiring immediate intervention or resuscitation
- chronically ill children known to a specialist clinic
- children who are oedematous or have severe joint contractures
- any child eight years and older who refuses to assent.

5.8.4 Data collection

Caregivers' and children will be invited to participate in the study as they arrive at the department. Following agreement, an information letter will be given to them, and caregivers' will be asked to sign informed consent while children eight years and older will be asked to sign an assent form (Appendix B).

Weight and height are routinely measured on arrival in the department, prior to joining the queue. The nursing staff will be approached to allow the researcher to do the routine measurements. The nursing sister who would usually record these variables will be asked to document them in the routine records.

Data will be collected in a summer month of 2014 at the CHBAH paediatric outpatient department, until the sample size is reached. Age, gender, ethnicity, weight and height will be recorded. Age will be rounded down to the last completed year. Ethnicity will be recorded as Black, White, Coloured, Indian or Asian. Weight will be rounded to the nearest 0.1 kg. Standardisation will be achieved by use of a calibrated, electronic, standing scale (Seca medical scale) and each child will be weighed with light clothing and no shoes. Children who are uncooperative or unable to stand will be weighed with their caregivers. The child's weight will then be obtained indirectly by subtracting the caregivers' weight from the combined weight of the caregiver and child. Height will be rounded to the nearest 0.1 cm and measured using a stadiometre fixed to the wall. Children will stand upright, backs and heels against the back bar of the stadiometre, arms to the side with palms facing inwards and facing straight ahead. If the child is unable to stand, the child will be measured on a flat, hard surface with a measuring tape.

5.8.5 Data analysis

The raw data will be captured on a Microsoft ® Excel 2007 spread sheet. The formulae used to estimate weight based on age, as well as the formula used to calculate BMI will be pre-programmed into this spread sheet. A sample of the data collection sheet is attached (Appendix C).

The data will be analysed using the software programme, Graphpad Prism©, in consultation with a biostatistician.

Age, gender, ethnicity, weight, height and BMI (derived from the measured weight and height) will be reported using descriptive statistics. Depending on the distribution of data, they will either be reported as using the means and standard deviations, or medians and interquartile ranges.

The assessment of accuracy for weight estimation techniques necessitates two analyses. The first is whether the technique on average calculates the correct

answer. The second is the degree of variability in a technique when applied to many children of almost identical weight. These two analyses are, respectively, measurement bias and precision (5). The bias is determined from the mean percentage difference (MPD). This is calculated as:

(True weight – estimated weight) / true weight x 100.

A positive value indicates an underestimation of weights on average, while a negative value would conversely apply an overestimation. The 95% limits of agreement includes the range in which 95% of the differences between true and estimated weight will occur. The standard deviation of the MPD is used to estimate the precision of the formulae in approximating the true weight.

A graphical representation of the measurement bias and precision is the Bland-Altman plot. The difference between the estimated weight and the actual weight is plotted on the y – axis while the average of the actual weight is plotted on the x – axis.

An analysis of the number of estimates within 10% of the measured weight will also be performed for each technique. This is a further indication and the most accepted evaluation of accuracy. The suggested minimum requirement for accuracy is 60% of estimates to be within 10% of actual weight (13).

In summary each weight estimation formula was assessed in terms of 3 evaluations:

- the MPD, 95% limits of agreement, and standard deviation
- the Bland Altman plot analysis
- the proportion of estimates within 10% of actual weight.

For all statistical tests a p value <0.05 will be considered to be significant**.**

BMI is graphically represented on gender specific BMI for age growth charts developed by the CDC (21). The interpretation is as follows for children of the same age and gender:

- underweight is defined as a BMI less than the 5th percentile
- healthy weight is defined as a BMI from the 5th percentile to less than the 85th percentile

- overweight is defined as a BMI at or above the 85th percentile and lower than the 95th percentile
- obesity is defined as a BMI at or above the 95th percentile (21).

The rationale for the use of these criteria is that a BMI at the 95th percentile corresponds to a BMI of 30 in adults, which is the value used to define obesity. A BMI at the 85th percentile corresponds to a BMI of 25, which is the value corresponding to the upper limit of normal weight (21).

5.9 SIGNIFICANCE OF STUDY

There is limited literature regarding the use of the most appropriate technique for the South African population, and to date only three studies have been identified. (11-13) The results from these studies, however, may not be able to be extrapolated to all regions of South Africa due to of the diversity of the population, both in terms of ethnic and socioeconomic distribution. Determinants of weight are complex and are influenced by gender, genetics, and ethnicity in addition to age and height/length. Therefore, there is a need to determine the most appropriate technique for the South African, CHBAH paediatric population.

This study attempts to compare the accuracy of the formula currently used by anaesthetists at CHBAH and other academic hospitals affiliated to Wits, to the measured weight. Two other formulae, The APLS and the Luscombe and Owens formulae will also be compared to the measured weight. The APLS formula, one of the earliest derived, has still been shown to be accurate in the developing world, whereas the Luscombe and Owens, derived in the developed world in order to address the problem of increasing weight of children, appears to be more accurate in the developed world. The results of this study would also give an indication of which of these two is more accurate for the children consulted at CHBAH.

The existence of a validated weight estimation technique can offer the clinician a baseline from which to work. Clinical judgement would then have to be incorporated in order to achieve the best weight estimation for a particular child.

The ethnicity and BMI of all the children will also be recorded, both variables providing valuable information about the South African population being serviced.

5.10 VALIDITY AND RELIABILITY

The validity and reliability of this study will be ensured by the following measures.

- A suitable study design has been chosen.
- An adequate, representative sample size.
- A standardised technique in obtaining the weight and height of each child.
- The measurements will be conducted by one researcher, and if necessary an assistant familiar with the data collection protocol.
- Data will be analysed with the assistance of a biostatistician.

5.11 POTENTIAL LIMITATIONS

A contextual limitation of this study is that the sample population may not be representative of the general population. The sample will be taken from one hospital in the Gauteng region, and although CHBAH is one of the largest hospitals in the southern hemisphere, it services a specific population in terms of ethnicity and socioeconomic status. The sample may therefore only be reflective of this population and not be generalisable to other regions of the country.

The sample will also be taken in the paediatric outpatient department, and therefore a few subgroups will be excluded. These include children attending specialist clinics, those with chronic conditions, (such as HIV, cardiac, renal or liver disease) and the critically ill.

This study will also only look at children aged 10 years and less, not taking into account the possibly more difficult prepubescent ages, where genetic factors and differences in growth spurts are more likely.

5.12 PROJECT OUTLINE

Time frame

Activity	June 2013	July 2013	Aug 2013		Jan 2014	Feb 2014	Mar 2014	Apr 2014	May 2014	June 2014	July 2014	Aug 2014
Proposal												
Writing Chapters 1,2,3												
Ethics Submission												
Post Grad Submission												
Data Collection												
Data Analysis												
Writing of Ch. 4 & 5												
Supervisor Discussion												
Editing Final Draft												
MMED Submission												

Financial plan

Expense Description	Quantity	Price per Unit	Cost (Rands)
Paper and printing	2000	R 0.6 per page	R 1200.00
Binding	3	R 150	R 450.00
Electronic scale	1	R 300	R 300.00
Total			**R 1 950.00**

The cost of the electronic scale and binding will be incurred by the researcher. The printing costs will be funded by the Department of Anaesthesiology, Wits.

References

1. Loo PY, Chong SL, Lek N, Bautista D, Ng KC. Evaluation of three paediatric weight estimation methods in Singapore. J Paediatr Child Health. 2013 Apr;49(4):E311-6. Epub 2013/03/16. Eng.10.1111/jpc.12141

2. Krieser D, Nguyen K, Kerr D, Jolley D, Clooney M, Kelly AM. Parental weight estimation of their child's weight is more accurate than other weight estimation methods for determining children's weight in an emergency department? Emerg Med J. 2007 Nov;24(11):756-9. Pubmed Central PMCID: PMC2658317. Epub 2007/10/24. Eng.10.1136/emj.2007.047993

3. Luscombe MD, Owens BD, Burke D. Weight estimation in paediatrics: a comparison of the APLS formula and the formula 'Weight=3(age)+7'. Emerg Med J. 2010 Jul;28(7):590-3. Epub 2010/07/28. Eng.10.1136/emj.2009.087288

4. Argall JA, Wright N, Mackway-Jones K, Jackson R. A comparison of two commonly used methods of weight estimation. Arch Dis Child. 2003 Sep;88(9):789-90. PubMed PMID: 12937099. Epub 2003/08/26. Eng

5. Black K, Barnett P, Wolfe R, Young S. Are methods used to estimate weight in children accurate? Emerg Med (Fremantle). 2002 Jun;14(2):160-5. PubMed PMID: 12147113. Epub 2002/07/31. Eng

6. House DR, Ngetich E, Vreeman RC, Rusyniak DE. Estimating the weight of children in Kenya: do the Broselow tape and age-based formulas measure up? Ann Emerg Med. 2013 Jan;61(1):1-8. Epub 2012/09/04. Eng.10.1016/j.annemergmed.2012.07.110

7. So TY, Farrington E, Absher RK. Evaluation of the accuracy of different methods used to estimate weights in the pediatric population. Pediatrics. 2009 Jun;123(6):e1045-51. Epub 2009/06/02. Eng.10.1542/peds.2008-1968

8. Partridge RL, Abramo TJ, Haggarty KA, Hearn R, Sutton KL, An AQ, et al. Analysis of parental and nurse weight estimates of children in the pediatric emergency department. Pediatr Emerg Care. 2009 Dec;25(12):816-8. Epub 2009/12/18. Eng.10.1097/PEC.0b013e3181c32eb6

9. Harris M, Patterson J, Morse J. Doctors, nurses, and parents are equally poor at estimating pediatric weights. Pediatr Emerg Care. 1999 Feb;15(1):17-8. PubMed PMID: 10069305. Epub 1999/03/09. Eng

10. Rosenberg M, Greenberger S, Rawal A, Latimer-Pierson J, Thundiyil J. Comparison of Broselow tape measurements versus physician estimations of pediatric weights. Am J Emerg Med. 2011 Jun;29(5):482-8. Epub 2010/09/10. Eng.10.1016/j.ajem.2009.12.002

11. Geduld H, Hodkinson PW, Wallis LA. Validation of weight estimation by age and length based methods in the Western Cape, South Africa population. Emerg Med J. 2011 Oct;28(10):856-60. Epub 2010/10/15. Eng.10.1136/emj.2010.098640

12. Georgoulas VG, Wells M. The PAWPER tape and the Mercy method outperform other methods of weight estimation in children at a public hospital in South Africa. S Afr Med J. 2016 Aug 07;106(9):933-9. Epub 2016/09/08. eng.10.7196/SAMJ.2016.v106i9.10572

13. Wells M, Coovadia A, Kramer E, Goldstein L. The PAWPER tape: A new concept tape-based device that increases the accuracy of weight estimation in children through the inclusion of a modifier based on body habitus. Resuscitation. 2013 Feb;84(2):227-32. Epub 2012/07/17. eng.10.1016/j.resuscitation.2012.05.028

14. Morgan G, Mikail M, Murray M. Clinical Anesthesiology Fourth Edition: McGraw-Hill Medical Publishing Division; 2006.

15. Bowen L, Zyambo M, Snell D, Kinnear J, Bould MD. Evaluation of the accuracy of common weight estimation formulae in a Zambian paediatric surgical population. Anaesthesia. 2017 Apr;72(4):470-8. Epub 2016/12/28. eng.10.1111/anae.13780

16. Britnell S, Koziol-McLain J. Weight estimation in paediatric resuscitation: A hefty issue in New Zealand. Emerg Med Australas. 2015 Jun;27(3):251-6. Epub 2015/04/08. eng.10.1111/1742-6723.12389

17. E HMaT. Validating a new formula for weight estimation in pediatric cancer patients. International Research Journal of Medicine and Medical Sciences

February 21 2013;Volume 1, Issue 1:34-9.

18. Park J, Kwak YH, Kim do K, Jung JY, Lee JH, Jang HY, et al. A new age-based formula for estimating weight of Korean children. Resuscitation. 2012 Sep;83(9):1129-34. Epub 2012/02/01. Eng.10.1016/j.resuscitation.2012.01.023

19. Theron L, Adams A, Jansen K, Robinson E. Emergency weight estimation in Pacific Island and Maori children who are large-for-age. Emerg Med Australas. 2005 Jun;17(3):238-43. Epub 2005/06/15. Eng.10.1111/j.1742-6723.2005.00729.x

20. Hegazy M, Taher E. Validating a new formula for weight estimation in pediatric cancer patients. Int J Med Med Sci. February 21 2013;1:34-9.

21. Centres for Disease Control and Prevetion. Using the BMI-for-Age Growth Charts. In: Prevention CfDCa, editor. 2010.

22. Advanced Paediatric Life Support. 3rd ed. London: BMJ Publishing Group; 2003.

23. Luscombe M, Owens B. Weight estimation in resuscitation: is the current formula still valid? Arch Dis Child. 2007 May;92(5):412-5. Pubmed Central PMCID: PMC2083737. Epub 2007/01/11. Eng.10.1136/adc.2006.107284

24. Department of Health. Guidelines for Good Practice in the Conduct of Clinical Trials with Human Participants in South Africa. In: Health. Do, editor. Pretoria, South Africa2006.

25. World Medical Association. World Medical Association. Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects. 2008.

26. Brink H, Van Der Walt C, Van Rensburg G. Fundamentals of research methodology for healthcare professionals. Cape Town Juta; 2006.

27. Katzellenbogen J, Joubert G, Abdool Karim S. Epidemiology: A manual for South Africa2002.

28. Burns N, Grove S. The Practice of Nursing Research Appraisal, Synthesis, and Generation of Evidence 6th Edition Saunders; 2009.

29. Burns N, Grove SK. Understanding Nursing Research: Saunders; 2003.

Appendix A

Letter to the Medical Advisory Committee requesting permission to conduct research

Dr Z Soni

Student number: 0300765N

Staff number: A0003881

Department of Anaesthesiology

University of the Witwatersrand

12 July 2013

Attention: Medical Advisory Committee

Re: Permission to conduct research at the Chris Hani Baragwanath Academic Hospital (CHBAH).

My name is Dr Zakiyya Soni. I am currently a registrar in the Department of Anaesthesia at CHBAH, and also registered for a Master of Medicine (Anaesthesia) at the Faculty of Health Sciences, University of the Witwatersrand, for which I am expected to conduct clinical research under supervision.

The title of my research proposal is: 'Comparison of weight estimation formulae in paediatric patients at Chris Hani Baragwanath Academic Hospital.'

With your permission I would like to measure the weight and height of all eligible children, aged 1-10 year, presenting to the CHBAH paediatric outpatient department. There will be no patient identifiers and the only other recorded variables will be age, gender and ethnicity, purely for demographic purposes. Using the raw data I would like to compare three age based formulae derived to provide an estimate of weight in children, to the measured weight. Permission will be sought from the Head of the Paediatric outpatient clinic before undertaking this research.

I hereby apply for permission to carry out this research at the CHBAH paediatric outpatient clinic. The proposed study and its procedures have been approved by the Human Research Ethics Committee (the clearance certificate number is M130704), and the Postgraduate Committee of the University of the Witwatersrand.

There will be no financial implications for CHBAH, or the Gauteng Provincial Department of Health.

Thank you for your time. Please feel free to contact me if there are any queries.

Yours faithfully,

Dr Zakiyya Soni

083 464 9316

sonizaks4@hotmail.com

Appendix B



GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

Department of Paediatrics, Metabolic Unit
Chris Hani Baragwanath Academic Hospital
Private Bag X01
Pimville, 1808
Tel: (011) 933-8416/8400
Fax: (011) 938-9074



6th November 2013

Professor Y. Jeenah
Protocol Review Committee
Chris Hani Baragwanath Academic Hospital
Soweto

Dear Prof Jeenah,

I would like to inform you that Dr Zakiyya Soni has been given permission to conduct her research in the Department of Paediatrics at Chris Hani Baragwanath Academic Hospital. The title of her study is, 'Comparison of weight estimation formulae in paediatric patients at Chris Hani Baragwanath Academic Hospital.' She will be conducting her study in the Paediatric Outpatient Department.

Yours Sincerely,

Professor Sithembiso Velaphi
Head of Department of Paediatrics
Chris Hani Baragwanath Academic Hospital

Appendix C

Information letter

Dear parent/caregiver/guardian

Hello, my name is Zakiyya Soni and I am a doctor at Chris Hani Baragwanath Academic Hospital. My job involves giving patients special gasses or drugs (medicines) to put them to sleep without pain for operations. I work with adults and children. In children most of the drugs and equipment we use depend on the child's weight. Often in an emergency situation when a child is very sick, we are unable to weigh the child. Also in some hospitals scales are not available. For this reason we use a formula to estimate the weight.

As part of my Master's degree in anaesthetics I will be comparing the formulas we use to estimate the weight of a child, to the actual weight of the child. To do this I will need the age, weight and height of your child. We will also be recording ethnicity (for demographics and not to discriminate), and whether your child is a girl or a boy. No names or any other information to identify your child will be put in any of the results of the study.

The reason why we take the age is because all of the formulas use age to estimate weight. The reason why we are measuring height is so that we can use it, together with the weight, to work out a Body Mass Index (BMI). The BMI will tell us the number of children that are normal weight, underweight or overweight. All your child will be asked to do is stand on a scale so the weight can be recorded, and then stand against the wall so the height can be recorded. These two measures are routinely done at the hospital by the nurses anyway, and it is a quick and pain free process.

I kindly ask for your permission to allow your child to participate in this study. All the information that we get in connection with this study will remain anonymous (a secret). Your decision to allow your child to take part in this study is completely voluntary, and will not affect your future treatment at the hospital. If you decide to take part, you are free to stop taking part at any time. The study has obtained approval from the Human Ethics Committee of the University of the Witwatersrand. This is a committee that makes sure that no research is being done that is harmful or dangerous to the patient.

If you are willing to allow your child to participate in the study, you will need to sign a CONSENT FORM. If your child is 8 years of age or older I will also ask his/her permission and he/she will be asked to sign an ASSENT FORM.

Before giving permission please make sure that you understand everything we have explained. If you are unsure we will make sure that someone is available to answer your questions in a language of your choice. Please feel free to ask questions at any time.

If you have any questions at a later stage or when we are not around, you are also welcome to contact me on 011 488 4397 or the Chairman of the Ethics Committee, Professor Cleaton-Jones on 011 717 1234.

Thank you for your time

Yours faithfully

Zakiyya Soni

Anaesthetic Doctor

Consent form

Research Title: Comparison of weight estimation formulae in paediatric patients at Chris Hani Baragwanath Academic Hospital

I _____ understand what this study is about and give consent of my child/ the child I care for to participate in this study. I have read and understand the information sheet and my questions have been answered. I am aware that the process will not harm the child in any way. I am aware that the child may withdraw from the study at any time without any prejudice toward the child or me. I understand that my name and that of my child will not appear in any of the results of the research.

_____

Parent/Caregiver name

_____

Parent/Caregiver signature

_____

Date

_____

Researcher name

_____

Researcher signature

_____

Date

_____

Assent form

Research Title: Comparison of weight estimation formulae in paediatric patients at Chris Hani Baragwanath Academic Hospital

I _____ am happy to take part in this study. I understand that my weight and height will be measured, and know that this will not hurt me. I understand what the study is about and my questions have been answered. I know that nobody will know that I was part of the study when it is finished and that I can say I don't want to take part in this study at any time.

_____

Subject name

_____

Subject signature

_____

Date

_____

Researcher name

_____

Researcher signature

_____

Date

Appendix D

Sample data collection table

Patient Number	Age	Gender	Ethnicity	Measured Weight	Measured Height	BMI	APLS formula Estimate	Luscombe and Owens Formula Estimate	Wits-A Formula Estimate