To compare the accuracy of the Broselow-Luten Tape and APLS, Theron and Shann's formulae in prediction of weight in children aged 5 to 10 years in Auckland

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ABSTRACT

Paediatric weight estimation methods commonly used in emergency situations tend to underestimate the weight of most children. This study aims to test the accuracy of four weight estimation methods used in New Zealand to predict a child's weight in an emergency situation.

This study was a prospective, observational study where data was collected over two weeks in July 2013 at 5 Auckland primary schools. Children between 5 and 10 years of age had their weight, height and Broselow-Luten tape (2011 version) weight recorded using standardised methods of measurement. Weight estimations were then calculated using age based formula derived by Advanced Pediatric Life Support (APLS), Shann and Theron as well as the length based Broselow-Luten tape. Age, ethnicity, gender and school decile data were collected for stratification. Percent error was calculated for each child and mean bias (actual weight – estimated weight) and Bland-Altman plots created.

Three hundred and seventy six children were included in this study. Theron's formula (mean bias -6.5) was least accurate clinically with 28.7% of weight estimates within 10% of actual weight. The Advanced Paediatric Life Support (APLS) formula showed positive bias (mean bias 7.8) and 39.1% of weight estimates within 10% of actual weight. Shann's formula was the most accurate among the age based weight estimation methods (mean bias 7.7) with 45.7% of estimates within 10% of actual weight. The Broselow-Luten tape was accurate within its parameters of 43 to 143 cm (n=305) and in this group of children, was the most accurate (mean bias 1.1) with 73.4% of weight estimates within 10% of actual weight.

The length based Broselow-Luten Tape is the most accurate method of weight estimation for a cross section of Auckland children aged 5 to 10 years who are below the height of 143 cm. Among the age based weight estimation methods, Shann's formula is the most accurate. These findings have important implications for prehospital and emergency resuscitation policy in New Zealand.

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ATTESTATION OF AUTHORSHIP

"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning."

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CHAPTER 1 INTRODUCTION

This introductory chapter introduces the topic for this thesis. It provides the background for this issue and introduces weight estimation methods in resuscitation while identifying the impact of obesity in relation to weight estimation.

Background

My clinical nursing experience spans over 15 years in varying work environments including adult surgical, medical, respite care, practice nursing and teaching. In addition, I have clinical and teaching experience within an ambulance service. Seven years in paediatric emergency nursing meant frequent experience with resuscitation of children. Previous adult resuscitation involved working within predictable clinical parameters around drug dosing, equipment size and defibrillation protocols. However, in the paediatric emergency department I came to realise that these consistent parameters could not be applied to children due to the variation in physical size and developmental stage. Luten (2002) and Croskerry (2000) recognise this difference and suggest that most health care workers are more familiar with adult physical size and drug dosing compared to that for the paediatric population. The variation of resuscitation knowledge, including, drugs and equipment based on size as well as child development, captured my attention. My desire to provide the best possible individualised nursing care for children and families prompted me to investigate weight estimation in resuscitation of children within Auckland, New Zealand. In this thesis, I compare the accuracy of four weight estimation methods in a sample of Auckland school aged children.

More so than adults, children are a diverse population particularly in weight, size, shape and developmental level (Thies & Travers, 2009). This means that children require greater individualization of their care. Obtaining an accurate weight of a child allows for optimum care of children. Measuring the weight of a child requires time and a systematic and uniform approach. Royal College of Nursing (2010) in the United Kingdom states all children under two years are to be weighed naked. Children over the age of two years are to be weighed wearing minimal clothing with nappies, shoes, slippers and the contents of pockets removed. In my experience working in a pediatric emergency department, children under 6 months of age were weighed naked and older children wearing minimal clothing. However, I noticed that children's shoes and jackets often remained on when the department was busy.

In a resuscitation setting body weight influences the selection of equipment size and is necessary for calculation of treatment doses. Many authors outline the need for accurate weight in paediatric emergencies as drug or fluid dosages, equipment size and defibrillator output are calculated based on weight (Abdel-Rahman, Ahlers, Holmes, Wright, Harris, Weigel, Hill, Baird, Michaels & Kearns, 2013a; Cattermole, Leung, So, Mak, Graham & Rainer, 2011; Mackway-Jones, 2005; Theron, Adams, Jansen & Robinson, 2005). Speed and accuracy in paediatric emergencies is necessary to achieve positive patient outcomes; however, obtaining the measured weight of a child before treatment is not always possible which in turn can influence the outcome of a resuscitation (Luten, 2002). There are many reasons why weighing a child during a resuscitation can not occur, whether in a prehospital or hospital setting. For example, scales may not always be at hand or the time taken to stop and weigh a child may be detrimental to their survival (Luten, 2002). Paediatric resuscitation involves making critical decisions in a short time frame which Luten (2002), referred to as cognitive loading. To support best individualised treatment and reduce errors during resuscitation, standardised weight estimation methods such as mathematical formulae and calculations based on length have been created (Black, Barnett, Wolfe & Young, 2002; Wells, Coovadia, Kramer & Goldstein, 2013).

Common Weight Estimation Methods used in Auckland, New Zealand

Four common paediatric weight estimation methods are widely used in Auckland. These are the Broselow-Luten Tape (length based method) as well as the Advanced Paediatric Life Support (APLS) formula, Shann's Formula and Theron's Formula (age based formulae).

Broselow-Luten Tape.

In the 1980s Robert Broselow invented a colour-coded Tape to give a weight estimate based on a child's length from head to heel. This was devised from 1979, United Kingdom (UK) growth chart data provided by the United States National Statistics Centre (Broselow, 2012). His rationale for the tape was to provide a simple and uniform method of paediatric weight estimation to decrease errors in the emergency department.

According to Ferner (2012) the most common paediatric drug errors are dose errors which are often based on weight estimate. Early versions of the Broselow Tape gave a weight estimate, but further calculations were required to obtain the medication dose. Broselow (2012) explains that this was resolved In the 1990s when he was joined by Robert Luten to create international paediatric drug dosing standards for use with the Broselow Tape. These were then printed on the Broselow Tape at the appropriate increment. Their combined work (Figure 1) shows the Broselow-Luten Tape with weight estimated by length and resuscitation drug doses and equipment size included to decrease the risk of error.

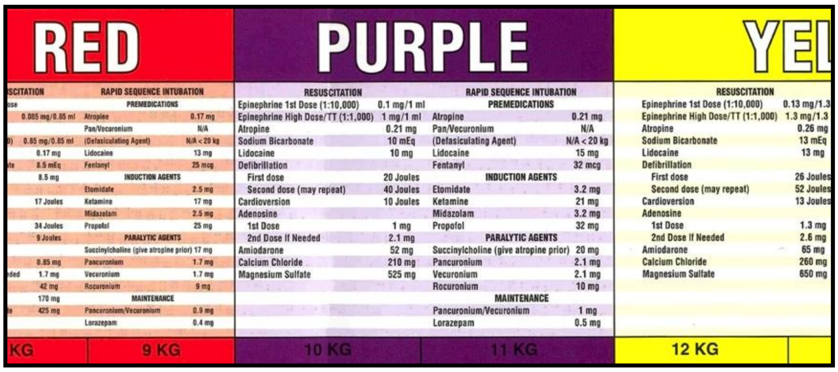

Figure 1 - Portion of the Broselow-Luten Tape

There have been several iterations of the Broselow-Luten Tape with updates to weight and drug information. The most recent iteration of the the Broselow-Luten Tape is the 2011 version used in this study. A limitation of 2011 Broselow-Luten Tape is that the data used to create this was from North American children which Park, Kwak, Kim do, Jung, Lee, Jang, Kim and Hong (2012) point out make using the tape worldwide difficult as it was designed for North American Children. Nevertheless, many studies worldwide have found length-based methods such as the Broselow-Luten Tape the most accurate of the weight estimation methods tested (Black et al., 2002; Cattermole et al., 2011; Lulic & Kovic, 2010; Sandell & Charman, 2009; So, Farrington & Absher, 2009; Theron et al., 2005). Although the Broselow-Luten Tape is usually the most accurate among weight estimation methods in the western world, Park et al. (2012) studied weight estimation in Korea (n = 7500) and found that the Broselow-Luten Tape underestimated one third of their sample.

Anecdotally, I found the Broselow-Luten Tape underutilised in my workplace. It was available in each resuscitation room however, staff preferred an age based mathematical formulae. The rationale staff offered was that mathematical formulae reduced time to treatment by allowing for equipment setup to occur before the arrival of the child when their age was known.

Another limitation of length based methods of weight estimation is that the child needs to be either standing or laying flat. Cattermole et al. (2011) explain that laying flat is not practical in some resuscitation situations such as severe asthma where laying flat is contraindicated making length based methods of estimation ineffective.

APLS Formula

- *Weight = (2 x age in years) + 8 or*
- *Weight = (age in years + 4) x 2*

The APLS formula is a mathematical formula used worldwide and recommended by the New Zealand Resuscitation Council (2010) for estimating weight of children aged 1 – 9 years. In the United Kingdom, the APLS formula has been updated to reflect the increasing weight of children aged 6 to 12 years (Resuscitation Council United Kingdom, 2012):

- *1 - 12 months = (0.5 x age months) + 4*
- *1 - 5 years = (2 x age years) + 8*
- *6 - 12 years = (3 x age years) + 7*

A study of New Zealand Maori and Pacific children by Theron et al. (2005) showed that these populations were considerably heavier than others in Auckland, therefore, the APLS formula consistently underestimated the weight of these children.

Theron's Formula

- *Weight = exp(2.20 + 0.175 x age)*

The Theron formula was designed in New Zealand by Theron et al. (2005) and is based on a sample of children in Auckland who were predominantly Maori and Pacific and large for their age. A limitation of this study is that the sample was predominantly Maori and Pacific which means that generalisation to the wider population may not be possible.

Shann’s Formula

- *1 – 9 years weight = (2 x age in years) + 9*
- *10 – 14 years weight = 3 x age in years*

Shann’s formula is a mathematical formula similar to the APLS formula. It was difficult to find research which includes the origin of Shann’s formula although it has been validated in later studies (Cattermole et al., 2011; Hegazy & Taher, 2013; Park et al., 2012; Theron et al., 2005). The New Zealand Resuscitation Council (2010) recommends a modified version of Shann's formula (weight = 3.3 x age in years) for children aged 10 – 14 years in New Zealand.

Significance of weight estimation formula selection.

Weight estimates can vary based on the choice of mathematical formula and parameters that govern their use as well as the age of the child. Table 1 shows a comparison of the APLS, Shann and Theron's formulae applied to children aged 1-9 years. The most noticeable difference is in a 9 year old child where a variation of 18 kg is evident. For example, if a 9-year-old child weighs 26 kg, the APLS formula is accurate, however, if Theron's formula was used their weight estimate would be 44 kg giving a possible variance of 18 kg or 40.9% of their body weight. In terms of medication doses, Adrenaline 1:10000 is 0.1 ml / kg or 0.01 mg / kg and at 26 kg this is a 0.26 mg dose and at 44 kg this is 0.44 mg dose. The result of this variation is the child could receive 0.26 mg or 0.44 mg depending on weight estimation method. According to Medsafe (2012) the outcome of an overdose, such as this one may be life threatening.

Table 1 - Comparison of results from age based weight estimation formulae

Age	APLS	SHANN	THERON
1 years	10 kg	11 kg	11 kg
2 years	12 kg	13 kg	13 kg
3 years	14 kg	15 kg	15 kg
4 years	16 kg	17 kg	18 kg
5 years	18 kg	19 kg	22 kg
6 years	20 kg	21 kg	26 kg
7 years	22 kg	23 kg	31 kg
8 years	24 kg	25 kg	37 kg
9 years	26 kg	27 kg	44 kg

The accuracy of weight estimation methods can be influenced by their design. The APLS and Shann's formulae are designed as linear equations to allow simplicity. However, according to the New Zealand Ministry of Health (2010) usual growth patterns for children are not entirely linear. One way to compensate for this is to create non-linear formulae like Theron's exponential formula or several formulae with age limits. To illustrate the difference between linear and non-linear formulae, Figure 2 shows two formulae (APLS and Shann) along with a non-linear equation by Theron.

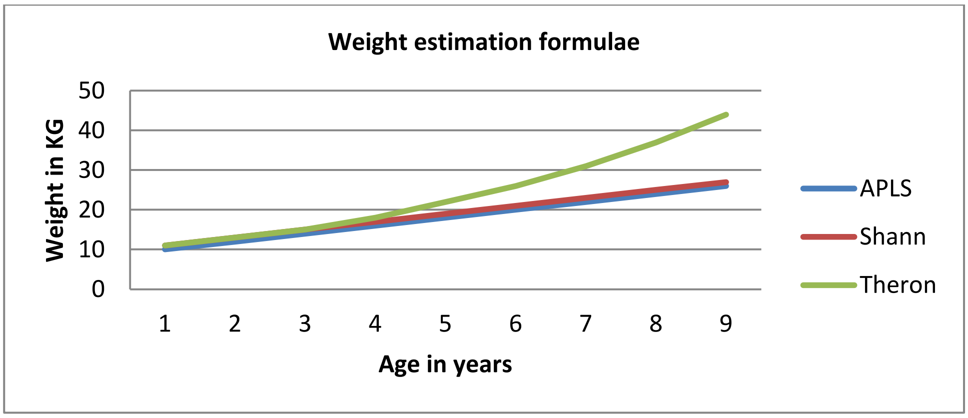

Figure 2 – Age based Formulae for Weight Estimation

New Zealand Weight Estimation Guidelines

As mentioned above, the New Zealand Resuscitation Council (2010) endorses the use of the APLS formula for children between 1- 9 years and suggest a modified version of Shann's formula for those 10 to 14 years. They also indicate that the Broselow-Luten Tape is an alternative length based method of estimation. However, they do not specify the accuracy or favour any one of these weight estimation methods.

Obesity in New Zealand

Changes in the body mass or variance in population may impact weight estimation methods, therefore prevalence of obesity needs to be investigated. Obesity is not a new phenomenon. A national children's nutrition survey carried out by Barnfather (2004) revealed that 21.3% of New Zealand children between 5 and 15 years were overweight and 9.8% were obese. However, according to New Zealand Ministry of Health (2008) these rates dropped with the narrowing of the age parameters in 2006-2007, where 20.9% of children aged 2-14 were overweight and 8.3% are obese. They also found that there was little change in prevalence of obesity in New Zealand of children between 2002 and 2006/7 which may indicate a plateau in the rise of obesity as other countries have recently reported. However, worldwide reports of a plateau in rising obesity vary, Australia, Switzerland, Ireland and Germany reported a plateau in prevalence of obesity while other developed countries such as Poland continue to report an increase in childhood obesity (Aeberli, Henschen, Molinari & Zimmermann, 2010; Bac, Wozniacka, Matusik, Golec & Golec, 2012; O'Dea, Nguyen Hoang & Dibley, 2011).

Population density, geographical location or ethnicity can influence the prevalence of obesity and in turn weight estimation. The New Zealand Ministry of Health (2008) states that BMI was considerably higher for children living in low socioeconomic or highly populated areas. They reported that the prevalence of obesity in these areas was 12.7% (95% CI), which was above the national average of 8.3% (95% CI). This is illustrated in, Table 2, which shows the prevalence of obesity related to geographical location. A trend noted is that geographical locations which have high proportions of Maori and Pacific children also have higher rates of obesity whereas other areas show lower rates of obesity.

Table 2 - Prevalence of Obesity in New Zealand

Area & Reference	Age of Children	Data Collection	Obesity Prevalence	Population Ethnicity	%
Hawkes Bay (Turnbull, Barry, Wickens & Crane, 2004)	12 years	1989	11.0%	European Maori Other Pacific	66.8% 25.8% 0.4% 3.1%
		2000	20.9%	European Maori Other Pacific	62.7% 30.8% 0.4% 4.5%
Auckland (Utter, Scragg, Schaaf, Fitzgerald & Wilson, 2007)	Teenagers	1997/1998	19.4%	European Maori Other Pacific	13.0% 20.9% 9.8% 56.3%
		2005	30.7%	European Maori Other Pacific	9.1% 19.5% 7.8% 63.3%
National (Utter, Scragg, Denny & Schaaf, 2009)	School Children	2002	9.2%	European / Other Maori Pacific	5.5% 16.2% 28.6%
National (Barnfather, 2004)	2 – 15 years	2002	9.8%		
Dunedin (Gordon, Ferguson, Toafa, Henry, Goulding, Grant & Guthrie, 2003)	3-7 years	2000	34.0 to 49.0%	Cook Island Other Samoan Tongan	12.0% 20.0% 46.0% 22.0%
National (Barnfather, 2004)	2 – 15 years	2006 - 2007	8.3%		

Body Mass Index (BMI) and Body Composition.

BMI gives a guide to obesity; however, its relevance in children is questionable. In studies by Barnfather (2004) and New Zealand Ministry of Health (2012), BMI was tailored to children using the International Task Force for Obesity (ITFO) cut-off points indicating Thinness, Overweight or Obese (shown in Table 3). This classification does not take into account the ethnicity, gender, activity level and muscle mass of children. Other methods of measurement such as bioimpedence[1] to measure muscle mass or body fat % may provide a more accurate view of obesity in New Zealand children (Black et al., 2002; Grant, Henry, Guthrie, Ferguson & Toafa, 2004).

1 Response of living tissue to an externally applied electric current to measure current through the tissues giving an indication of body fat

Table 3 - International Task Force for on Obesity (ITFO) BMI cut-off points for Children aged 5 – 10 years

Age in Years	Thinness		Overweight		Obese	
	Male	Female	Male	Female	Male	Female
5.0	14.21	13.94	17.42	17.15	19.30	19.17
5.5	14.13	13.86	17.45	17.20	19.47	19.34
6.0	14.07	13.82	17.55	17.34	19.78	19.65
6.5	14.04	13.85	17.71	17.53	20.23	20.08
7.0	14.04	13.86	17.92	17.75	20.63	20.51
7.5	14.08	13.93	18.16	18.03	21.09	21.01
8.0	14.15	14.02	18.44	18.35	21.60	21.57
8.5	14.24	14.14	18.76	18.69	22.17	22.18
9.0	14.35	14.28	19.10	19.07	22.77	22.81
9.5	14.49	14.43	19.46	19.45	23.39	23.46
10	14.63	14.58	19.80	19.78	23.96	23.97

Conversely, a study by Duncan, Duncan and Schofield (2008a) tested the accuracy of a BMI tool from the Centre for Disease Control and Prevention (CDC)[2] with ITFO cut-off points and found that both provided remarkably similar results in matching body fat to BMI for New Zealand girls of similar ethnicity. Rush, Puniani, Valencia, Davies and Plank (2003) studied the relationship between body fat and body mass index in Maori, Pacific and European children. They found that Pacific and Maori girls between 5 and 14 years have less body fat than those of the same BMI who are New Zealand European. This indicates that a higher BMI is acceptable in the Maori and Pacific population due to the decreased body fat percentage. Duncan et al. (2008a) suggests that ethnicity specific BMI cut-off points for use in countries with diverse ethnicities such as New Zealand may provide more accurate estimates of obesity.

Impact of obesity on weight estimation and treatment of children.

Effective resuscitation in a paediatric emergency is of utmost importance and variations in weight can increase the risk of medication dose or equipment size error. According to Wu, Yu, Lan and Tang (2012) most medication errors in the emergency department are related to dose errors which are often calculated from weight, Kozer, Scolnik, Keays, Shi, Luk and Koren (2002) add that many medications administered to children are “off label”[3] and frequently require calculation of body surface area (calculated using weight and height) to gain the appropriate dose. Luten (2002) explains that speed and accuracy in paediatric emergencies are necessary to achieve positive patient outcomes. However, obtaining the measured weight of a child before treatment in emergency situations is not always possible which has led to the introduction of weight estimation methods for children.

The proportion of overweight children is on the rise in New Zealand and this can impact the accuracy of current weight estimation methods. A national childrens health survey 2011/2012 stated that 10% of children aged 2-14 years were obese and 21% of children were considered overweight (New Zealand Ministry of Health, 2012). To allow comparison, Figure 3 shows obesity rates reported by the New Zealand Ministry of Health over several years using CI 95% (New Zealand Ministry of Health, 2008, 2012, 2013). These results are reported using the

[2] Part of the Department of Health and Human Services in the USA
[3] The use of a drug that is unauthorised or not unauthorised in a particular age group

ITFO[4] cut of points for BMI and categorise children into four categories *Underweight, Normal, Overweight and Obese*. The graph indicates that the number of children of normal weight are declining and children who are obese or overweight are slowly climbing. This shows the need for constant reassessment of weight estimation methods and validates the need for this study.

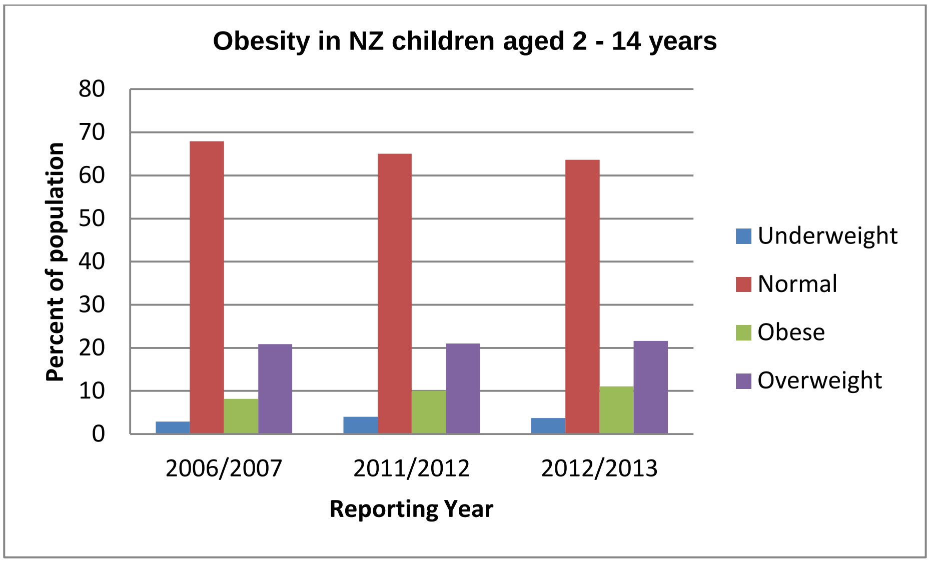

Figure 3 - Obesity of New Zealand children aged 2 - 14 years (New Zealand Ministry of Health, 2013).

The effect of variation or change in body mass of children coupled with rising obesity levels in can impact the therapeutic effect of medications that are based on age. For example, Table 4 calculates paracetamol dose using age based weight estimation formulas and age based instructions published by Medsafe (2004). A one year old child could receive a dose of paracetamol that is either 150 mg or 240 mg depending on which method of dose calculation is used, this is a difference of 90 mg or 37.5% of the maximum dose. Although both of these doses are well below the toxicity level for children of 200 mg / kg in an 8 hour period the child could still receive an underdose or overdose based on their weight estimate which could influence subsequent doses, toxicity and effectiveness of the drug (Manias, Bullock & Galbraith, 2006). This example shows a relationship between accuracy of weight estimation and medication dose. One area where more research is required is the safe margin of error in medication doses as there is a risk that both a weight estimation error and medication error could compound. The majority of studies consider a weight estimate that is within 10% of a child's measured weight accurate for use in a resuscitation, however, studies validating this margin of error are non-existent which shows the need for research in this area.

4 International Task Force on Obesity

Table 4 - Paracetamol drug doses calculated using age based weight estimates

Age in years	Paracetamol dose in mg (15 mg / kg)				Dose Range		Difference	
	Medsafe	APLS	Shan	Theron	Min	Max	mg	%
1	240	150	165	161	150	240	90	37.5
2	240	180	195	192	180	240	60	25.0
3	240	210	225	229	210	240	30	12.5
4	240	240	255	273	240	273	33	12.0
5	240	270	285	325	240	325	85	26.1
6	480	300	315	387	300	480	180	37.5
7	480	330	345	461	330	480	150	31.3
8	480	360	375	549	360	549	189	34.4
9	480	390	405	654	390	654	264	40.4
10	480	495	450	779	450	779	329	42.2
11	480	545	495	928	480	928	448	48.3
12	480	594	540	1105	480	1105	625	56.6

Summary

Children are an extremely diverse population and individualisation of their healthcare is required. Body weight is used to gauge equipment size and treatments such as calculation of the safe kilojoules output of a defibrillator or the dose of medication (Hockenberry, 2005; Mackway-Jones, 2005). Current weight estimation methods used in New Zealand are not standardised and do not specifically cater for the diverse paediatric population of New Zealand. Determining how close a weight estimate is to a child's measured weight (accuracy) will allow exploration of specific weight estimation needs of Auckland children. The aim of this study is to compare the accuracy of the Broselow-Luten Tape and APLS, Theron and Shann's formulae in prediction of weight in the Auckland children.

CHAPTER 2 LITERATURE REVIEW

Introduction

As identified in the introduction of this thesis, weight of a child affects multiple areas of medical treatment, particularly in emergency situations. This literature review will outline common methods of weight estimation used in healthcare and analyse current research in relation to these. Common themes will be critiqued and it will go on to identify gaps in this research.

Studies investigating weight estimation began to appear in the early 1980s and prior to this references to weight estimation were published in Emergency Medicine textbooks. Weight estimation methods broadly fit into 4 categories, "age based", "length based", "visual estimation" and "other methods". Current international weight estimation methods are categorised in Table 5 while Figure 4 shows a timeline of common weight estimation methods. This Literature review will focus on age and length based weight estimation methods as these are commonly in use in New Zealand.

Table 5 - Weight estimation categories

Age Based	**Length Based**	**Visual Estimate**	**Other**
Advanced Paediatric Life Support (APLS) Australian / New Zealand Resuscitation Council (ARC / NZRC) Argall Best Guess Formula Chinese Weight Assessment Rule Leffler Luscombe & Owens Nelson Park Formula Shann Theron	Devised Weight Estimation Method (DWEM) Broselow-Luten Tape Kloek Tape Lo Tape Malawi Tape Oakley Tables PAWPER Tape PREM Tape Sandell Tape Traub-Johnson Traub-Kichen Mercy Tape	Physician Ambulance Parent Nurse	Clothing Label Size Haftel Hanging Leg Arm Circumference

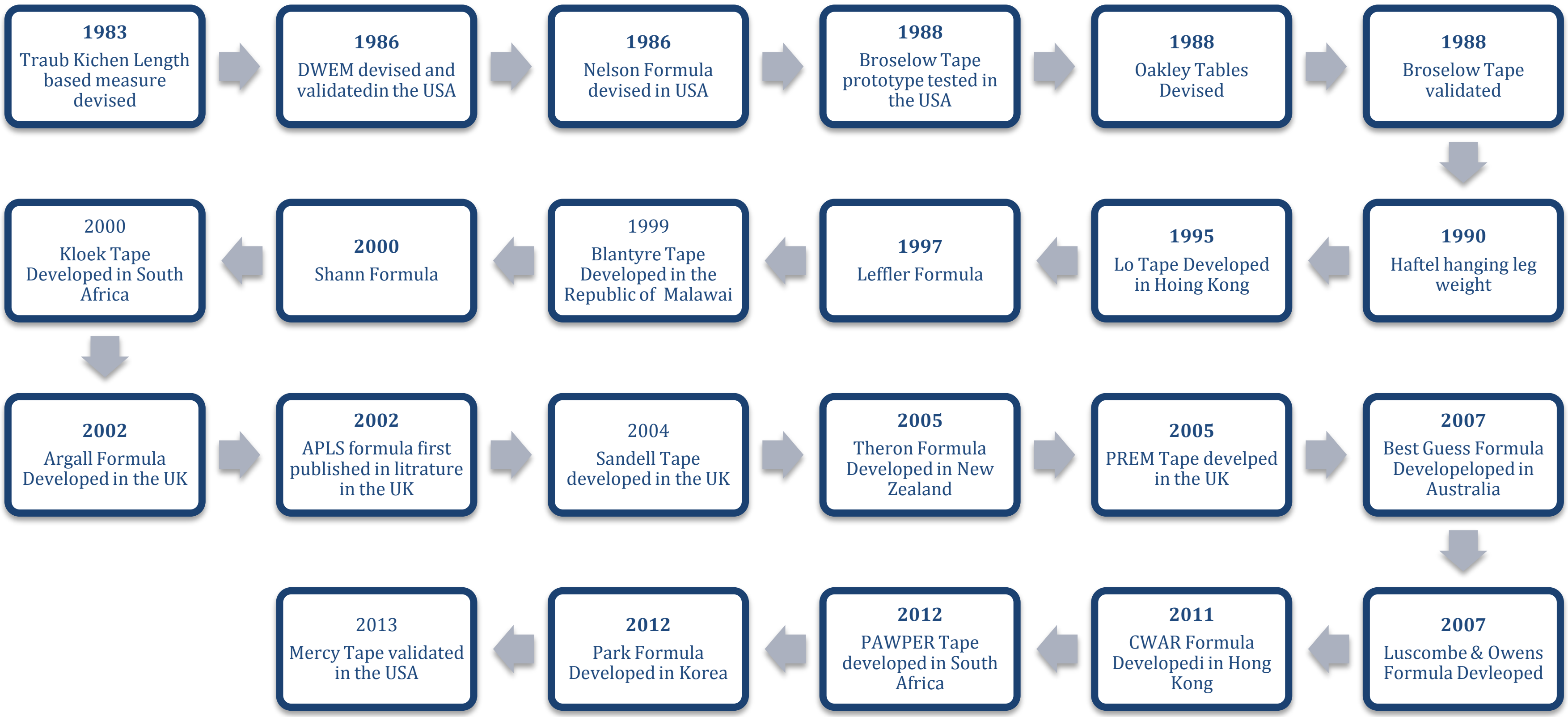

Figure 4 - Timeline for common weight estimation method

This literature review will focus on weight estimation methods commonly used in Auckland, New Zealand. Other estimation methods can be seen in Appendix A on page 66 of this thesis. The rationale for this was the abundance of localised weight estimation methods internationally that may not necessarily be applicable to the New Zealand population. The following weight estimation methods will be reviewed:

- APLS Formula
- Shann's Formula
- Theron's Formula
- The Broselow-Luten Tape

Accuracy in weight estimation

The methods used to measure the accuracy of weight estimation are not uniform across studies. Many authors report accuracy based on selection of a clinically relevant cut-off; most commonly, weight estimates within 10% of a child's measured weight are considered accurate (Abdel-Rahman et al., 2013a; Cattermole et al., 2011; Geduld, Hodkinson & Wallis, 2011; Loo, Chong, Lek, Bautista & Ng, 2013). Alternatively, other studies use mean percentage error, mean percent difference or actual error in kg to report statistical significance (Black et al., 2002; Casey & Borland, 2010; Luscombe, Owens & Burke, 2011; Luscombe & Owens, 2007; Park et al., 2012; Theron et al., 2005; Thompson, Reading & Acworth, 2007). This makes comparison and synthesis of information from these studies difficult and therefore this literature review will group and discuss studies according to accuracy reporting method for each weight estimation technique.

Age based weight estimation

Age based weight estimation is via a mathematical formula containing the child's age to calculate a weight estimate. Although, each formula has parameters to govern application such as age limits a large disparity remains apparent between formulae (see Table 6 and Appendix A on page 66 of this thesis). Table 6 illustrates this inconsistency showing that Shann's formula estimates the weight of a 10 year old child as 30 kg, whereas Theron's formula estimates a 10 year old child at 52 kg which gives a 22 kg difference depending on formula used to estimate weight. A difference in weight of this size can influence resuscitation medication dosages and equipment. Applying the above weights to a medication that the New Zealand Resuscitation Council (2010) recommends (10 micrograms (mcg) / kilograms (kg) of Adrenaline in cardiac arrest), a 10 year old child could receive either a 300 mcg or 520 mcg dose.

Table 6 - Estimation of weight using age-based formulae for children 1, 5, 10 and 14 years

Weight estimation formulae and parameters	**Estimated weight (kg)**				**Origin**	**Year**
	Age in years					
	1	**5**	**10**	**14**		
APLS / ARC 1 – 9 years – weight = (age in years + 4) * 2 10 – 14 years – weight = 3.3 * age in years	10	18⇓	33	46	UK	2010
Argall (age in years + 3) * 3	12⇑	24			UK	2003
Best Guess 1 – 4 years – weight = (2 x age in years) + 10 9 – 14 years – weight = 4 x age in years	12⇑	20	40	56⇑	Australia	2007
CWAR 1 – 6 years – weight = (3 x age in years) + 5	8⇓	20			China	2011
Leffier 1 – 10 years – weight = (age in years + 2) x 4	12⇑	28⇑	48		USA	1997
Luscombe and Owens 1 – 10 years – weight = (3 x age in years) + 7	10	22	37		UK	2011
Nelson 1 – 6 years – weight = (2 x age in years) + 8 7 – 12 years – weight = ((age in years * 7) - 5) / 2	10	18 ⇓	32	46	USA	2006
Park 1 – 4 years – weight = (2 x age in years) + 9 5 – 14 years – weight = (4 x age in years) - 1	11	19	39	55	Korea	2012
Shann 1 – 9 years – weight = (2 x age in years) + 9 10 – 14 years – weight = 3 x age in years	11	19	30⇓	42⇓	Pacifics	2005
Theron 1 – 10 years – weight = exp(2.20 + 0.175 x age in years)	11	22	52⇑		New Zealand	2005
Sandall 1 – 11 years – Table of values	10	19	32		UK	2009

⇓ = minimum weight estimation for this age, ⇑ = maximum weight estimate for this age

The design of weight estimation formula can affect it's application and ultimately patient outcomes in a resuscitation situation. For example, Figure 4 illustrates that the relationship between age and weight is not necessarily linear which, according to Cattermole et al. (2011), influences the ability to apply one weight estimation formula to a diverse range of children. Advantages and disadvantages are evident when using both linear and non-linear weight estimation methods. Theron et al. (2005) produced a non-linear formula which was exponential, however, their formula requires more advanced mathematics in a time critical situation than other linear formulae. According to Luten (2002) and Theron et al. (2005) complex calculations can be more prone to error and are time intensive which can in turn affect resuscitation outcomes by increasing cognitive loading. One solution to address this issue is to use multiple simple formula for different age groups to simplify the mathematics in a time sensitive and decision dense situation. However, multiple formula requires the user to recall more than one formula as well as age parameters of these, which Luten (2002) claims ultimately impact the outcome of a resuscitation. This illustrates the need to balance cognitive loading with simplicity of weight estimation method. Presently this is managed by staff choice of weight estimation method and the influence of New Zealand Resuscitation recommendations (New Zealand Resuscitation Council, 2010).

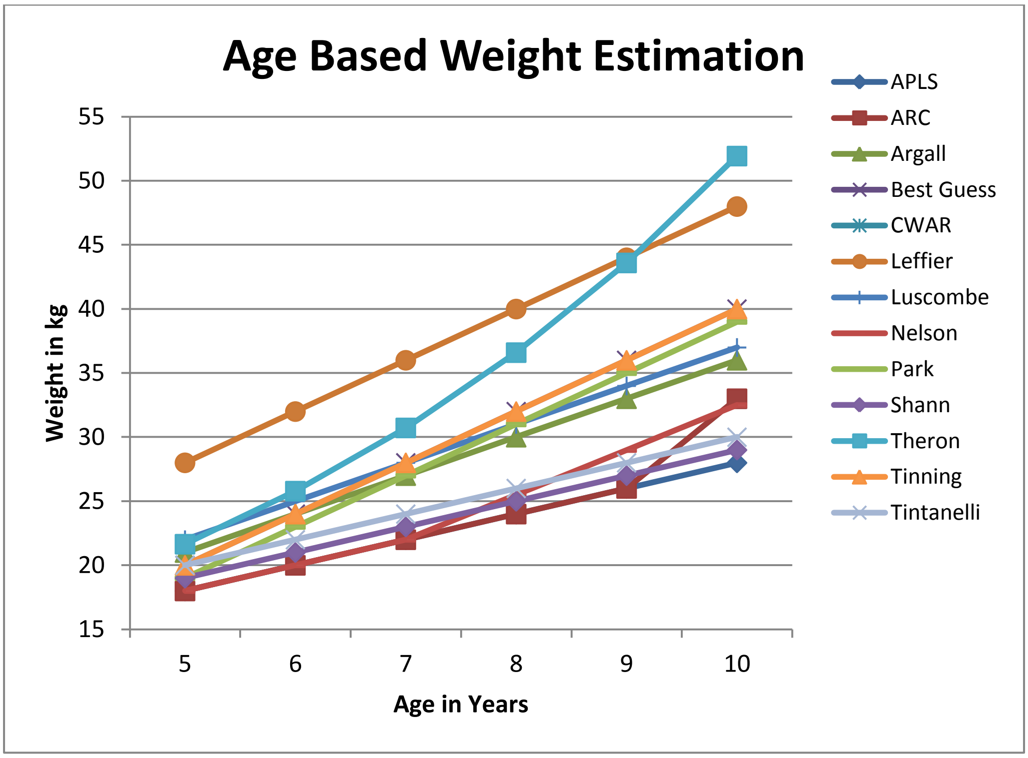

Figure 5 - Age based weight estimation

Advanced Paediatric Life Support (APLS) weight estimation formula.

The APLS weight estimation method is used internationally and taught during Advanced Paediatric Life Support (APLS) courses worldwide (Mackway-Jones, 2005). The first reference to the APLS course was in the Journal of Paediatrics in 1982 as a scheduled course, content was not disclosed and therefore, it can only be assumed that a weight estimation formula was included in this course ("Scheduled meetings," 1982).

The APLS formula generally underestimates weight of children with accuracy decreasing as age or weight increases. Table 7 illustrates this trend where studies completed by Ali, Sammy and Nunes (2012), Cattermole et al. (2011) and Geduld et al. (2011) show limits of agreement that widen with increasing age. However, when results are considered in a clinical context judgement of accuracy becomes more challenging. Abdel-Rahman et al. (2013a), Ali et al. (2012), Cattermole et al. (2011) and Loo et al. (2013) consider weight estimates within 10% of a child's measured weight accurate. Their results show that 34% to 58% of weight estimates were within 10% of a child's measured weight which demonstrates that the APLS formula generally gives an accurate weight estimate in less than 58% of cases. Reporting in clinical context raises two important issues for further investigation, firstly is 58% of weight estimates within 10% of measured weight enough? Secondly, external validation of 10% as a cut-off point for accuracy is required.

Table 7 – Summary of studies of the APLS formula that consider a weight estimate 10% of measured weight accurate

Authors	n	Age (years)	≤10% of measured weight	Bias / Difference	LOA	Country	Design and Setting
Krieser, Nguyen, Kerr, Jolley, Clooney and Kelly (2007)	410	1 – 10	34.0%	-4.3 kg	RMSE 7.5	Australia	Prospective, observational in ED.
Cattermole et al. (2011)	1248	1 – 6 7 – 10	30.1% 25.8%		-39.8 to 24.7 -59.6 to 28.2	China	Population based, observational in School / Kindergarten. Part of a larger study
Geduld et al. (2011) negative values show an over-estimation	2832	1 – 5 6 – 10 All	58.4% 57.1% 57.9%		±0.78 ±1.04 ±0.63	South Africa	Prospective Database at Hospital.
Ali et al. (2012)	1784	1 2 3 4 5 All	 45.6%	-0.6 kg -1.2 kg - 1.2 kg -2.0 kg - 2.4 kg -1.4 kg	-4.4 to 3.1 -6.6 to 4.1 -6.7 to 4.3 -9.4 to 5.3 -11.4 to 6.6 -7.8 to 5.0	Trinidad and Tobago	Prospective, observational study in ED
Abdel-Rahman et al. (2013a)	976	<1 to 16	34.4%			USA	Prospective, multicentre, observational study. Children from Hospital & Daycare & Family
Loo et al. (2013) negative values show overestimation	875	1 – 10	47.5%	7.6%	-26.8% to 28.1%	Signapore	Prospective, observational study in ED

ED = Emergency Department, RMSE = root mean square error, LOA = limits of agreement shaded cells represent developing countries

Standardisation of weight collection techniques are not guaranteed in some studies and this could impact the accuracy of results. This is demonstrated in a 2011 prospective study in Cape Town, South Africa by Geduld et al. (2011) set in a children's emergency department. Authors report a mean underestimation of 3.2% with 57.8% estimated weights within 10% of each child's measured weight when using the APLS formula. This study included a generous sample size of 2832 children over a nine month period which gives the study power and authors indicate that education of staff and calibration of tapes and scales allowed them to achieve standardisation of measures. However, as data was collected via retrospective chart standardisation and adherence to study protocols for measurement can not be guaranteed which could impact the accuracy of study results. Standardisation of information nationally and internationally would allow for uniform comparison of studies.

A further limitation of the study by Geduld et al. (2011) is in categorisation of ethnicity, in this case, Black, Coloured, Asian, White and Other which makes comparison of ethnicity data difficult as this does not categorically identify ethnicity. This highlights the need for a uniform approach to ethnicity categorisation across nations and worldwide. Geduld et al. (2011) stratified children by age into two large groups, 1 to 5 years and 6 – 10 years and smaller groups for stratification such as age increments of one year which would assist with comparison of data with other studies.

Variation of accuracy is evident on analysis of limits of agreement. An example of this is shown in a study by Cattermole et al. (2011), set in Hong Kong, China. Wide limits of agreement (-51.2% to 27.7%, bias -11.7%) for children 1-10 years showed that some children had a difference between weight estimate and measured weight of more than half of their body weight causing ambiguity of results in this study. A Singaporean study completed by Loo et al. (2013) shows a similar trend, with wide limits of agreement particularly in older children. However, Table 8 shows the widening of limits of agreement with age in their study is not as consistent among age groups which shows that demographics including geographical location or ethnicity may influence this trend.

An Auckland study conducted by Theron et al. (2005) shown inTable 8 (n = 909) considered ethnicity and also showed a large variance between weight estimate and measured weight in an Asian cohort (9% of population). Although, the Asian cohort were not the main focus of this study and made up a unusually small proportion of the sample this could bias results when viewed alone. The main focus of this study was Maori (46%) and Pacific (25%) children who were considered large for their age where weight estimates using the APLS formula significantly underestimated the weight with a large SD for both cohorts of 33.86 and 26.63 respectively (Theron et al., 2005). This shows that body mass differences related to ethnicity may alter weight estimation accuracy. Rush, Freitas and Plank (2009) confirm large body mass of Pacific children living in Auckland in the Pacific Island Family Study which tracked children from birth to 13 years. Results revealed that 95% of children aged 10 years are above the 50^{th} percentile using CDC growth charts meaning that the body mass of this proportion of children is large. This statistic shows that the prevalence of lean or large body mass could be a potential bias in weight estimation methods. It is worth noting that that CDC growth charts used in this study are not designed primarily for characteristics of New Zealand children and this needs to be considered in their application.

A limitation of this study by Theron et al. (2005) is that the setting is a single Emergency Department, where most of the sample identified as Pacific or Maori ethnicity. This makes generalising the results to wider populations challenging due to the predominance of two main ethnicities. This highlights the need for studies that can be generalised and shows that further research is required around selection of appropriate setting for weight estimation studies.

Table 8 – Summary of results from studies of the APLS formula analysed by Mean Percentage Difference (MPD)

Authors	n	Age / Weight Group	MPD	SD	LOA	Country	Design and Setting
Theron et al. (2005) A positive reading shows an under-estimate	226 420 160 79	Maori Pacific European Asian / Indian	5.51% 11.13% 5.85% -5.12%	33.86 26.63 25.71 40.14		Auckland, New Zealand	Prospective observational study in ED
Loo et al. (2013) Negative values show an over-estimation	875	1 year 2 years 3 years 4 years 5 years 6 years 7 years 8 years 9 years 10 years All	5.9% 8.0% 6.4% 6.6% 3.7% 9.0% 12.6% 11.6% 12.9% 7.8% 7.6%		-20.1 to 31.9 -20.1 to 36.1 -25.0 to 37.8 -26.1 to 39.4 -38.3 to 45.7 -27.4 to 45.4 -36.3 to 61.4 -23.7 to 46.9 -22.1 to 47.9 -29.6 to 45.2 -26.5 to 41.7	Signapore	Prospective, observational study in ED

ED = Emergency Department, shaded cells represent developing countries, SD = standard deviation, MPD = mean percentage difference, LOA = limits of agreement

$$MPD = \frac{estiamted\ weight - \ actual\ weight}{(estimated\ weight + actual\ weight)/2} \times 100$$

In contrast to wide limits of agreement discussed above, Thompson et al. (2007) (n = 1843) show narrow limits of agreement which means that the APLS formula is more consistent in weight estimation in this Australian population. However the mean percentage error for this study 12.1% in pre-school children and 19.9% in school aged which is above the 10% of measured weight cut-off, explaining these results in clinical context as a percent of measured weight would assist further breakdown and allow more in-depth analysis and comparison. An advantage of this study is that the focus was on Triage category 1 and 2 children, the most seriously ill when categorised using the Australasian triage scoring system endorsed by the Australian Resuscitation Council (2003), which is the exact population where weight estimation is required. However, to include this population Thompson et al. (2007) used retrospective chart audit to collect data which (as discussed earlier) can bias results as standardisation of weight collection can not be guaranteed.

As identified above, inconsistent measures were used in reporting of results (Table 9) and can make results difficult to compare. An Australian study by Casey and Borland (2010) report similar results to Thompson et al. (2007) for APLS weight estimates 1 – 4 years (MPE -12.61%) and 5 - 10 years (MPE -17.36). However, Casey and Borland (2010) go on to state that 29% to 42% of weight estimates are within 20% of measured weight which indicates accuracy in less than half of the population. Using the unvalidated cut-off point of 20% to discuss the accuracy of the APLS formula makes comparison of this particular result difficult.

As with the majority of studies investigating the accuracy of the APLS formula, Casey and Borland (2010), Black et al. (2002), Thompson et al. (2007) and Park et al. (2012) in Table 9 confirm that the accuracy of the APLS formula decreases with increasing weight and age.

Table 9 – Studies testing the APLS formula using Mean Percentage Error (MPE)

Authors	**n**	**Age / Weight Group**	**MPE**	**SD**	**LOA**	**Country**	**Design and Setting**
Black et al. (2002)	502	10.1 – 25 kg 25.1 – 40 kg > 40 kg	-4.7% -20% -42%			Australia	Prospective, observational study in ED
Thompson et al. (2007)	1843	Pre School School aged	-12.1% -19.9%	13.3 19.3	-13.0 to -11.2 -21.3 to -18.5	Australia	Retrospective chart audit of Triage 1 & 2 presenting to ED
Casey and Borland (2010)	1235	1 – 4 years 5 – 10 years	-12.61% -17.36%			Australia	Prospective, observational study in ED
Park et al. (2012)	124094	Pre School School aged	-9.53% -13.19%		-9.29 to -9.76 -12.91 to -13.47	Korea	Data from previous studies collected by 28 Hospital Teams
House, Ngetich, Vreeman and Rusyniak (2013)	967	1 – 14 years	-5.2%		± 1.2	South Africa	Prospective, observational study in ED

ED = Emergency Department, Shaded cells represent developing countries

$$MPE = \frac{estiamted\ weight - \ actual\ weight}{actual\ weight} \times 100$$

The need for weight estimation is validated in the target population in two studies in the same United Kingdom Emergency department. Both studies were a retrospective chart audit and collected data showing severity of illness as well as data for weight and height (Luscombe et al., 2011; Luscombe & Owens, 2007). The 2007 study reported that critically ill children had their weight recorded in less than half of presentations (41.5%, n = 82). This shows the need for weight estimation methods in acute emergencies however, the use of weight estimation can increase the chance of an error in prescription of medication, dose calculation and administration of medication or treatment (Croskerry, 2000; Croskerry & Sinclair, 2001; Luten, 2002) . Further studies of the relationship of severity of illness and weight estimation would allow for further analysis.

The first study by Luscombe and Owens (2007) found that the APLS formula underestimated the weight of children with a MPD of 11.47 – 36.65%, when stratified by age (shown in Table 10). The second study outlined in Table 10 was performed at the same hospital however, data collection dates included the timeframe of the first study and the rationale for presenting a subset of data from 2005 when the second study spans 2003 to 2008 is not stated. The study published in 2011 showed an increase in MPD which ranged from 16.0% to 39.7% compared with 11.47 – 36.65% in the smaller subset (Luscombe et al., 2011; Luscombe & Owens, 2007). It is difficult to determine what caused the increase in the lower end of this range and further investigation of factors influencing population weight gain between 2005 and 2008 may supplement this research.

Table 10 – Summary of results from studies validating the APLS formula using MPD

Authors	n	Age	MPD	LOA	Country	Design and Setting
Luscombe and Owens (2007) A positive result indicates an underestimate.	17244	1 year 2 years 3 years 4 years 5 years 6 years 7 years 8 years 9 years 10 years	11.47% 14.36% 14.92% 16.28% 15.91% 18.63% 22.20% 27.39% 31.69% 36.65%	10.87 to 12.07 13.64 to 15.08 14.10 to 15.75 15.19 to 17.38 14.63 to 17.19 17.20 to 20.06 20.53 to 23.87 25.77 to 29.01 29.91 to 33.47 34.87 to 38.43	UK	Retrospective Chart Audit in ED
Luscombe et al. (2011) – This study applied the APLS formula to children up to 16 years (limits of the formula are 1 – 10 years) therefore results for children above 10 years of age are not shown	93827	1 year 2 years 3 years 4 years 5 years 6 years 7 years 8 years 9 years 10 years	19.6% 17.4% 16.1% 16.0% 15.7% 19.0% 23.2% 26.8% 33.5% 39.7%	19.2 to 20.1 17.0 to 17.7 15.8 to 16.5 15.6 to 16.5 15.2 to 16.2 18.4 to 19.6 22.5 to 23.9 26.1 to 27.5 32.7 to 34.3 38.9 to 40.6	UK	Retrospective Chart Audit in ED

ED = Emergency Department

$$MPD = \frac{estiamted\ weight - \ actual\ weight}{(estimated\ weight + actual\ weight)/2} \times 100$$

An alternative method of weight estimation which utilises the APLS formula includes the use of clothing size label as a proxy for age. This new approach using the APLS formula by Elgie and Williams (2012) was tested in the UK in 2011 by using the child's clothing label size (age) rather than their actual age in the APLS formula calculation. They found that the clothing label age was more accurate than using the child's actual age (n = 188, bias 3.3 kg, Limits of Agreement ± 8.0 kg). However, further validation of clothing size as a proxy for age in the APLS formula is required.

Shann's weight estimation formula.

It has been difficult to find reference to the original publication of Shann's weight estimation formula. A thesis by Wells (2009) mentions that this formula was designed for Pacific Children and refers to Theron et al. (2005) for this information. However, these authors did not indicate the population the formula was designed for or validated in. They reference a textbook titled *Emergency Medicine at Your Fingertips* by *Wayne Hazell* as their source (New Zealand 2nd edition published in 2000) however, I have been unable to locate this edition and no explicit reference was made to Shann's formula in the later edition published in 2004 (Hazell, 2004).

Shann's formula is the most accurate weight estimation formula in Maori and Pacific and European children who are large for their age, however this can not be generalised to a diverse population. This New Zealand study, set at Middlemore Hospital in Auckland was conducted by Theron et al. (2005) and was the first to validate Shann's formula. This study tested multiple weight estimation formulae using children presenting to the emergency department in 2005 with the aim being to determine the best fit for Maori and Pacific children who were large for their age. Results show MPD of less than 10% of Pacific, Maori and European children. However, it significantly overestimated the weight of Asian and Indian children. The overall limits of agreement for the Shann's method of weight estimation this study were wide -8.65 – 12.32 showing ambiguity of results when coupled with the large SD shown in Table 11. Furthermore, limiting the focus to predominantly Maori and Pacific ethnicities makes generalisation of results to the wider and more diverse New Zealand population difficult.

As with the APLS formula, the accuracy of Shann's formula decreases with increasing age. A Chinese study of weight estimation by Cattermole et al. (2011) illustrates this where mean percentage difference is -1.5% in children aged 1 to 6 years and -8.1% for children 7 to 10 years. However, further analysis of of this phenomenon is difficult due to the fact results are reported in two large age groups (1 – 6 years and 7 – 10 years) rather than smaller age groupings.

Table 11 – Summary of studies of Shann's Formula for weight estimation using Mean Percentage Difference (MPD)

Authors	n	Age / Weight Group	MPD	LOA or SD	Country	Setting
Theron et al. (2005) A negative measure represents an overestimation.	226 420 160 79	Maori Pacific European Asian / Indian	-2.27% 3.65% -1.79% -13.9%	SD 37.89 SD 29.90 SD 28.92 SD 44.87	New Zealand	Prospective Observational Study in ED
Cattermole et al. (2011)	1248	1 – 6 years 7 – 10 years	-1.5% -8.1%	-28.8 – 37.1% -52.5 – 36.4%	China	Population based, observational in School & Kindergarten.

ED = Emergency Department, Shaded cells represent developing countries, LOA = Limits of Agreement

$$MPD = \frac{estiamted\ weight - \ actual\ weight}{(estimated\ weight + actual\ weight)/2} \times 100$$

Ethnicity or geographical location could impact the accuracy of Shann's formula. A Korean study conducted by Park et al. (2012) using MPE to assess the accuracy of Shann's formula on a large population (n = 124094) found Shann's formula more accurate in pre-school children with the MPE of -2.67% as opposed to school children who had an MPE of -12.39%. This confirms that accuracy of this formula decreases with increasing age. However, the narrow limits of agreement (Preschool, -2.92 to -2.42 and School aged -12.39% to -12.66%) make this study stand out when compared with others. This means that Shann's formula was consistently precise in this population even though it systematically overestimated the weight of many children. The overestimation may be related to body mass or demographic characteristic such as ethnicity. Furthermore, this study is set in schools and kindergartens which may not match the population requiring weight estimation in resuscitation situations and shows the need for further investigation of presentation patterns in prehospital and emergency department settings.

Table 12 - Summary of results from studies testing the Shann's formula using Mean Percentage Error (MPE)

Authors	**n**	**Age / Weight Group**	**MPE**	**LOA or SD**	**Country**	**Setting**
Park et al. (2012)	124094	Pre School School aged	-2.67% -12.39%	-2.92 to -2.42% -12.39 to 12.66%	Korea	Data from previous studies collected by 28 Hospital Teams
Hegazy and Taher (2013)	508	1 – 10 years 11 – 16 years	-5.3% 8.0%	-8.5% to -2.7% 2.1%-13.9%	Egypt	Prospective, observational study in a Children's Cancer Hospital

Shaded cells represent developing countries, LOA = Limits of Agreement

$$MPE = \frac{estiamted\ weight -\ actual\ weight}{actual\ weight} \times 100$$

Theron's Formula

As mentioned previously, Theron's formula was designed for use in children of Maori or Pacific origin who were large for their age where it has outperformed other formulae currently in use for this population (Theron et al., 2005).

The two studies in Table 13 and Table 14 have tested Theron's formula. A study set in the USA conducted by So et al. stands out with a MPD of 106% and SD of 85% in children under 10 kg which shows a gross overestimation using Theron's formula as well as poor precision in children under 10 kg. The authors explain, that if children who are considered overweight using BMI and under 2 years were removed from the dataset that these statistics improved; however, the authors do not specify the level of improvement. The specific method for determining cut-off points for BMI classification was not specified and therefore may impact results by altering the proportion of children under two years of age who are considered overweight. However, So et al. (2009) recognise this and suggest that Theron's formula is only suitable for children over the age of two years which shows the importance of adhering to limitations when applying weight estimation techniques.

Table 13 - Summary of studies testing Theron's weight estimation formula using Mean Percentage Error (MPE)

Authors	n	Age / Weight Group	MPE	LOA or SD	Country	Setting
So et al. (2009)	1011	< 10 kg 10.1 – 25 kg 25.1 – 40 kg > 40 kg	106% 12% 20% -10%	SD 85% SD 26% SD 34% SD 23%	USA	Prospective, observational study in a hospital using inpatient charts for measured weight data.

LOA = Limits of Agreement, $MPE = \frac{estiamted\ weight -\ actual\ weight}{actual\ weight} \times 100$

Table 14 - Summary of studies assessing of Theron's weight estimation is within 10% of children's measured weight

Authors	n	Age / Weight Group	Within 10%	LOA or SD	Country	Setting
Cattermole et al. (2011)	1248	1 – 6 years 7 – 10 years	36.8% 13.5%	-27.0 – 43.3% -12.6 – 74%	China	Population based, observational in School & Kindergarten.

Shaded cells represent developing countries, LOA = Limits of Agreement

Length Based Weight Estimation Methods

Broselow-Luten Tape.

The Broselow-Luten Tape was first validated in the USA in 1988 in a study by Lubitz, Seidel, Chameides, Luten, Zaritsky and Campbell (1988) set in Emergency Departments and Outpatients Clinics. The study, included a sample of 937 children aged 2 weeks to 10 years presenting between August and October 1986 with weights between 2.01 kg and 50.10 kg, 57% were boys. Table 15 shows that the SD remains small for all age groups (< 3.67) giving it precision, however, when assessing the total population actual error spans 15 kg which according to Mackway-Jones (2005) could lead to a significant discrepancy in medication dosage or equipment size in resuscitation. As with studies discussed earlier in this thesis, SD increases in heavier children and means that precision of weight estimation decreases with increasing weight. Lubitz et al. (1988) claimed that the Broselow-Luten Tape was highly accurate when compared with other methods in use at the time, however studies of these methods in the early 1980s are difficult to locate making verification of this claim impossible. The Broselow-Luten Tape encounters similar issues to other weight estimation methods discussed earlier. For example, studies listed in Table 15 show that 43.2% - 65.4% of subjects have weight estimates within 10% of their measured weight. This shows that more than 35% of weight estimates were considered inaccurate and that validation of the choice of 10% as a cut-off point for weight estimate accuracy is required.

Most studies in Table 15 show that with increasing age or weight, the accuracy of the Broselow-Luten Tape decreases (Lubitz et al., 1988; Trakulsrichai, Boonsri, Chatchaipun & Chunharas, 2012). An exception to this is a South African study in 2011 where the Broselow-Luten Tape estimated 65.38% of 6 – 10 year old children as within 10% of measured weight which shows greater accuracy than the younger age group (Geduld et al., 2011). Possible influencing factors identified by the author include ethnicity (56% Black, 30% Coloured, 8% Asian, 4% White and 2% Other) where the majority of children are black or coloured and South Africa's status as a developing country. This again, illustrates the need for a standardised classification system for ethnicity to allow comparison of studies and both of these influences require further investigation.

Interestingly little variance is evident between studies conducted from 1988 to 2013 where 10% is used as a cut-off point for accuracy. This may indicate that changes in body mass over time have little impact on the accuracy of weight estimation methods or iterations of the

Broselow-Luten Tape have kept up with body mass changes over time. However, further research of this phenomenon is required.

Table 15 - Summary of studies assessing the accuracy of the Broselow-Luten Tape using percent of estimates within 10% of measured weight

Authors	n	Age / Weight Group	Within 10%	LOA	Country	Setting
Lubitz et al. (1988)	395 449 93 937	3.5 to 10 kg 10 to 25 kg > 25kg Total	55.9% 65.0% 49.5% 59.7%	SD 0.95 SD 1.62 SD 3.67 AE -5.7 to 15.7 kg	USA	Prospective, observational multicentre study in ED & OPD
Nieman, Manacci, Super, Mancuso and Fallon (2006) –	2249 1403 1224 2937	Infant Toddlers Preschool School Aged	59.5% / 55.0% 64.3% / 60.0% 61.4% / 59.4% 57.6% / 51.2%		USA	Prospective, observational study set in School & Paediatric Clinic. Tape Version 1998 / 2002A
Geduld et al. (2011)	2832	1 – 4 years 6 – 10 years	63.46% 65.38%	±0.65 ±0.90	South Africa	Prospective via Database at Hospital.
Abdel-Rahman et al. (2013a)	976	2 – 14 years	55.3%		USA	Prospective, multicentre, observational, children from Hospital, Daycare & Family
Milne, Yasin, Knight, Noel, Lubell and Filler (2012)	6361	< 10 years	56.3%	-7.71 - 10.95 kg	Canada	Prospective, observational study in Urban & Rural Health Centre / School
Trakulsrichai et al. (2012)	300 (ED) 295 (OPD)	< 10 kg 10 – 25 kg 25 – 40 kg > 40 kg	60.36% 59.68% 43.20% N/A	-2.68 - 6.31 kg -3.91 - 4.48 kg -13.22 - 7.26 kg	Thailand	Prospective, observational study in ED & OPD
Abdel-Rahman, Paul, James, Lewandowski and Best Pharmaceuticals for Children Act-Pediatric Trials (2013b)	415	2 months - 16 years	58.6%	53.8 - 63.3	South Africa	Prospective, multicentre, observational study with children from Hospital & Daycare & Family Events

ED = Emergency Department, OPD = Outpatients, AE = Actual Error, kg – Kilograms, Shaded cells represent developing countries

Consistency of data needs to be considered within literature. A 2011 USA study shown in Table 16 immediately stands out as the MPE are reported in positive integers whereas all other studies shown report negative MPE (Rosenberg, Greenberger, Rawal, Latimer-Pierson & Thundiyil, 2011). For example, Rosenberg et al. (2011) reports that the MPE of Broselow-Luten Tape estimates is 9.3 to 15.5% however they also report that the MPD is −3.0% (LOA −85.6% to 29.3%). These statistics do not match and the wide LOA with a negative bias makes me question reporting in this study.

Presentation patterns and data collection time may influence results. Table 16 shows that an early Australian study by Black et al. (2002) shows excellent accuracy and precision of weight estimates with the Broselow-Luten Tape (MPE -0.4% to -0.6%, SD -2.8 – 1.5) in children under 25kg. However data collection occurred between 0800 and 1800 hrs which means that a significant proportion of the population may have been excluded due to presentation outside of study hours. A British study completed by Sacchetti, Warden, Moakes and Moyer (1999) (n = 28344) confirms this stating that most presentations in emergency departments occur in between 1600 – 0000 hrs. This shows that presentation patterns in relation to weight estimation require further research in Australasia.

Table 16 - Overview of results from studies of the Broselow-Luten Tape using Mean Percentage Error (MPE)

Authors	n	Age or other Group	MPE	CI, SD or LOA	Country	Setting
Black et al. (2002)	121 132 86	< 10 kg 10 – 25 kg 25 – 40 kg > 40 kg	-0.6% -0.4% -6.4% N/A	SD -2.8 to 1.5 SD -2.0 to 1.3 SD -9.1 to 3.7	Australia	Prospective, observational study in ED
DuBois, Baldwin and King (2007)	100 100 100 100	< 10 kg 10.1 – 20 kg 20.1 – 36 kg > 30 kg	-9.91% -7.12% -7.50%	-12.99 to -6.83 -9.36 to -4.88 -10.16 to -4.84	USA	Prospective, Observational study set in ED – Does not differentiate between measuring height and Broselow-Luten Tape measurement
Rosenberg et al. (2011)	372	0 – 2 years 2 – 6 years > 6 years	9.3% 9.4% 15.5%	CI 8.1 to 10.5 CI 7.8 to 11.0 CI 12.0 to 19.0	USA	Prospective, observational study set in ED
Casey and Borland (2010)	174 520 541 191	< 1 year 1 – 4 years 5 – 10 years 11 – 14 years	7.24% -6.97% -5.28% N/A		Australia	Prospective, observational study in ED (Triage Category dependant)
Park et al. (2012)	1240 94	Infant Pre School School aged	-4.86% -3.98% -5.47%	SD 12.18 SD 9.0 SD 11.69	Korea	Data from previous studies collected by 28 Hospital Teams

ED = Emergency Department, SD = Standard Deviation, kg = Kilograms, Shaded cells represent developing countries, LOA = Limits of Agreement

$$MPE = \frac{estiamted\ weight - \ actual\ weight}{actual\ weight} \times 100$$

Later studies demonstrate less accuracy. Casey and Borland (2010) conducted a study in an Australian emergency department which shows a higher MPE, however this study is stratified by age rather than weight which makes comparison to earlier studies challenging. This study excluded children who were seriously ill, which is the population where weight estimation would generally be utilised which illustrates an area where further research is required.

Three studies in Table 17 report results stratified by weight, although these groupings differed, the MPD becomes less accurate with increasing weight in all studies (Kun, Cheng, Yuen & Tung, 2000; So et al., 2009; Wells et al., 2013). One study stands out, So et al. (2009) record a MPD of 0.2% for children under 10kg which shows that the Broselow-Luten Tape is accurate in this population. However, the SD is high when compared with older age groups which means that precision is less in this age group. As discussed above, the authors report a high percentage of children under two years being considered overweight in their sample which could impact the proportion of children under 10kg.

Table 17 - Summary of studies using Mean Percentage Difference (MPD) to assess the Broselow-Luten Tape

Authors	n	Age or Weight Group	MPD (%)	LOA or SD	Country	Setting
Kun et al. (2000)	909	< 10 kg 10 – 25 kg > 25 kg	-0.296 0.006 -2.258	-0.480 to -0.113 -0.1190 to 0.131 -3.1107 to -1.406	China	Prospective, observational study in a Hong Kong ED
So et al. (2009)	471 382 119 39	< 10 kg 10 – 25 kg 25.1 – 40 kg > 40 kg	0.2 -3.7 -12.0 -38.0	SD = 24 SD = 16 SD = 17 SD = 12	USA	Prospective, observational study in a hospital using inpatient charts for measured weight data.
Bourdeau, Copeland and Milne (2011) a negative measure is an overestimate	243	< 10 years	11.9	-17.3 to 41.1	Canada	Retrospective chart audit in two Community Health Centres.
Wells et al. (2013)	453	< 12 kg 12.1 – 20 kg > 20 kg All	-0.2 -0.5 -2.0 -0.9%	−2.1 to 1.7 -3.7 to 2.7 -10.5 to 6.3 -6.3 to 4.5	South Africa	Prospective, observational study in two ED's.

ED = Emergency Department, SD = Standard Deviation, kg = Kilograms, Shaded cells represent developing countries, LOA = Limits of Agreement

$$MPD = \frac{estiamted\ weight - \ actual\ weight}{(estimated\ weight + actual\ weight)/2} \times 100$$

Small sample size and restricted geographical location can impact the credibility of studies. Bourdeau et al. (2011) completed a study with a sample of Canadian children. They reported an underestimation of 11.9% when using the Broselow-Luten Tape for weight estimates with exceptionally wide limits of agreement -17.2 – 41.1. On examination, this study had a small sample size of 243 participants which can affects the power of this study. Furthermore, all participants were under 20 kg and selected by postal code from two medical centres which restricted the geographical spread of participants. These characteristics may affect the power of the study while limiting generalisability.

Summary of Literature

Study Design.

Most studies are prospective in nature, collecting their own height and weight data. Retrospective data or an existing data set were used in some studies which makes it difficult to guarantee that height and weight data was collected in a uniform manner when comparing studies (Bourdeau et al., 2011; Cattermole et al., 2011; Luscombe & Owens, 2007; Park et al., 2012; Thompson et al., 2007). The advantage of retrospective chart audit is that this type of data collection allows for large sample and children who are more seriously ill can be included with a weight added soon after their resuscitation. However, as discussed earlier the measure of weight and height may not be collected uniformly in retrospective chart audits and could affect the accuracy of data collected. This can be addressed by training or education of data collectors, however this was variable with authors such as Park et al. (2012) training regional teams to collect data and others such as Luscombe et al. (2011) using retrospective chart audits where standardisation of data collection could not be guaranteed.

Study Setting.

Many studies are in paediatric emergency departments and share some common limitations or confounding factors (Ali et al., 2012; Black et al., 2002; Casey & Borland, 2010; DuBois et al., 2007; House et al., 2013; Loo et al., 2013; Luscombe et al., 2011; Luscombe & Owens, 2007; Theron et al., 2005; Wells et al., 2013). For example, some studies such as one conducted by Black et al. (2002) restricted data collection times to daytime hours (i.e.| 0800 - 1800 hours) and this does not always give an accurate cross section of patients. Furthermore, peak time for emergency department presentations extended well beyond these hours of which meant that a significant proportion of the population was excluded.

Presentation patterns of seriously ill children are difficult to predict, which impacts the choice of setting for studies of weight estimation. A weakness in studies set in the ED is the exclusion of seriously ill children presenting to the Emergency Department, which excludes the target population (those requiring weight estimation) (Black et al., 2002; Casey & Borland, 2010; Theron et al., 2005; Wells et al., 2013). The same limitation exists in studies performed in mixed settings, for example, OPD and ED, or School, Clinic and Staff Events (Abdel-Rahman et al., 2013a; Bourdeau et al., 2011; Cattermole et al., 2011; Nieman et al., 2006; Sinha, Lezine, Frechette & Foster, 2012; So et al., 2009; Trakulsrichai et al., 2012). Until the prediction of presentation patterns in the ED is possible studies can not uniformly validate weight estimation of the population.

One solution, is to recruit a cross section of the general population rather than just those presenting in an emergency. This was attempted in a Korean study, where Park et al. (2012) used a national data set held by the Korean Pediatric Society where children were weighed at school or kindergarten. This allowed them to ensure a cross section; however, it is unclear if this matches the presentation pattern of seriously ill children who present to the emergency department. Further research investigating presentation patterns of seriously ill children to identify the appropriate population would ensure weight estimation methods are tested in an appropriate population.

Sample Size and Stratification.

Less than half of the studies reviewed included reference to the use of a sample size calculation in their methods (Ali et al., 2012; Black et al., 2002; House et al., 2013; Loo et al., 2013; Luscombe & Owens, 2007; Rosenberg et al., 2011; So et al., 2009). The lowest sample size calculation was in a study by Ali et al. (2012) which included 252 children this was at a power of 80% rather than 95% used in many studies. Bourdeau et al. (2011) study used a sample of 243 children with an unstratified sample, which is slightly lower than the above calculation which can influence results by decreasing the statistical significance of this study by increasing the effect size.

The ability to compare studies is impacted by the ability to stratify results. According to Luscombe et al. (2011) when stratifying their sample by age, 400 children were required to achieve a power of 80% and 5% statistical significance. However some studies that stratify do not use evenly distributed groups, which in turn can affect the ability to compare studies (Black et al., 2002; Casey & Borland, 2010; Nieman et al., 2006; So et al., 2009; Theron et al., 2005).

Acceptable limits of accuracy.

No studies reviewed have identified an evidence based acceptable limit for accuracy in studies of weight estimation in children. The most common measure appears to be an estimated weight within 10% of measured weight is considered accurate (Abdel-Rahman et al., 2013b; Ali et al., 2012; Cattermole et al., 2011; Geduld et al., 2011; Loo et al., 2013; Nieman et al., 2006; So et al., 2009; Trakulsrichai et al., 2012). Using 10%, weight estimates could vary considerably from 350 grams in a 3.5 kg baby to 6 kg in a 60 kg child. According to Mackway-Jones (2005) a weight variation of 350 g is clinically significant in some resuscitation settings and can influence resuscitation outcomes of a small baby. Other studies reviewed in Table 7 to Table 17 consider 20% or 30% of a child's measured weight accurate or report results using MPE and MPD which makes clinical comparison of studies difficult. Also, none of these studies report what they consider a safe margin of error when discussing accuracy cut-off points. Therefore, further research is required on safe margins of error for weight estimation estimate in relation to a child's actual body weight.

Variances in Population.

Finding a method of weight estimation which fits all children is difficult. Variances in the population are evident and are often related to ethnicity, location, social status, poverty and other factors. Increasing obesity of society impacts weight estimation methods. Weight estimation studies reviewed in Table 7 to Table 17 are a mixture of developed and developing countries which could skew overall results as 85% of the world's children live in developing countries (Blair, 2010). A developing country has less economic capital, infrastructure and availability of services to the people, which can, in the extreme equate to poor drinking water and food which could in turn impact child health and child development (Bornstein, Britto, Nonoyama-Tarumi, Ota, Petrovic & Putnick, 2012). This disparity between developed and developing countries could have influenced study results. This is confirmed in Table 7 to Table 17 that show that studies of the Broselow-Luten Tape set in developing countries are often more accurate than those in developed countries and therefore, this requires further investigation with clear links to weight estimation methods.

A similar lens could be applied microscopically within cities such as Auckland, New Zealand to further understand the population. New Zealand has a diverse spread of ethnicities, yet the only research available on weight estimation in New Zealand children focused on the Maori and Pacific population in a particular geographical location (South Auckland) (Theron et al., 2005). Investigation of matching nationwide ethnicity statistics with sample population may assist in ensuring generalisation of weight estimation methods to the wider population and is an area which requires investigation.

Time to Treatment.

Time to treatment issues were raised early in the evolution of weight estimation and these are still an issue in resuscitation today (Croskerry & Sinclair, 2001; Luten, 2002). A study conducted in 2008-2009 by Sinha et al. (2012) in the United States of America investigated the feasibility of stopping to weigh a child during an emergency situation would affect the outcome of their care. Two hundred and thirty one children were included in this study and had their measured weight recorded; in 145 (62.7%) of these cases, environmental factors or equipment impacted the ability to weigh children. For example, the bed scales not tared / zeroed, the child was immobilised on a spinal board or the staff were unable to operate the bed / scales. They also recognised that CPR and other invasive procedures can put pressure on the bed scale giving a false reading (Sinha et al., 2012). One trend in this study showed that children without a documented weight from the bed scale were more seriously ill than those who were weighed. The authors also recognise that lack of a recorded weight in a trauma situation relates to the equipment and suggest that weighing children during medical emergencies appears to be easier to investigate than children who have suffered trauma (Sinha et al., 2012). Diffinitive research that would randomise children to be weighed or assigned a weight estimate during resuscitation would be unethical, thus reinforcing the need for weight estimation methods.

Cognitive loading in resuscitation.

Errors can occur in the Emergency Department and several authors implicate decision density or cognitive load (the volume of decisions in a short period of time) contributes to these errors (Croskerry & Sinclair, 2001; Luten, 2002). According to Luten et al. (2002) the resuscitation environment can increase the risk of error in acute situations due to the number of clinical decisions requiring action in a small timeframe. He also states that preparation for paediatric resuscitation can be cognitively taxing, due to the variability in size and weight of a child and there are many decisions to be made on appropriate equipment and medication dosages based on size and weight.

Croskerry (2000); Croskerry and Sinclair (2001) reviewed cognitive loading in relation to diagnostic decision-making and provided strategies for decreasing cognitive loading. These included: developing insight, considering alternatives, decrease reliance on memory, role-specific training, simulation, minimising time pressure and obtaining feedback. Some of these strategies are at the personal level, or part of team development, for example, developing insight and simulation training. However some situations can not be altered by strategic training, for example, time pressure and decision density will always be present. One way to address this is using repeatable systems that are simple and easy to use (Croskerry & Sinclair, 2001). Many weight estimation methods such as the Broselow-Luten Tape and mathematical formula are designed to meet this need. One example of this is the Broselow-Luten checklist and education model which provides a systems approach and increases staff competence in weight estimation (Hohenhaus, 2002).

Staff Competency.

Parameters that govern weight estimation methods and staff competence impact weight estimation. Croskerry and Sinclair (2001) recognises this and suggest training for staff who work with paediatrics and streamlining of processes around drug calculation could also be applied to weight estimation to decrease this impact. This can include weight estimation methods and further investigation of this in relation to weight estimation is required.

Conclusion

This Literature Review has compared, contrasted and critiqued studies of the accuracy of weight estimation using the APLS, Shann's and Theron's formulae as well as the Broselow-Luten Tape. Trends and gaps in research have been identified and are discussed below.

Trends identified in literature.

Comparison and synthesis of information reported in studies was difficult due to multiple methods of reporting using different analysis methods. For example, studies were reported using, mean percentage error, mean percentage difference, actual difference, limits of agreement or a weight estimate within 10% of measured weight.

Ethnicity and geographical diversity was not addressed in early studies used to develop weight estimation techniques. We now know that demographic characteristics such as ethnicity and socioeconomic status influence the accuracy of weight estimates. Furthermore, prospective studies and those set in the emergency department often exclude the target population, critically ill children.

In general, length based weight estimation methods appear to be more accurate than those based on age and accuracy of all methods of estimation generally decreases with increasing age or weight. The APLS formula generally underestimates the weight of children, in particular those over 25 kg.

Gaps in research identified.

Common characteristics of the population requiring weight estimation is not readily available and can often be difficult to predict. Frequently children requiring weight estimation are excluded from studies as they require immediate treatment. To include these children may be unethical in a resuscitation situation which raises the issue of study setting - is the emergency department the correct location for this research? Further investigation of presentation patterns to the emergency department and common characteristics of those requiring weight estimation may allow further understanding of study setting needs.

No studies indicate what is considered a clinically accurate weight estimation. Many studies use 10% of measured weight as a guide however no studies validating this choice are available. A standardised view of accuracy of weight estimation is required.

The influence of geographic location, socioeconomic status, ethnicity and migrant movement on weight estimation require further investigation.

The impact of weight estimation on morality is absent in research, however this is unethical to research.

After reviewing literature many gaps in the research are evident. In particular a lack of New Zealand studies investigating the accuracy of weight estimation techniques commonly used in paediatric emergencies. One New Zealand study is available, however, this is unable to be generalised as the sample is predominantly Maori and Pacific children presenting to an emergency department in one geographical location in Auckland. Further, generalisable, New Zealand research on accuracy of weight estimation methods is required. Therefore, the aim of this study is to compare the accuracy of four weight estimation methods in a sample of Auckland school aged children.

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CHAPTER 3 METHODS

The aim of this study is to fill a gap in research by comparing the accuracy of commonly used weight estimation methods in prediction of weight in Auckland children. The effect of demographics (age, gender, ethnicity, body habitus and school decile) on the accuracy of weight estimation methods in Auckland children will also be investigated by stratification of results.

Research Question

Are the Broselow-Luten Tape and weight estimation formulae (Theron, Shann and APLS) accurate when compared with the measured weight in a cross section of the Auckland children aged 5 – 10 years?

Ethics

Ethics approval was obtained from AUTEC the AUT University Ethics Committee on 29th April 2013 with an amendment letter on 6th June 2013 (see Appendix C beginning on page 68 of this thesis). Active parental consent and written child assent was gained prior to data collection and copies of information sheets and consent forms these can be found in Appendix D on page 70 of this thesis.

Study Design

This study is a prospective observational study comparing the measured weight of school children aged 5 – 10 years with estimated weights using APLS, Theron and Shann weight estimation formulae as well as the Broselow-Luten Tape.

Variables.

Variables are defined in Table 18, along with precision and data level of measurement.

Table 18 - Variables

Source / Variable	Variable	Notes	Data Type
Researcher			
Date of Data Collection	DD/MM/YYYY	Date the data was collected.	Continuous
Researcher Name	Text	Name of the person measuring the child.	Nominal
Ministry of Education spreadsheet			
School Name	Text	Obtained from the Ministry of Education spread sheet of schools decile and	Nominal
School Decile	Whole number	demographic 2013.	Ordinal
School Suburb	Text		Nominal
Parent Survey			
Class	Number or Text	Class Identifier	Nominal
Gender	M / F	As recorded in the school records with the knowledge that there may be some	Nominal
Date of Birth	DD/MM/YYYY	error in the data supplied by each school.	Continuous
Ethnicity	Text		Nominal
Measured			
Height 1		Measured while the child is standing straight against a stadiomenter with no	Interval
Height 2	0.5 cm	shoes or hat on using a Wedderburn portable height rod (specifications -	
Height 3		http://www.wedderburn.co.nz/weighing-solutions/health-and-medical/wshrp-	
Weight 1		portable-height-rod).	
Weight 2	0.1 kg	Measured using a brand new Seca High Capacity Electronic Flat Scale that was	
Weight 3		callibrated by Weightech NZ Ltd on 27/6/2013 (3 days prior to data collection).	
Broselow Weight 1		Child weighed without shoes and without heavy outer clothing.	
Broselow Weight 2	1.0 kg	Measured using the 2011 version of the Broselow-Luten Tape. Child laying	
Broselow Weight 3		supine from measurement from crown of the head to heel following the directions	
Body Habitus 1		printed on the Broselow-Luten Tape. Weight will be read from tape at heel.	Ordinal
Body Habitus 2	1 (Yes) / 0 (No)	"Does the child look overweight?" Using classifications and pictures (with permission of the author) (Warschburger & Kröller, 2009).	
Calculated			Interval
APLS Formula Weight Estimate	kg	(age in years + 4) x 2	
Theron Formula Weight		Exp((2.20 + 0.175) x age in years)	
Shann Formula Weight Estimate		1 – 9 years - weight in kg = (2 x age in years) + 9 10+ years – weight in kg = 3 x age in yeaars	
Exact Age	Number (2 DP)	Age = (Date of Assessment – Date of Brith) / 365	
TruncatedAge	Whole Number	Truncated Age as a whole number	
BMI	Number (2 DP)	Acutal weight / (Actual height in m x Actual height in m)	
Actual Weight	kg	Median (Weight 1, Weight 2, Weight 3)	
Actual Height	0.5 cm	Median (Height 1, Height 2, Height 3)	

Sample Size Estimation.

A calculation of sample size found that with an error probability of 0.05, a power of 0.9 with a sample size of 44 participants is required. Standard deviation in this sample size calculation was difficult due to lack of existing data sets in New Zealand. Multiple international studies did not indicate sample size calculation and therefore, it was also difficult to use these as a guide (Argall, Wright, Mackway-Jones & Jackson, 2003; Cattermole et al., 2011). Due to the lack of research with sample size calculations reported the above sample size calculation was devised by an AUT University statistician using studies by Theron et al. (2005) and Argall et al. (2003) as a guide. To allow for comparison of data, each variable (such as age) analysed requires a sample of ≥ 44 participants sharing that variable. Therefore, the aim was to collect data from a total 600 children with 100 participants of each age group (5, 6, 7, 8, 9 and 10 years) from each school. This allows for 100 children from each school or decile and 120 children from each age group, which is well over the 44 participants required to maintain the power of this study.

School Selection.

The selection of schools was random within decile groups to allow for a cross section of the Auckland population. The process of school eligibility is outlined in Figure 6, with a list of eligible schools shown in Appendix E on page 76. The sampling frame included the 245 Auckland Schools that cater to 5 – 10 year old children with a total roll > 150 students, this data was provided by the Ministry of Education in June 2012.

Eligible schools were then given a unique study number between 1 and the 245. The random number generator within Microsoft Excel 2011 was used to select one school from each decile group giving 5 initial schools to include in this study. Three backup schools in each decile were also randomised prior to data collection in anticipation of a selected school refusing to participate.

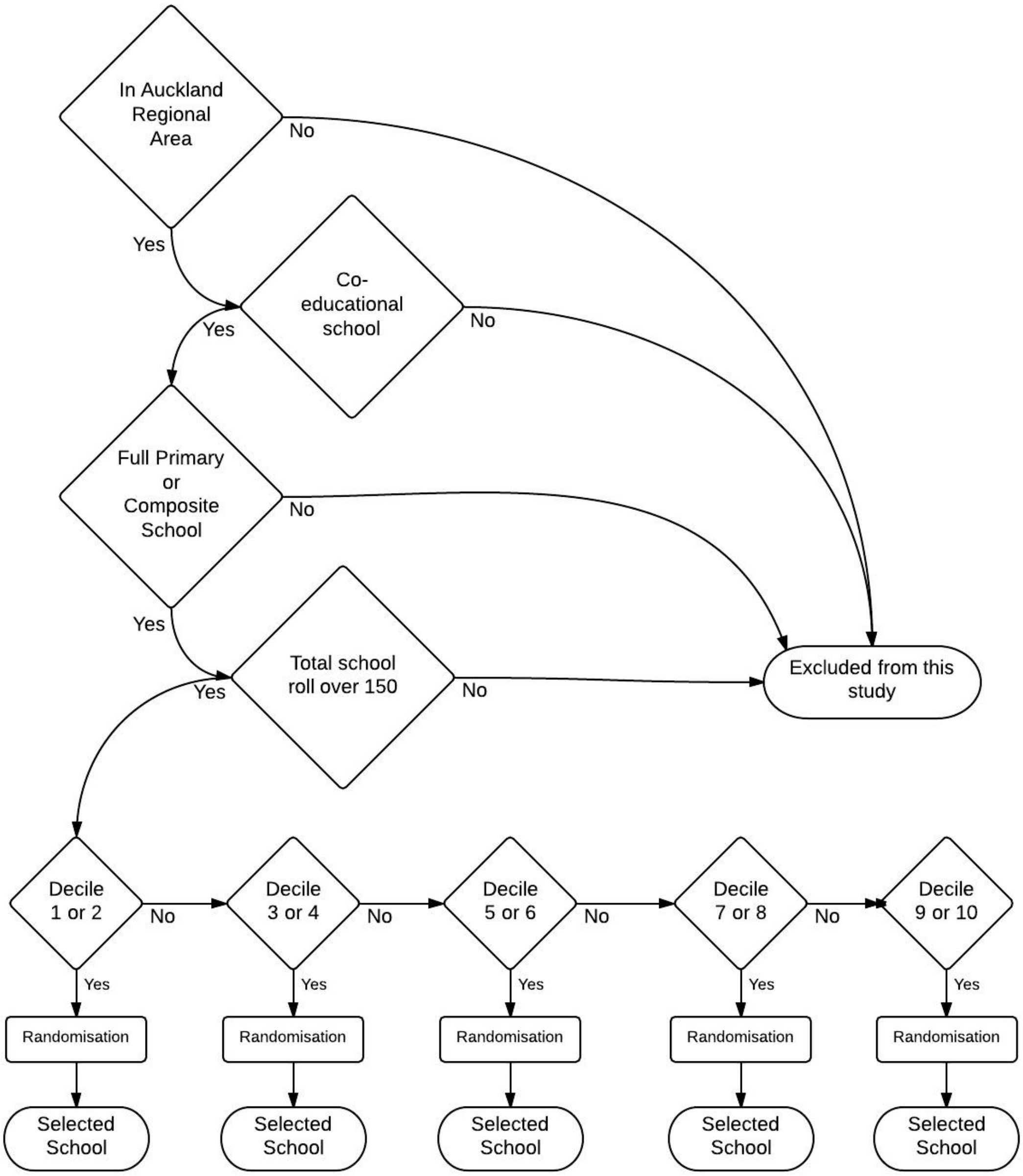

Figure 6 - Eligibility of schools

Eligible Schools.

Distribution of eligible Schools geographically in the Auckland area sorted by decile are shown in Figure 7 to

Figure 11[5]. Clustering of schools in a geographical area is evident. The majority of decile 1 and 2 schools are located in South Auckland, whereas a cluster of decile 3 and 4 schools is evident in West Auckland.

[5] Maps in Figures 7 – 11 created using Auckland School data provided by New Zealand Ministry of Education (2012a) and the website maps.google.com

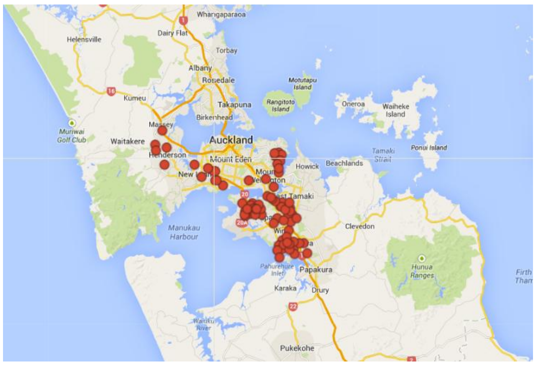

Figure 7 - Decile 1 and 2 school distribution

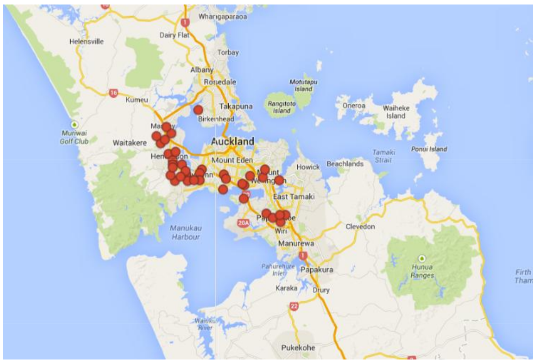

Figure 8 - Decile 3 and 4 school distribution

Figure 9 and Figure 10 show that decile 5-6 and 7-8 schools are more evenly spread across Auckland. However, fewer eligible schools in these decile categories clustering is not as easily visible on each map.

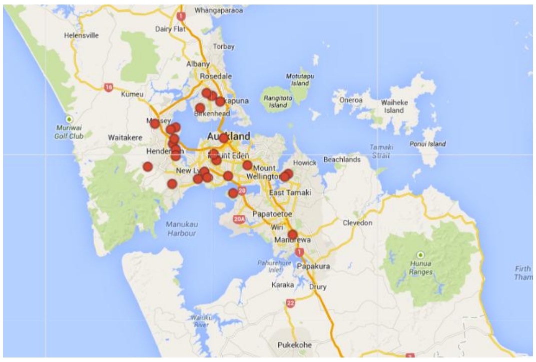

Figure 9 - Decile 5 and 6 school distribution

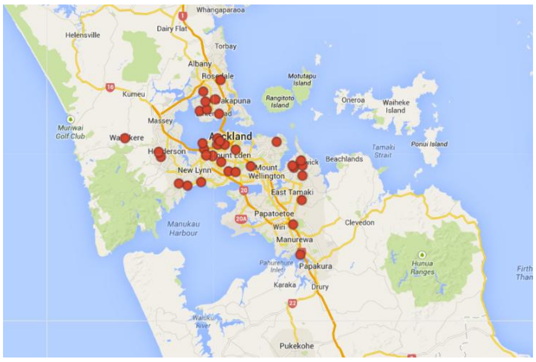

Figure 10 - Decile 7 and 8 school distribution

Figure 11 shows that decile 9 and 10 schools are clustered costally and in the central Auckland area.

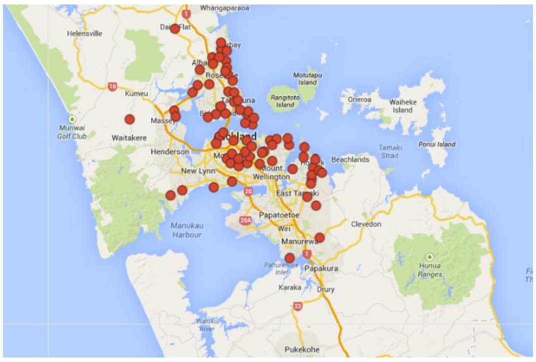

Figure 11 – Decile 9 and 10 school distribution

Class Selection.

Participants within each school were selected by convenience, consent forms were sent to all children at each school and the intent was that the school administration nominated whole classes of children within each age band to be included in this study. This would allow 20 students in each age group (5, 6, 7, 8, 9, 10 years), however, the sporadic and limited return of parental consent forms did not allow the use of this method in all schools and all children who returned consent forms were then included in this study.

Participant Selection.

Each child had inclusion and exclusion criteria to meet; these are outlined in Figure 12 on the following page that shows the decision tree governing participant inclusion.

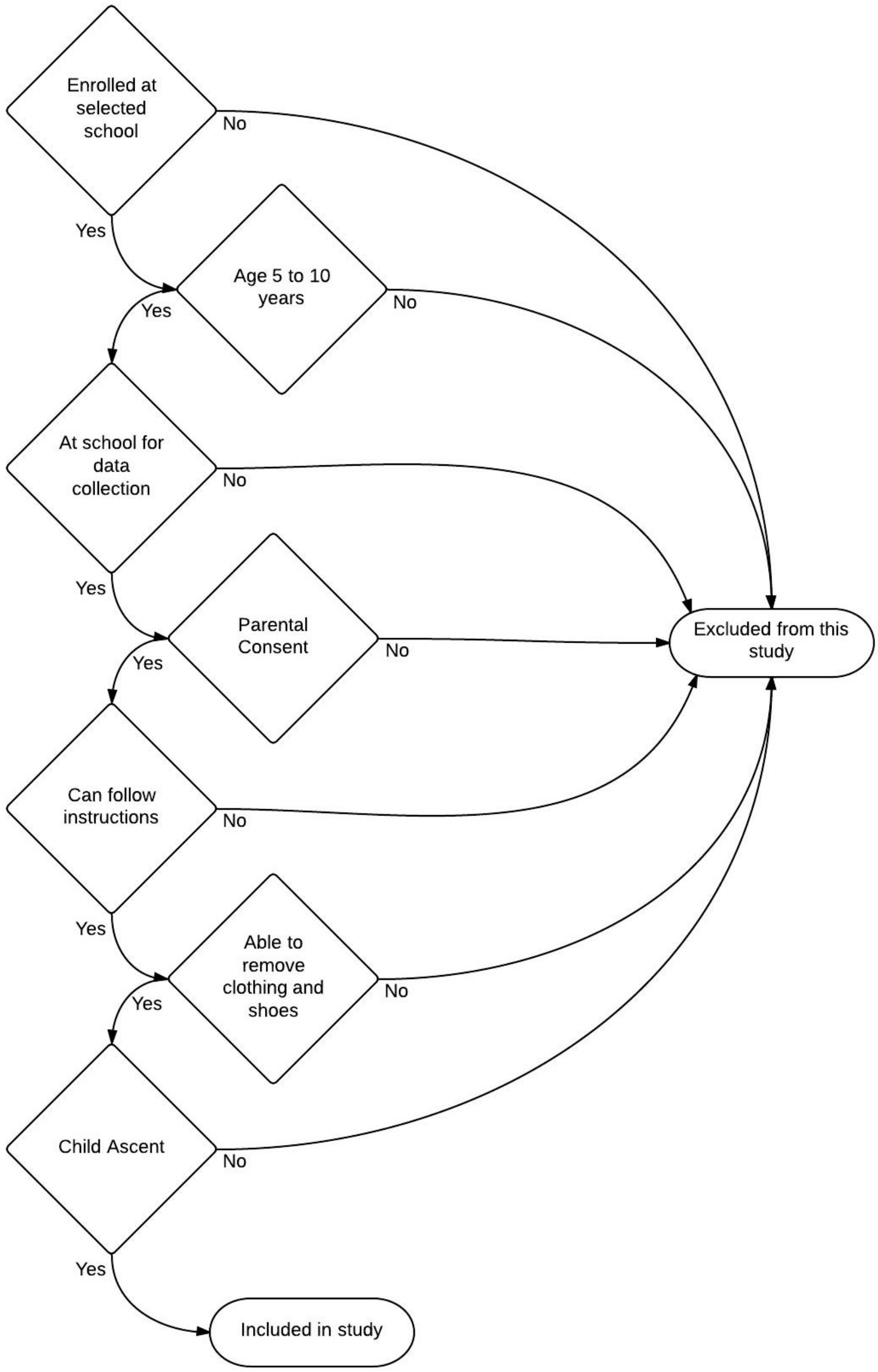

Figure 12 - Inclusion and Exclusion of Participants

Data Collection

Data was collected by the main researcher with assistants to manage the flow of children through the data collection area. Participating schools provided a list of children in each class which identified their name (however this was not included in collected data), ethnicity, gender and date of birth. Other variables were calculated or collected from the Demographics Questionnaire completed by parents in Appendix D on page 83 of this thesis.

Study Protocol.

The protocols used in this study are shown in detail in Appendix G on page 80 of this thesis. Within these protocols, methods of height and weight collection are using protocols set out in standards for anthropometric assessment endorsed by the International Society for the Advancement of Kinanthropometry (ISAK) Bornstein (Olds & Marfell-Jones, 2006). The Broselow-Luten Tape (2011 version) was used as per instruction printed on the tape.

Body habitus estimate was performed by the researcher and an observer for each child. Classification of children occurred by visual estimate using silhouettes developed by Petra Warschburger as a guide. The silhouettes' shown in Figure 13 were derived using children's measures (height of body, spinal and symphysis, shoulder/head broadness, intercristal and thorax diameters, head circumference, as well as arm length) collected during the longitudinal study of children in Germany (Warschburger & Kroller, 2009). Children were classified as having a large body habitus if they matched the two silhouettes on the right of each line of children in Figure 13. Children were given a score of 1 in this study if they were considered as having a large body habitus. Interrater reliability was addressed by the calculation of the kappa statistic using body habitus scores of the researcher and observer. SPSS produced k = 0.903 which according to Viera and Garrett (2005) shows almost perfect agreement between researcher and observer. Therefore, the body habitus score presented in the results chapter is the one determined by the researcher.

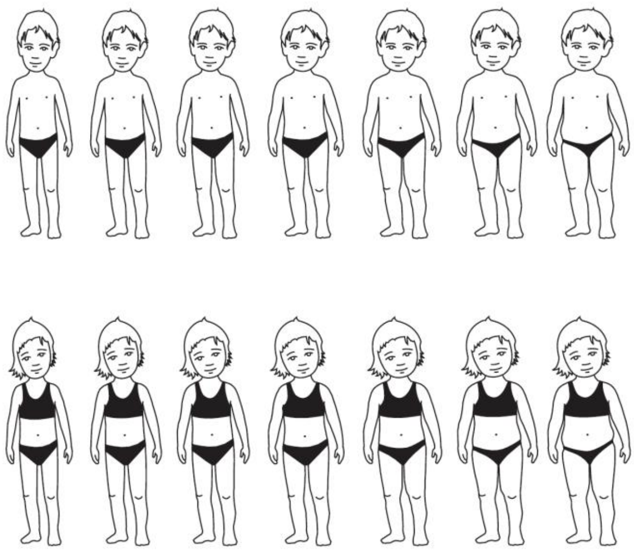

Figure 13 - Body Habitus Classification (Permission for use of these silhouettes was granted from the author prior to this study (Warschburger & Kroller, 2009)

Data Collector Training.

All anthropometric data was collected by the researcher who attended an Anthropometry Course (ISAK Level 1) run by AUT University and ISAK in May 2013 to prepare for data collection. A certificate of completion is shown in Appendix F on page 88 of this thesis.

Time was taken at the beginning of each data collection day to ensure that research assistants understood their roles:

- Check in children on arrival
- Read out information sheet and check parental consent
- Coordinating colouring of assent forms. All children who had questions or were unsure of the explanation were referred to the researcher for explanation
- Entering data onto the iPad and body habitus observer

Data Management.

Direct entry of data onto an iPad mini (model A1432) was used to decrease the risk of transcription errors. Database software called Bento (an iOS version of Filemaker for OSX) was used. Data was then imported into IBM SPSS software (version 19 and 20) for analysis. The iPAD was password protected and remained with the researcher at all times. The iPad was a WiFi only model and the WiFi remained switched off throughout data collection period. These measures ensured that accidental transmission of this data could not occur. An encrypted and password protected backup are stored on the computer of the main researcher and all paperwork is stored in a locked cupboard at AUT North Shore Campus in AA219.

Data Analysis

SPSS was used to analyse data and to calculate variables identified in Table 21. Data was checked for accuracy and missing values and outliers were identified. A study on weight estimation conducted by Luscombe et al. (2011) excluded data above two standard deviations of the mean to ensure severely underweight and overweight children are excluded from the population. However their earlier study excluded those ± 4 SD from the mean from their data set (Luscombe & Owens, 2007). Outliers in this study were discussed with a statistician who suggested including these as the main researcher who collected data could verify these as true and correct. Therefore outliers were included.

Ethnicity was then coded according to guidelines for management of ethnicities from the Ministry of Health, Level 1 codes and sorted into 5 main ethnicity groups (New Zealand Ministry of Health, 2004).

Olds and Marfell-Jones (2006) suggest that three measures are obtained in measurement of height and weight. The median of these is used as the actual measurement. This study utilises this technique in determining height, weight and Broselow-Luten Tape measurements in children.

Descriptive Statistics.

A table outlining descriptive statistics is included and bar graphs to show the distribution the frequency of demographics. Variables included are age, gender, school decile and ethnicity. According to the New Zealand Ministry of Education (2012b) a school decile is a 10% band rating that shows the socioeconomic status of the community it serves. A decile score of

1 would indicate a low socioeconomic community whereas a rating of 10 indicates an affluent area.

As discussed in the Literature review of this thesis, authors present their results in multiple ways for example Bland Altman, scatter graphs with a regression line, MPE, MPD and percentage of measured weight. This causes problems when comparing studies, this study will present results using Bland Altman plots, MPE and will address clinical significance using 10% of a child's measured weight considered accurate.

Bland Altman Method.

Data was analysed and displayed using the Bland Altman method, which is presented in graphical form (Preiss & Fisher, 2008). The Bland Altman method of calculating and presenting limits of agreement was chosen over correlation as it illustrates agreement between two measures and according to Lowenstein, Koziol-McLain and Badgett (1993) reduces the risk of systematic bias as well as undue weight on p values. Bland and Altman (2003) suggest their method is more meaningful when clinical application of measurements is required.

Generally a Bland Altman plot compares two methods or measurements which are usually a current test and new test. The y-axis shows the difference (bias) between these tests while the x-axis shows the average between the two tests as an approximation of 'the true value' (Delaney, 2003). This study uses a modified implementation of this method suggested by Krouwer (2008) where the measured weight is plotted on the y axis rather than the average of actual and estimated weight. The rationale for this is that measured weight is considered the gold standard measurement and is therefore the reference value. The limits of agreement are shown in Bland Altman plots with solid lines drawn horizontally showing the mean difference ± 1.96 multiplied by mean difference SD; this gives a range of values which 95% of the sample will fall between (Bland & Altman, 2007).

Mean Percentage Error (MPE) Krieser et al. (2007) and Clinical Significance.

According to Krieser et al. (2007) MPE is the difference between actual and estimated weight shown as a percentage of each child's measured weight and provides another measure of accuracy. The majority of studies consider a child's weight estimate to be accurate if it falls ± 10% of their measured weight. Therefore, proportions of the sample (%) are shown for those children who had a weight estimate within 10% of their measured weight. The cut-off of 10% is used in many studies including Krieser et al. (2007), Cattermole et al. (2011), Geduld et al. (2011) and Ali et al. (2012). However, validation of the clinical significance of 10% of measured weight is not available. Therefore, this study reports results using 10% of measured weight as a cut-off but it is acknowledged that the clinical significance of this cut-off requires validation. Stratification of results using common demographics such as age, gender, school decile, body habitus and ethnicity is presented in tabular form using MPE to show clinical significance in differing populations.

Methodological Limitations

Study Setting.

As discussed in the literature review we are unable to anticipate presentation patterns to the emergency department, this means that we are unable to anticipate the demographics of the population who require weight estimation. Also, seriously ill children are often excluded from studies set in the ED. Therefore, this study was set in schools to allow for collection of data from a cross section of Auckland school children in the hope of including children similar to those who may be excluded based on the severity of their illness.

Measurement Bias.

A measurement bias may be evident in body habitus measurement as this classification is based on a visual estimate of body size which may differ when more than one researcher is taking this measurement. This was addressed in this study by working out the interrater reliability.

Selection Bias.

Schools ultimately choose the class to participate which was dependant on parental consent both of which may lead to a selection bias.

CHAPTER 4 RESULTS

This chapter presents the results of this study. It will begin by showing geographical location of selected schools and go on to demonstrate stratification using demographic information to show accuracy of weight estimation methods when applied to a cross section of Auckland children.

Geographical Location of Schools

Geographical distribution for schools selected to participate in this study are shown in Figure 14. Although the distribution of randomised schools is even across decile ratings, two of these schools are in located eastern suburbs (decile 8 and 10).

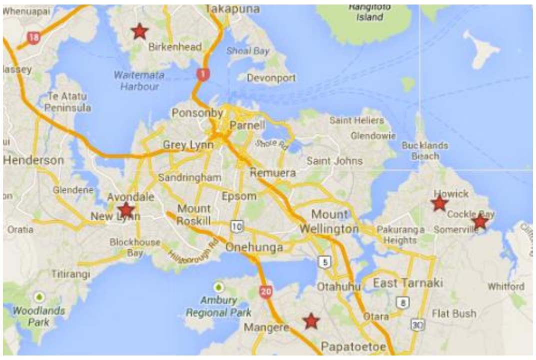

Figure 14 - Distribution of selected schools across Auckland[6].

Participation Rate

All 1569 children at participating schools received study information and parental consent forms for their family to consider. Of these, 412 (26.3%) consent forms were returned by a parent or guardian. During data collection, nine children were absent from school, eight children were over the age of 10 years and 20 children did not wish to participate in this study. These children were excluded leaving 376 (23.9%) of eligible children included in this study.

The return rate of parental consent forms ranged from 15.2% to 34.1% with the smallest school (decile 5) returning only 31 forms (Table 19). All schools were aware of the target of 100 children at each school (20 in each age group). Return rate of parental consent forms did not allow this. After excluding children over 10 years of age and those who did not give verbal assent, children included from each school ranged from 12.8% to 31.1%. Return rates stratified by class and gender for each school is included in Appendix H (page 84).

[6] Maps in Figure 14 created using Auckland School data provided by New Zealand Ministry of Education (2012a) and the website maps.google.com

Table 19 - Parental consent and inclusion rates sorted by school

Decile of School	School Suburb	Area of Auckland	Total school Roll	Returned parental consent forms		Children included	
				n	%	n	%
1	Mangere	South	513	107	20.9%	97	18.9%
3	Avondale	West	222	72	32.4%	68	30.6%
5	Birkdale	North	204	31	15.2%	26	12.8%
8	Howick	East	302	103	34.1%	94	31.1%
10	Howick	East	328	99	30.2%	89	27.1%
Total			1569	412	26.3%	376	24.0%

Demographic information

Demographic information is shown in Table 20. Parents were asked to record age, gender and ethnicity for their child. Age of children was between 5 and 10 years with a mean of 7.49 years and SD of ±1.7 years (Standard Error (SE) 0.088).

Table 20 - Demographic Information

	n	%
Age in years		
5	66	17.6
6	57	15.2
7	65	17.3
8	65	17.3
9	61	16.2
10	62	16.5
Gender		
Female	218	58.0
Male	158	42.0
Primary Ethnicity		
Asian / Indian	49	13.0
European	151	40.2
Maori	56	14.9
MELAA	6	1.6
Other	1	0.3
Pacific	113	30.1
School Decile		
1	98	26.1
3	68	18.1
5	26	6.9
8	94	25.0
10	90	23.9

Stratification by School Decile

School decile was included as a proxy for socioeconomic status. Table 21 shows the distribution of age, ethnicity and gender in decile groups. The aim of this study was to have even numbers of children of each ethnicity, age and gender within every decile group, this was not possible due to reduced return rates of consent forms within the study timeframe and therefore this will influence results received. This meant that some stratification was possible however there are some inconsistences between demographic groups. The decile 1 school included more older children whereas children attending the decile 10 school were evenly distributed across age groups. Children of Pacific denomination predominately attended schools of decile 1 and 3 whereas European children predominantly attended decile 8 and 10 schools. Gender appears to be evenly spread throughout all schools.

Table 21 - School decile stratified by age, ethnicity and gender

	School Decile									
	1		3		5		8		10	
	n	%	n	%	n	%	n	%	n	%
Age in years										
5	7	7.1	15	22.1	4	15.4	23	24.5	17	18.9
6	11	11.2	7	10.3	3	11.5	20	21.3	16	17.8
7	14	14.3	16	23.5	6	23.1	14	14.9	15	16.7
8	18	18.4	13	19.1	7	26.9	16	17.0	11	12.2
9	20	20.4	8	11.8	2	7.7	14	14.9	17	18.9
10	28	28.6	9	13.2	4	15.4	7	7.4	14	15.6
Gender										
Female	55	56.1	41	60.3	15	57.7	53	56.4	54	60.0
Male	43	43.9	27	39.7	11	42.3	41	43.6	36	40.0
Ethnicity										
Asian /Indian	9	9.2	11	16.2	4	15.4	20	21.3	5	5.6
European	3	3.1	1	1.5	11	42.3	53	56.4	83	92.2
Maori	26	26.5	6	8.8	9	34.6	14	14.9	1	1.1
MELAA	0	0.0	3	4.4	0	0.0	3	3.2	0	0.0
Other	0	0.0	1	1.5	0	0.0	0	0.0	0	0.0
Pacific	60	61.2	46	67.6	2	7.7	4	4.3	1	1.1

Stratification by Age

When stratified by age, gender is fairly even across male and female children. However, a disparity is apparent when school decile is compared with ethnicity. Table 22 shows stratification by age, where more younger children were included in all school deciles. A similar trend is seen when age is compared with ethnicity.

Table 22 - Stratification of demographic data by age

	Age in years											
	5		6		7		8		9		10	
	n	%	n	%	n	%	n	%	n	%	n	%
School Decile												
1	7	10.8	11	16.9	14	21.5	15	23.1	13	20.0	5	7.7
3	15	25.4	7	11.9	16	27.1	12	20.3	7	11.9	2	3.4
5	4	18.2	3	13.6	6	27.3	7	31.8	1	4.5	1	4.5
8	23	27.7	19	22.9	14	16.9	14	16.9	11	13.3	2	2.4
10	17	22.4	16	21.1	15	19.7	10	13.2	11	14.5	7	9.2
Gender												
Female	35	20.1	32	18.4	41	23.6	31	17.8	27	15.5	8	4.6
Male	31	23.7	24	18.3	24	18.3	27	20.6	16	12.2	9	6.9
Ethnicity												
Asian	12	27.9	9	20.9	8	18.6	7	16.3	6	14.0	1	2.3
European	31	24.2	23	18.0	27	21.1	19	14.8	21	16.4	7	5.5
Maori	10	20.4	7	14.3	12	24.5	10	20.4	6	12.2	4	8.2
MELAA	1	16.7	2	33.3	0	0.0	1	16.7	1	16.7	1	16.7
Pacific	12	15.2	15	19.0	18	22.8	21	26.6	9	11.4	4	5.1

Stratification by Gender

Table 22 shows that gender is fairly evenly spread between male and female children over age groups and school decile. However, Table 23 illustrates that gender is not as evenly spread when compared with ethnicity. All ethnicities had more female (53.1 – 83.3%) participants than male children (16.7 – 46.9%) and this may influence weight estimation in this population.

Table 23 - Ethnicity stratified by gender

	Gender			
	Female		Male	
	n	%	n	%
Ethnicity				
Asian	29	67.4	14	32.6
European	68	53.1	60	46.9
Maori	30	61.2	19	38.8
MELAA	5	83.3	1	16.7
Pacific	42	53.2	37	46.8

Ethnicity can influence body mass. Figure 15 shows a comparison of ethnicity data between this study sample, schools selected and the Auckland Region 2013 census data (New Zealand Ministry of Education, 2012a; Statistics New Zealand, 2014). The distribution of ethnicity in this study sample correlates well with the selected schools which shows that this study has a similar representation of ethnicities as selected schools (New Zealand Ministry of Education, 2012a). However when compared with the Auckland population this study and the selected schools have less children identified as Asian or European and a significantly higher proportion of children identifying as Maori of Pacific ethnicity.

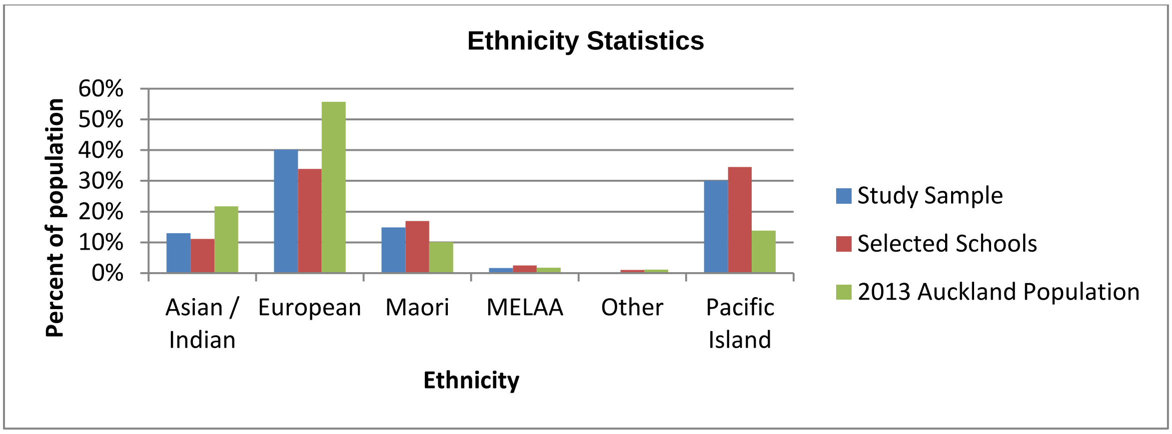

Figure 15 - Comparison of ethnicity in the study sample, school and Auckland population (Statistics New Zealand, 2014)

Weight

The weight of 376 children was measured; the range of weight was 14.2 kg to 93.1 kg. The mean of the group was 31.80 kg with a SD of 11.5 kg. Distribution of the sample is shown in Figure 16, which illustrates a positive skew. The Skewness was 1.667 with significance of <

0.001 (Kolmogorov-Smirnov normality test). This shows that the distribution of height is non-normal as significance is < 0.05. Peaks are higher than a bell curve which confirmed Kurtosis is 4.054. When weight distribution is analysed by age can be seen in Figure 17.

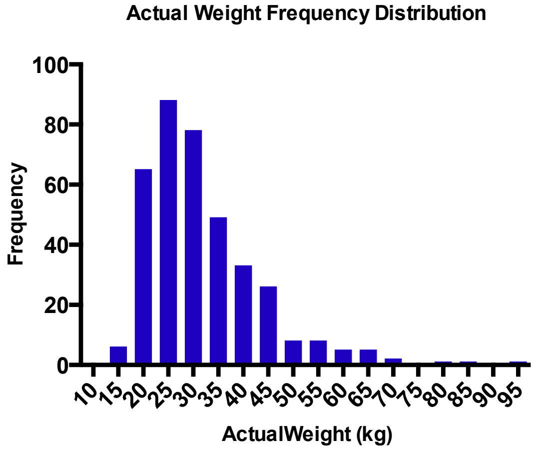

Figure 16 - Distribution by weight

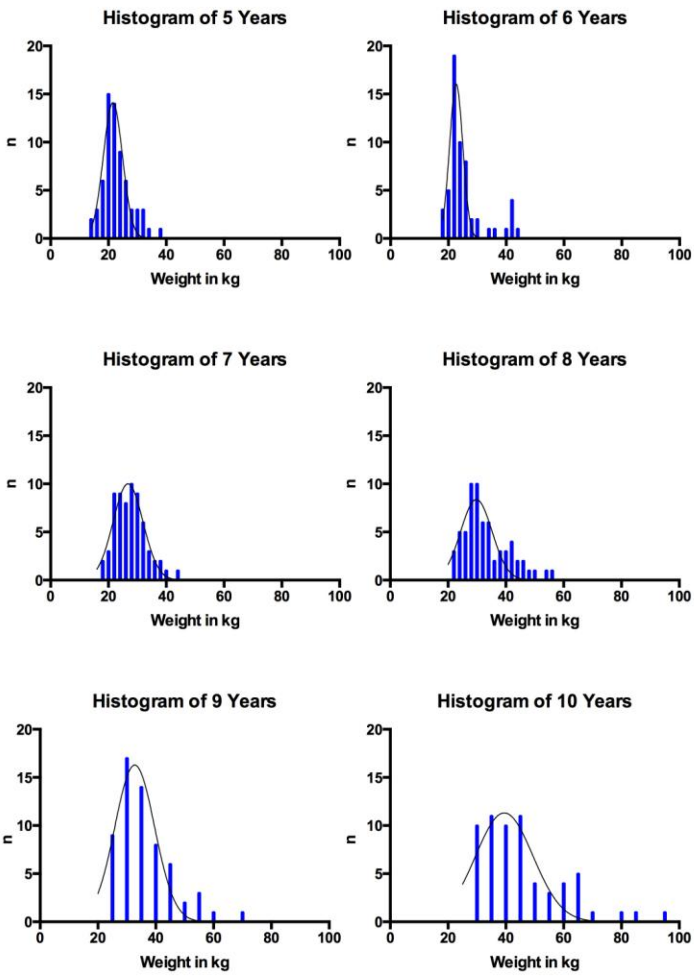

Figure 17 - Distribution of weight sorted by age.

Height

Height was recorded for 376 children and is distributed normally as shown in Figure 18. Height of participants ranged from 102.6 cm to 163.5 cm with a mean of 130.4 cm. The

Skewness was 0.1496 and Kurtosis is -0.689 with significance of 0.055 with Kolmogorov-Smirnov normality test p value of 0.055 . The normality test significance is > 0.05 which means that this distribution is categorised as normal.

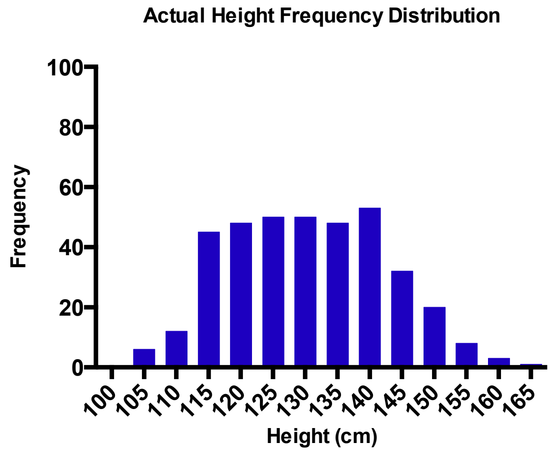

Figure 18 - Distribution of height

Body Habitus

Body habitus is reported in Table 24 and shows an even distribution of body habitus across 5, 6, 8 and 9 year old children (18.2% - 19.7%). The exceptions are children of 7 years who had the minimum percentage of children estimated as overweight / obese. Children of 10 years had a higher prevalence of overweight/obesity (33.9%). School decile influenced obesity as the decile 1 school had estimates of body habitus showing 36.7% of children obese, whereas the decile 10 school had 11.1%. A similar trend is seen on analysis of ethnicity, with Pacific children estimated as having a large body habitus in 55.6% of instances. Ethnicity and age may also influence results for example, children in the decile 1 school were predominantly older, whereas those in the decile 10 school were predominantly younger in age, also the decile 1 school had a higher proportion of Pacific children. Table 24 also shows overweight or obese children categorised by BMI alongside the visual estimate. In general the proportion of children classified as overweight / obese by visual estimate was significantly lower than the same classification using BMI. An exception to this is gender, where visual estimate of overweight / obese female subjects is 63.9%, whereas the BMI classifies only 36% of children as obese. A further exception body habitus is stratified by ethnicity. European children were classified as overweight by visual estimate on more occasions that BMI classified children as overweight or obese, however Pacific children are almost evenly spread with 55.6% classified as overweight or obese using visual estimate and 61.0% using BMI. Furthermore, it is apparent in Table 24 that children who are obese and overweight decreases with increasing school decile. This means that socioeconomic status may influence the prevalence of obesity and overweight children in these areas.

Table 24 - Body Habitus stratified by age, school decile, gender and ethnicity

		Visual Estimate Large Children		Body Mass Index
	n	n	%	Overweight or Obese
Age in years				
5 years	66	12	18.2	35.0
6 years	57	11	19.3	19.0
7 years	65	4	6.2	31.0
8 years	65	12	18.5	32.0
9 years	61	12	19.7	39.0
10 years	62	21	33.9	47.0
School Decile				
1	98	36	36.7	55.0
3	68	14	20.6	53.0
5	26	2	7.7	27.0
8	94	10	10.6	20.0
10	90	10	11.1	13.0
Gender				
Female	218	46	63.9	36.0
Male	158	26	36.1	32.0
Ethnicity				
Asian / Indian	49	7	9.7	27.0
European	151	15	20.8	17.0
Maori	56	10	13.9	36.0
MELAA	6	0	0.0	17.0
Other	1	0	0.0	0.0
Pacific	113	40	55.6	61.0

The body habitus was scored 0 = not large, 1 = large.

Age Based Formulae

The correlation graph (left) in Figure 19 shows that the APLS formula appears more accurate in lighter children. The Bland Altman plot shows that the APLS formula generally underestimates the weight of children (mean bias = 7.8) and bias in this method of weight estimation appears to increase as children get heavier. This means that the APLS weight estimate is less accurate in heavier children.

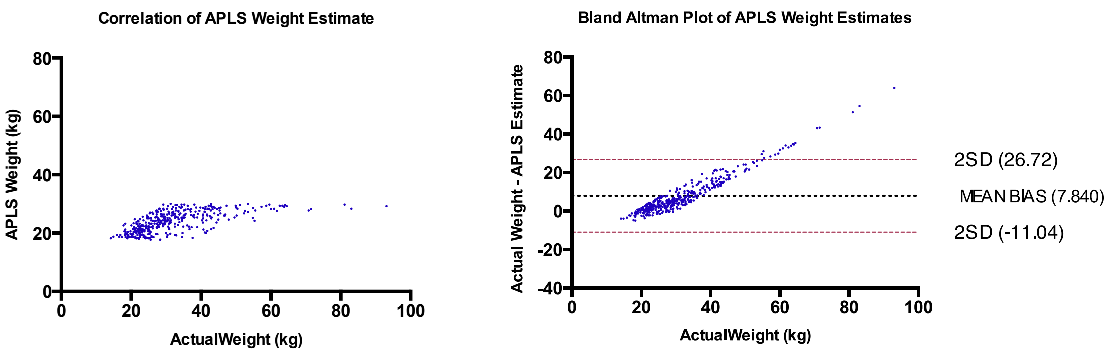

Figure 19 - Correlation of measured weight and APLS weight estimation and Bland Altman Plot for APLS weight estimation formula

Shann's weight estimation method shows similar results to the APLS formula as the limits of agreement span a similar spread and the mean bias is similar (mean bias = 7.7). It is evident in both graphs in Figure 20 that this formula is more accurate in lighter children as the bias increases with increasing weight. This means that similar to APLS, Shann's formula becomes less accurate in estimating the weight of children as they become heavier.

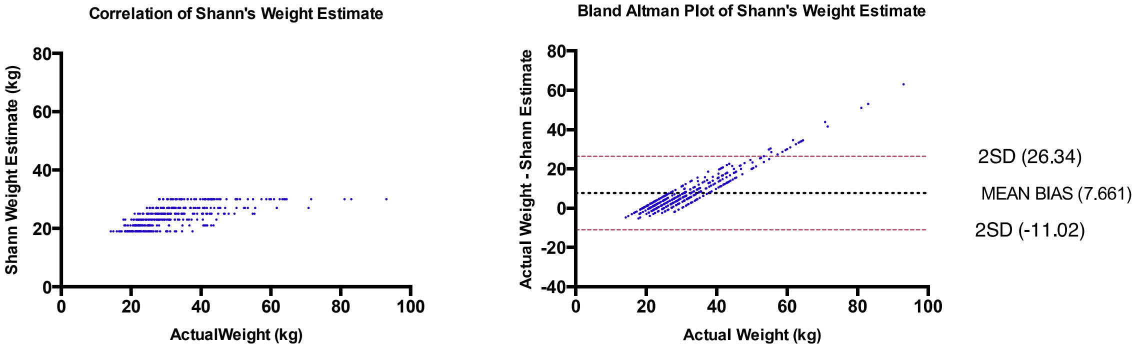

Figure 20 - Correlation of Shann's weight estimation formula with weight and Bland Altman Plot for Shann's weight estimation formula

Theron's exponential formula, shown in Figure 21, tends to overestimate the weight of children in this study (mean bias = -6.5). Theon's weight estimates differ from Shann and APLS as outliers exist both above and below limits of agreement. The Bland Altman plot shows less clustering near the mean with points becoming wider as a child's weight increases. This means that this formula also becomes less accurate with increasing weight.

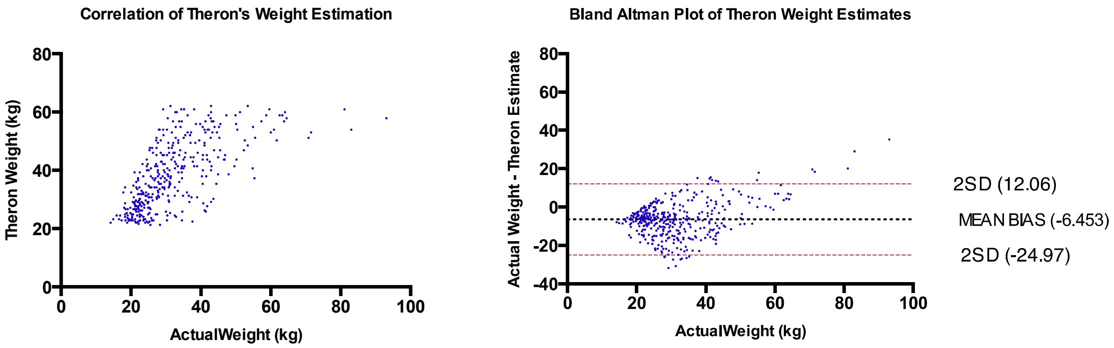

Figure 21 - Correlation and Bland Altman Plot for Theron's weight estimation formula

Length Based Methods

The Broselow-Luten Tape weight estimates shown in Figure 22 show a clear cut-off point of 36 kg and 143 cm limits of the tape. These limits meant that 305 of the 376 children could be included in this analysis. Correlation shows consistent spread of points and the Bland Altman plot shows the narrowest limits of agreement and lowest bias (1.1) of all estimation methods tested. This means that for those children under 143 cm the Broselow-Luten Tape is the most accurate method of weight estimation in this population.

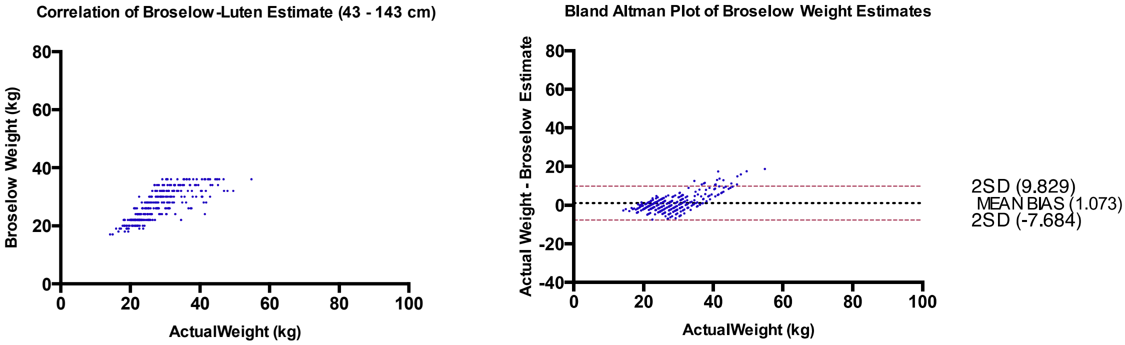

Figure 22 - Correlation of Broselow-Luten weight estimate with measured weight and Bland Altman Plot of Broselow-Luten weight estimate

Clinical Significance

Table 25 shows the percentage of weight estimations within 10% of a child's measured weight for each age based formulae. Shann's linear estimation formula was the most accurate in all age groups. The age band with the highest accuracy is 6 years with 68.4% of children within 10% of their measured weight. School decile is used as a proxy for socioeconomic class in this study and has an effect on accuracy of weight estimation formulae. Weight estimates in lower decile schools (generally in lower socioeconomic areas) are less accurate than those schools in high decile areas. Table 25 reveals that Theron formula are most accurate in the Decile 1 school, whereas the Shann's formula is the most accurate in decile 10 schools.

Table 25 – Clinical significance of age based formulae

		APLS		SHANN		THERON	
	n	n	%	n	%	n	%
Age in Years							
5	66	29	43.9	35	53.0	33	50.0
6	57	36	63.2	39	68.4	13	22.8
7	65	28	43.1	30	46.2	20	30.8
8	65	22	33.8	27	41.5	16	24.6
9	61	18	29.5	23	37.7	12	19.7
10	62	14	22.6	18	29.0	14	22.6
School Decile							
1	98	23	23.5	28	28.6	31	31.6
3	68	14	20.6	19	27.9	29	42.6
5	26	10	38.5	15	57.7	5	19.2
8	94	54	57.4	60	63.8	23	24.5
10	90	46	51.1	50	55.6	20	22.2
Gender							
Female	218	88	40.4	99	45.4	60	27.5
Male	158	59	37.3	73	46.2	48	30.4
Ethnicity							
Asian / Indian	49	33	67.3	34	69.4	7	14.3
European	151	78	51.7	89	58.9	34	22.5
Maori	56	19	33.9	24	42.9	12	21.4
MELAA	6	4	66.7	4	66.7	3	50.0
Other	1	0	0.0	0	0.0	0	0.0
Pacific	113	13	11.5	21	18.6	52	46.0
Total	376	147	39.1	172	45.7	108	28.7

n (first column) = the total sample in each category, n (except first column) = number of children within10% of measured weight, % = the percent of children within 10% of measured weight, Total = the proportion of the sample that is withn 10% of measured weight

Gender has little effect on accuracy of weight estimation methods. However, Table 25 indicates that more female than male subjects were measured (218 male and 158 female) which may have affected results.

Ethnicity affects the accuracy of all weight estimation formulae. Table 25 shows that linear Shann's formula is the most accurate in Asian / Indian, European and Maori children while Theron's formula is more accurate in Pacific children with 46.0% of children estimated within 10% of their measured weight.

Table 26 shows an analysis of age and length based methods of estimation using only the children who fell within the Broselow-Luten Tape parameters. Generally the Broselow-Luten Tape appears to be the most accurate overall in these children, with the Theron Formula being the least accurate. However the Broselow-Luten Tape only included 305 children 43 – 143 cm in height whereas other formulae include children up to 163.5 cm therefore a proportion of children between 143 and 163.5 cm (18.9%) would not be recorded in Table 26.

Table 26 - Comparison of Broselow-Luten Tape with age-based methods of weight estimation on the population of children who were between 45 cm and 143 cm only (Broselow-Luten Tape Limitations)

	n	APLS		SHANN		THERON		BROSELOW	
		n	%	n	%	n	%	n	%
Age in Years									
5	66	29	43.9	35	53.0	33	50.0	49	74.2
6	56	35	62.5	38	67.9	13	23.2	42	75.0
7	65	28	43.1	30	46.2	20	30.8	55	84.6
8	58	22	37.9	27	46.6	13	22.4	38	65.5
9	43	18	41.9	22	51.2	5	11.6	29	67.4
10	17	9	52.9	10	58.8	0	0.0	11	64.7
School Decile									
1	65	22	33.8	25	38.5	17	26.2	42	64.6
3	59	13	22.0	18	30.5	25	42.4	35	59.3
5	22	9	40.9	14	63.6	4	18.2	17	77.3
8	83	52	62.7	56	67.5	21	25.3	65	78.3
10	76	45	59.2	49	64.5	17	22.4	65	85.5
Gender									
Female	174	84	48.3	92	52.9	45	25.9	121	54.0
Male	131	57	43.5	70	53.4	39	29.8	103	46.0
Ethnicity									
Asian / Indian	43	32	74.4	33	76.7	5	11.6	27	62.8
European	128	75	58.6	85	66.4	29	22.7	110	85.9
Maori	49	18	36.7	22	44.9	10	20.4	37	75.5
MELAA	6	4	66.7	4	66.7	3	50.0	4	66.7
Pacific	79	12	15.2	18	22.8	37	46.8	46	58.2
Total	305	141	46.2	162	53.1	84	27.5	224	73.4

n (first column) = the total sample in each category,
n (except first column) = number of children within10% of measured weight
% = the percent of children within 10% of measured weight,
Total = the proportion of the sample that is withn 10% of measured weight

Body habitus can influence the accuracy of weight estimation methods. Table 27 shows that APLS, Shann and the Broselow-Luten Tape are less accurate in children who have a large body habitus. An exception to this is Theron's formula where 48.6% of weight estimates were within 10% of a child's measured weight.

Table 27 - Accuracy of weight estimation methods according to body habitus

		APLS		SHANN		THERON		BROSELOW	
	n	n	%	n	%	n	%	n	%
Body Habitus									
Not Large	304	146	48.0	170	55.9	73	24.0	220	72.4
Large	72	1	1.4	2	2.8	35	48.6	4	5.6

Overall Accuracy

The length based Broselow-Luten Tape was most accurate method of weight estimation in children under 143 cm, with 73.4% of weight estimates within 10% of measured weight. However, due to height restrictions when using the Broselow-Luten Tape fewer children were included in this cohort which may influence these results (Table 28). The accuracy of the Broselow-Luten Tape is confirmed using Mean Percentage Error (MPE) in Table 28. Shann's formula was the most accurate among the three age based weight estimate methods, but less than half (45.7%) of weight estimates were within 10% of the child's measured weight.

Table 28 - Mean Percentage Error

Estimation Method	n	Minimum	Maximum	MPE	SD
Broselow-Luten	305	-42.03	33.33	-1.72	13.19
APLS	376	-68.64	28.17	-19.04	18.11
Theron	376	-40.37	108.89	24.87	29.17
Shann	376	-28.92	102.52	17.47	27.30

MPE = Mean Percentage Error, SD = Standard Deviation

CHAPTER 5 DISCUSSION

In this study the Broselow-Luten Tape is the most accurate weight estimation method for children under 143 cm in height. The Broselow-Luten Tape estimated weight of 73.4% of the sample (n = 305, < 143 cm height) within 10% of a child's measured weight. This statistic is higher than other studies of the Broselow-Luten Tape, which also found this length based method of weight estimation outperformed age based weight estimation methods for children (Abdel-Rahman et al., 2013b; Geduld et al., 2011; Milne et al., 2012; Nieman et al., 2006; So et al., 2009; Trakulsrichai et al., 2012). Nevertheless, the question remains, are weight estimates within 10% of measured weight for three out of every four children sufficient for safe and effective resuscitation?

The Broselow-Luten Tape outperformed Theron, Shann and the APLS formula in all age groups. As in other studies, the accuracy of all weight estimation methods generally decreases with increasing age (Argall et al., 2003; Luscombe et al., 2011; Ramarajan, Krishnamoorthi, Strehlow, Quinn & Mahadevan, 2008; So et al., 2009; Theron et al., 2005; Thompson et al., 2007; Tinning & Acworth, 2007; Varghese, Vasudevan, Lewin, Indumathi, Dinakar & Rao, 2006).

When stratified by school decile as a proxy for socioeconomic status, those in decile 1 and 3 (less affluent communities) the Broselow-Luten Tape outperformed other methods of weight estimation producing a fairly even spread of estimates within 10% of measured weight across school deciles (49.2% - 68.2%). Conversley age based methods of weight estimation (stratified by school decile) were less accurate, with a wider range of estimates within 10% of measured weight (APLS - 15.3% – 55.3%, Shann– 13.6% - 53.0% and Theron -13.2% – 25.4%). As this is the first weight estimation study to consider school decile / socioeconomic status comparisons with literature can not be made.

Stratification by ethnicity produced similar results to school decile and a clear link between ethnicity and school decile is evident. For example, Pacific children make up 61.2% of sample from the Decile 1 school and 67.6% of the sample from the decile three school whereas, the decile 8 school was 56.4% European and the decile 10 school 92.2% European. One surprising statistic is that the Broselow-Luten Tape outperformed the Theron formula in both Maori and Pacific children under 143 cm, Pacific children were within 10% of their measured weight in 50.6% of cases using the Broselow-Luten Tape compared with 32.9% when calculated using Theron's formula. In an earlier study Theron et al. (2005) derived their formula the percent difference between estimated and measured weight for Pacific children was 11.02% (SD 11) compared with 9.86% (SD 9.82) in this study. The data set which the Theron formula was derived from in their 2005 study has been validated in China and the USA, however these studies are difficult to compare as age and weight stratification is grouped broadly which means detailed comparison with this study is difficult (Cattermole et al., 2011; So et al., 2009). Cattermole et al. (2011) found that Theron's formula did not perform as well in this study for children age 1 – 10 of any height with 17.3% of weight estimates within 10% of a child's measured weight.

A limiting factor when comparing these results is the place of data collection. This study was set in schools spread across Auckland geographically and by school decile whereas Theron et al. (2005) used a convenience sample of children presenting to a Middlemore Hospital in South Auckland to derive their formula.

Shann's formula was the most accurate of the three age based weight estimation formula with 45.74% (MPE -17.47, SD 27.30) of weight estimates using Shann's formula are within 10% of their measured weight. This finding is similar to the Auckland study Theron et al. (2005) who found that Shann's formula was the most accurate formula overall. Furthermore, Table 29 shows that when stratified by ethnicity Theron's formula is more accurate in Pacific children with an MPE of 8.44% (SD 26.95).

Table 29 - Overall clinical significance of age based weight estimation methods

	APLS		SHANN		THERON	
	MPE	SD	MPE	SD	MPE	SD
Ethnicity						
Asian / Indian	-8.70	17.26	5.24	22.33	35.30	27.27
European	-12.65	14.61	7.93	20.73	33.98	26.81
Maori	-19.26	16.55	16.42	25.57	22.71	26.44
MELAA	-9.80	16.19	9.27	16.89	37.69	34.16
Other	-27.64	.	28.08	.	40.38	.
Pacific	-32.36	15.91	36.40	16.69	8.44	26.95
Total	-19.04	18.11	17.47	27.30	24.87	29.17

MPE = Mean Percentage Error
SD = Standard Deviation

A limitation of this study is that the distribution of ethnicity does not match the Auckland Region. This is also evident as a trend in other studies in the literature review of this thesis and leads to the conclusion that this is an area which requires further investigation.

None of the weight estimation methods commonly in use in New Zealand (Theron, Shann, APLS and the Broselow-Luten Tape) take into account body habitus. With rising obesity rates introduction of body habitus in weight estimation may increase accuracy of weight estimation methods. Several overseas methods of weight estimation do take into account body habitus. For example, DWEM method, PAWPER Tape and Mercy Tape (Abdel-Rahman et al., 2013b; Garland, Kishaba, Nelson, Losek & Sobocinski, 1986; Wells et al., 2013). An example of this is the DWEM weight estimation method for calculation by Garland et al. (1986), a child with the height of 50 cm could weigh 2 – 4 kg dependant on body habitus and a child of 165 cm could be between 40 – 70 kg and adding body habitus allows for more specific weight estimates. Body habitus estimates have only been included in length based methods of weight estimation thus far. Therefore, addition of body habitus to aged based formulae may increase the accuracy of age based weight estimates and is an area that requires further investigation.

A variance was apparent in overweight or obese children classified by visual estimate in this study. 19.9% of children were considered large in visual estimates of body habitus and 34.0% were classified as overweight or obese using ITFO BMI cut-off points. Limitations of BMI use in children has been identified earlier in this thesis and this disparity indicates a need for further research around accuracy of both visual estimate of body habitus and BMI use in children. External factors could influence this disparity for example the silhouettes designed by Warschburger and Kroller (2009) used in this study were designed using anthropometric measurements of German children who may have differences in body fat, muscle mass and bone density to New Zealand children and further research could focus on design of silhouettes to measure body habitus based on anthropometric data of New Zealand children. However, according to Duncan et al. (2008a); Duncan, Schofield, Duncan and Rush (2008b) and Rush et al. (2009) the cultural diversity of New Zealand children could make this challenging due to ethnic differences in body composition of children.

A limitation of this study was directly related to return rates of parental consent forms. Only 24% of these were returned which has impacted the ability to stratify all results as planned. For example, due to low parental consent return rates only 26 children were included from the decile 5 school which will skew results for this decile, less, ≥ 44 children were required.

The setting of this study may influence results. This study was set in primary schools to obtain a cross section of Auckland children. However, the subset of the population that requires weight estimation is seriously ill children who require emergency treatment. Some studies are set in the Emergency Department however they often exclude the exact population that requires weight estimation, the seriously ill children (Casey & Borland, 2010; DuBois et al., 2007; Kun et al., 2000; Rosenberg et al., 2011; Wells et al., 2013). Investigation of presentation patterns of Auckland children to the Emergency Department would assist in the analysis of results and is an area which requires further study.

Further Research

Four areas are apparent where further study is required. Firstly, a standardised measure of accuracy in weight estimation, such as 10% of measured weight, would simplify reviewing literature and allow easy comparison of studies. Validation of this standard measure could also strengthen the authority and impact on clinical judgement. Secondly, investigation of presentation patterns to the emergency department would identify the demographics of those requiring weight estimation. This was highlighted by the exclusion of severely ill children (the target population) in many studies as well as appearance of research that excluded data collection in the most busy time in the emergency department. Thirdly, addition of body habitus scoring to age based weight estimation methods is an area requiring further study. Finally, the influence of population demographics, such as geographical location, socioeconomic status, ethnic spread and migrant movements on weight estimation accuracy requires further analysis.

Conclusion

In summary, this study identified which method of weight estimation, based on a sample of Auckland school children, provides the highest level of accuracy.

- Broselow-Luten Tape (2011 version) is the most accurate method of weight estimation for a cross section of Auckland children aged 5 – 10 years who are below the height of 143 cm.
- Generally Shann's formula is the most accurate age based weight estimation formula for Auckland children aged 5 – 10 years.
    - 1 – 9 years

        - weight = (2 x age in years) + 9
    - 9 years
        - 3 x age in years
- Theron's weight estimation formula is the most accurate weight estimation formula for Pacific children living in Auckland aged 5 – 10 years.
    - exp(2.20 + 0.175 x age in years)

These findings have important implications for prehospital and emergency resuscitation policy as they differ from guidelines produced by New Zealand Resuscitation Council (2010).

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CHAPTER 6 APPENDICES

Appendix A

Limitations of age based formula

Age Based Estimation Methods	Age Parameters	Formula	Other suggested limits	Original Author(s)	Country or origin
APLS / ARC	1 - 9 years	(age in years + 4) x 2		(New Zealand Resuscitation Council, 2010)	UK
	10 - 14 years	3.3 x age in years			
Argall	1 – 10 years	(age in years + 2) x 3		(Argall et al., 2003)	UK
Best Guess	< 1 year	(age in months + 9) / 2		(Thompson et al., 2007)	Australia
	1 - 4 years	(2 x age in years) + 10			
	5 - 14 years	4 x age in years			
CWAR	1 - 6 years	(3 x age in years) + 5	Caution with children > 7 years	(Cattermole et al., 2011)	China
Leffler	< 1 year	(age in months / 2) x 4	Original study tested children ≤ 5 years	(Leffler & Hayes, 1997)	USA
	≤ 10 years	(age in years + 2) x 4			
Luscombe & Owens	1 – 10 years	(3 x age in years) + 7		(Luscombe et al., 2011)	UK
Nelson	3 months - 1 year	(age in months + 9) / 2		(Varghese et al., 2006)	USA
	1 - 6 years	(2 x age in years) + 8			
	7 - 12 years	((age in years * 7) - 5) / 2			
Park	< 1 year	(age in months + 9) / 2		(Park et al., 2012)	Korea
	1 - 4 years	(2 x age in years) + 9			
	5 - 14 years	(4 x age in years) - 1			
Shann	1 - 9 years	(2 x age in years) + 9		(Theron et al., 2005)	Pacific Islands
	> 9 years	3 x age in years			
Theron	1 - 10 years	exp(2.20 + 0.175 x age in years)		(Theron et al., 2005)	New Zealand

Length Based Formula

Limitations of length based weight estimation methods

Length Based Weight Estimation Method	Age Limit	Height Limit	Other suggested limits	Original Author(s)	Country of origin
Broselow-Luten Tape		46 - 144 cm 46 – 143 cm		(Cattermole et al., 2011) (Lubitz et al., 1988)	USA
DWEM		50 – 175 cm		(Garland et al., 1986)	USA
Kloeck Tape	Mentioned in Thesis by Michael Wells however on searching no literature available (he states it is not validated). His thesis references a personal communication in 2008 with W Kloeck.			(Wells, 2009)	South Africa
Lo Tape				(Wells, 2009)	Hong Kong
Malawai Tape		45 -130 cm		(Wells, 2009)	USA
MERCY Tape					USA
Oakley Tables	≤ 14 years	50 – 160 cm		(Oakley, 1988)	
PAWPER Tape				(Wells, 2009)	
PREM Tape	No evidence of existence other than mention in a thesis by Michael Wells. Reference made to website of Joe Brierly (www.premsystem.co.uk) however this link is broken.			(Wells, 2009)	UK
Sandell Tape	0 + years			(TSG Associates, 2014)	UK
Traub-Johnson	1 – 18 years			(Traub & Johnson, 1980)	Australia
Traub-Kichen	1 – 17 years	> 74 cm		(Traub & Kichen, 1982)	Australia

Visual Estimate

- Ambulance Estimate
- Nurse Estimate
- Parent Estimate
- Physician Estimate

Other Methods

- Arm Circumference
- Clothing Label Size
- Hanging Leg Weight

Appendix B – Ethics Approval and Amendments

Ethics Approval Letter

AUTEC
SECRETARIAT

29 April 2013

Jane Koziol-McLain
Faculty of Health and Environmental Sciences

Dear Jane

Re Ethics Application: **13/62 Are weight estimation methods accurate when compared with actual weight in children aged 5-10 years.**

Thank you for providing evidence as requested, which satisfies the points raised by the AUT University Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 29 April 2016.

As part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online throughhttp://www.aut.ac.nz/researchethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 29 April 2016;
- A brief report on the status of the project using form EA3, which is available online throughhttp://www.aut.ac.nz/researchethics. This report is to be submitted either when the approval expires on 29 April 2016 or on completion of the project.

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this.

To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

All the very best with your research,

Madeline Banda
Acting Executive Secretary
Auckland University of Technology Ethics Committee

Cc: Sally Britnell sally

Ethics Approval Amendment Letter

AUTEC SECRETARIAT

6 June 2013

Jane Koziol-McLain
Faculty of Health and Environmental Sciences

Dear Jane

Re: Ethics Application: **13/62 Are weight estimation methods accurate when compared with actual weight in children aged 5-10 years.**

Thank you for your request for approval of amendments to your ethics application.

I have approved minor amendments to your ethics application to include the user of a poster.

I remind you that as part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through http://www.aut.ac.nz/researchethics. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 29 April 2016;
- A brief report on the status of the project using form EA3, which is available online through http://www.aut.ac.nz/researchethics. This report is to be submitted either when the approval expires on 29 April 2016 or on completion of the project.

It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to obtain this. If your research is undertaken within a jurisdiction outside New Zealand, you will need to make the arrangements necessary to meet the legal and ethical requirements that apply there.

To enable us to provide you with efficient service, please use the application number and study title in all correspondence with us. If you have any enquiries about this application, or anything else, please do contact us at ethics@aut.ac.nz.

All the very best with your research,

Madeline Banda
Acting Executive Secretary
Auckland University of Technology Ethics Committee

Cc: Sally Britnell sally.britnell@aut.ac.nz

Appendix C – Consent Forms

Parent Information Sheet

Parent Information Sheet

29 April 2013

My name is Sally Britnell, I am a lecturer at AUT university and previously a Nurse in the Children's Emergency Department at Starship Hospital. I am conducting research at your child's school from July 1 2013 and invite children aged 5 - 10 to participate in this study.

Research Title:

Are weight estimation methods accurate when compared with actual weight in children aged 5 – 10 years?

Purpose of this study:

This study will compare the weight and height of children in Auckland with a weight estimation methods used by New Zealand Hospitals and Ambulance services.

Who will benefit from this study:

Children throughout New Zealand will benefit from your child's participation in this study. This research provides height and weight measurements from New Zealand children to compare with weight estimation methods. Collecting New Zealand specific data is important as most weight estimation methods were derived using data from children in other countries. Results of this study will inform practice in medical treatment of children in New Zealand by allowing accurate individualised medical treatment.

What will happen in this research:

Sally and a research assistant will explain the research to each class of children on the day they are at your school. The research assistant will check for parent / guardian consent and prepare children to be weighed and measured; this includes removal of any heavy outer clothing such as jackets and jerseys, as well as each child's shoes.

Sally will measure each child's weight on a standing scales and measure height both standing up using a standometer and laying down with a specialised tape (Broselow Tape) used in the Emergency Department for weight estimation.

After measurements are taken, each child will be thanked for their help and will be able to choose a sticker in return for participation.

Privacy:

Child and family privacy will be protected at all times. No identifying information will be used in this study. The child and parent's name will only appear on the consent form and these will be stored in a locked cupboard at AUT.

Discomforts and risks:

Privacy will be maintained at all times and no weight or height measurements will be stated out loud to decrease the risk of discomfort and stigma to each child.

The cost of participating in this research:

The cost of participating is giving 5 – 10 minutes of time out of each child's school day.

Consent (parent and child):

A consent form is attached to this letter, if you are happy for your child to participate, please return this to your child's school or by post to the researcher at the address below. You or your child can withdraw from this study at any time, to do this please contact the researcher.

Approved by the Auckland University of Technology Ethics Committee on 29 April 2013, AUTEC Reference 13/62.

Feedback on this research:

On completion of this study, a report outlining results will be available at your child's school. Schools will be asked to inform parents when this is available.

What to do if you have concerns about this research:

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Jane Koziol-McLain, 921-9670, jkoziolm@aut.ac.nz.

Concerns regarding the conduct of the research should be notified to the Acting Executive Secretary of AUTEC, Madeline Banda, ethics@aut.ac.nz, 921 9999 ext 8316.

Further Information:

A child friendly information sheet is attached to this letter for children.

If you would like further information or have questions about this study, please contact Sally Britnell or Jane Kozol-McLain.

Researcher Contact Details:

Sally Britnell

AUT University

School of Health Care Practice, AA217,

Phone: 921 9999 xn 7539,

Email: sally.britnell@aut.ac.nz.

Project Supervisor Contact Details:

Jane Koziol-McLain,

AUT University,

School of Health Care Practice,

Phone: 921-9670,

Email: jkoziolm@aut.ac.nz

Yours faithfully,

Sally Britnell

Researcher

Approved by the Auckland University of Technology Ethics Committee on 29 April 2013, AUTEC Reference 13/62.

Parent Consent Form

Parent/Guardian Consent Form

Project title: Are the Broselow Tape and weight estimation formulae accurate when compared with the actual weight in cross section of the Auckland children aged 5 – 10 years?

Project Supervisor: Jane Koziol-McLain (phone 921 9670)

Researcher: Sally Britnell (phone 921 9999 ext 7539)

Dear Parent/Guardian:

Your child's school is participating in a study examining weight estimation methods used in medical emergencies for children in New Zealand. This study will compare the weight and height of children in Auckland with weight estimation methods used by New Zealand Hospitals and Ambulance services.

Children throughout New Zealand will benefit from your child's participation in this study. This research provides New Zealand height and weight information to compare with weight estimation methods used by emergency services. Current weight estimation methods are based on height and weight data from children in other countries and this study will collect information form children in Auckland, New Zealand.

Children who participate in this study will be weighed and have their height measured, their ethnicity, age, class and school location will be recorded. However, no identifying information (such as your child's name) will be collected.

The researcher and her assistant will visit your child's school between July and December 2013. At this time, children will be weighed and measured wearing school clothes or uniform; children will need to remove their shoes and any heavy outer clothing such as Jackets, Jerseys and Hats.

If you are happy for your child to participate, please fill in this form and return this form and the attached questionnaire to school or by post before 1 July 2013.

Child's Name: .... Date: ....

Parent/Guardian's name: .... Parent/Guardian's signature: ....

If you require further information, please contact:

Researcher:
- Sally Britnell
- 921 9999 ext 7539
- Sally.britnell@aut.ac.nz

Supervisor:
- Jane Koziol-Mclain:
- 921 9670

Approved by the Auckland University of Technology Ethics Committee on 29 April 2013, AUTEC Reference 13/62

Please retain a copy of this form for your records.

Demographics Questionnaire

Demographic Information Questionnaire

AUT UNIVERSITY
TE WĀNANGA ARONUI O TAMAKI MAKAU RAU

Please fill in the following information and return this by 1 July 2013 with your consent form to school or post to:

Sally Britnell
AUT University (A9)
Private Bay 92006
Auckland 1142

1. Child's Name: ....
2. Child's School: ....
3. Child's Date of Birth: ....
4. Child's Ethnicity: ....

Only Date of Birth, School and Ethnicity will be included in research data. Your child's name will only be used to identify them at the time of measurement.

Approved by the Auckland University of Technology Ethics Committee on 29 April 2013, AUTEC Reference 13/62

Child Assent Form

Printed A4 Landscape.

Information for Children

WEA Study

Supervisor: Jane Koziol-McLain

Researcher: Sally Britnell

What is this study?

This study compares the weight and height of children in Auckland with methods used to estimate children's weight in an emergency department or ambulance.

Why do we need this study?

In an emergency we may need to guess a child's weight to help them. This study will make sure that weight estimation methods work for children in New Zealand.

What do I need to do?

- You will need to remove any heavy outer clothing (such as jackets and Jerseys) as well as their shoes.
- Sally will weigh you using scales that you stand on.
- She will measure your height (laying down and standing up).
- Weight and height are private and will not be said out loud.
- Sally will write your height and weight on an iPad.
- You can ask questions at any time.

What if I don't want to take part?

If you do not want to take part please tell your parent or guardian, teacher or Sally.

Family are invited to be present while their child's height and weight are measured.

How can families help?

By allowing you to be weighed and measured in this study.

If you and your family are happy to help your parent / guardian needs to return the attached consent form either to school or by post to Sally by 1 June 2013.

What if we have questions?

Children can ask their teacher any questions about this study or Sally when she is at your school.

Questions can also be asked by phone or email:

Researcher:

Sally Britnell:
921 9999 ext 7539
Sally.britnell@aut.ac.nz

Supervisor:

Jane Koziol-Mclain:
921 9670

Ethics Approval gained from the AUT Ethics Committee on 29 April 2013
(Approval number 13/62)
Child information Sheet (Version 2, 26 April 2013)

Who are you?

Please write your name?

____

Write the name of the school do you go to?

____

Please write your class number?

____

Do you have any questions?

Write any questions you have here?

____

____

____

____

I want to take part!

Please colour in this face do want to have your weight and height measured today:

YES

I don't want to take part!

Please colour in this face if don't want to have your weight and height measured today:

NO

I don't know if I want to take part!

Please colour in this face if you don't know or have questions?

MAYBE

Poster Supplied to Schools

Printed A3 size

Appendix D – School and Participant

List of Eligible Schools

Name	Decile	Unique Number
Southern Cross Campus	1	1
Te Kura Maori o Nga Tapuwae	1	2
Bairds Mainfreight Primary School	1	3
Birdwood School	1	4
Clendon Park School	1	5
Sir Edmund Hillary Collegiate Junior School	1	6
Dawson School	1	7
East Tamaki School	1	8
Favona School	1	9
Finlayson Park School	1	10
Flat Bush School	1	11
Glen Innes School	1	12
Glen Taylor School	1	13
Glenbrae Primary School	1	14
Kingsford School	1	15
Koru School	1	16
Mangere East School	1	17
Manurewa South School	1	18
Mayfield School (Auckland)	1	19
Nga Iwi School	1	20
Otahuhu School	1	21
Panama Road School	1	22
Panmure Bridge School	1	23
Pt England School	1	24
Robertson Road School	1	25
Rongomai School	1	26
Roscommon School	1	27
Rowandale School	1	28
Ruapotaka School	1	29
St John The Evangelist School (Otara)	1	30
St Pius X Catholic School (Glen Innes)	1	31
Sutton Park School	1	32
Takanini School	1	33
Tamaki School	1	34
Viscount School	1	35
Wesley School	1	36
Wiri Central School	1	37
Wymondley Road School	1	38
Yendarra School	1	39
St Mary MacKillop Catholic School	1	40
Te Matauranga	1	41
Randwick Park School	1	42
Al-Madinah School	2	43
Clayton Park School	2	44
Fairburn School	2	45
Glenavon School	2	46
Hay Park School	2	47
Henderson South School	2	48
Holy Cross School (Papatoetoe)	2	49
Homai School	2	50
Jean Batten School	2	51
Leabank School	2	52
Mangere Central School	2	53
Manurewa East School	2	54
Manurewa Central School	2	55
Manurewa West School	2	56
May Road School	2	57
Mountain View School	2	58
Owairaka District School	2	59
Papatoetoe South School	2	60
Pomaria Road School	2	61
Ranui School	2	62
Redoubt North School	2	63
Rosebank School (Auckland)	2	64
Royal Road School	2	65
St Anne's Catholic School (Manurewa)	2	66
St Joseph's School (Otahuhu)	2	67
Sylvia Park School	2	68
Te Papapa School	2	69
Weymouth School	2	70
Chapel Downs School	2	71
South Auckland S D A School	2	72
TKKM o Mangere	2	73
Avondale Primary School (Auckland)	3	74
Bailey Road School	3	75
Colwill School	3	76
Dominion Road School	3	77
Don Buck School	3	78
Glendene School	3	79
Henderson North School	3	80
Henderson School	3	81
Kelston School	3	82
Lincoln Heights School	3	83
Oranga School	3	84
Papatoetoe East School	3	85
Papatoetoe North School	3	86
Papatoetoe West School	3	87
Prospect School	3	88
Puhinui School	3	89
Riverina School	3	90
St Joseph's School (Onehunga)	3	91
St Leonards Road School	3	92
St Mary's School (Avondale)	3	93
Waikowhai School	3	94
West Harbour School	3	95
TKKM o Hoani Waititi	4	96
Beach Haven School	4	97
Chaucer School	4	98
Edmonton School	4	99
Fruitvale Road School	4	100
Glen Eden School	4	101
Holy Cross Catholic School (Henderson)	4	102
Mangere Bridge School	4	103
Massey Primary School	4	104
Mt Roskill Primary School	4	105
New Lynn School	4	106
Onehunga Primary School	4	107

Papatoetoe Central School	4	108
Stanhope Road School	4	109
Sunnyvale School	4	110
Birkdale Primary School	5	111
Edendale School (Auckland)	5	112
Flanshaw Road School	5	113
Henderson Valley School	5	114
New Windsor School	5	115
Rutherford School	5	116
Peninsula Primary School	5	117
St Paul's School (Massey)	5	118
Elm Park School	6	119
Freemans Bay School	6	120
Freyberg Community School	6	121
Glenfield Primary School	6	122
Hillpark School	6	123
Konini School (Auckland)	6	124
Manuka Primary School	6	125
Marshall Laing School	6	126
Matipo Road School	6	127
Monte Cecilia School (Mt Roskill)	6	128
Mt Albert School	6	129
Pakuranga Heights School	6	130
St Dominic's Catholic School (Blockhouse Bay)	6	131
St Mary's School (Ellerslie)	6	132
Sunnybrae Normal School	6	133
Tirimoana School	6	134
Waterlea Public School	6	135
Everglade School	7	136
Bayview School	7	137
Conifer Grove School	7	138
Ellerslie School	7	139
Green Bay Primary School	7	140
Grey Lynn School	7	141
Kauri Park School	7	142
Marist School (Mt Albert)	7	143
Marist Catholic School (Herne Bay)	7	144
Marlborough School	7	145
Newton Central School	7	146
St Francis Catholic School (Pt Chevalier)	7	147
St Mary's School (Northcote)	7	148
Sunnynook School	7	149
Three Kings School	7	150
Verran Primary School	7	151
Western Heights School (Auckland)	7	152
Windy Ridge School	7	153
Summerland Primary	7	154
Elim Christian College	8	155
Blockhouse Bay School	8	156
Gladstone School (Auckland)	8	157
Good Shepherd School (Balmoral)	8	158
Howick Primary School	8	159
Kaurilands School	8	160
Macleans Primary School	8	161
Newmarket School	8	162
Pt Chevalier School	8	163
Richmond Road School	8	164
Royal Oak School	8	165
St Heliers School	8	166
St Mark's School (Pakuranga)	8	167
Waitakere School	8	168
Wakaaranga School	8	169
Baverstock Oaks School	8	170
Westminster Christian School	9	171
Michael Park School	9	172
Stonefields School	9	173
Alfriston School	9	174
Balmoral School (Auckland)	9	175
Bayswater School	9	176
Epsom Normal School	9	177
Forrest Hill School	9	178
Glendowie School	9	179
Halsey Drive School	9	180
Hillsborough School	9	181
Hobsonville School	9	182
Mt Carmel School (Meadowbank)	9	183
Northcote School (Auckland)	9	184
Owairoa School	9	185
Pigeon Mountain School	9	186
St Joseph's Catholic School (Takapuna)	9	187
Star of the Sea School (Howick)	9	188
Takapuna School	9	189
Willow Park School	9	190
Marina View School	9	191
Oteha Valley School	9	192
Willowbank School (Howick)	9	193
Reremoana Primary School	9	194
Kadimah College	10	195
Mission Heights Primary School	10	196
Albany School	10	197
Bayfield School	10	198
Belmont School (Auckland)	10	199
Birkenhead School	10	200
Botany Downs School	10	201
Browns Bay School	10	202
Bucklands Beach Primary School	10	203
Campbells Bay School	10	204
Chelsea School	10	205
Churchill Park School	10	206
Cockle Bay School	10	207
Cornwall Park District School	10	208
Dairy Flat School	10	209
Devonport School	10	210
Glamorgan School	10	211
Greenhithe School	10	212
Hauraki School	10	213
Kohimarama School	10	214
Long Bay School	10	215
Mairangi Bay School	10	216
Maungawhau School	10	217
Meadowbank School	10	218
Mellons Bay School	10	219
Milford School (Auckland)	10	220
Mt Eden Normal School	10	221
Murrays Bay School	10	222
Our Lady Sacred Heart School (Epsom)	10	223
Parnell School	10	224

Ponsonby Primary School	10	225	Sunnyhills School	10	234
Remuera School	10	226	Taupaki School	10	235
Shelly Park School	10	227	Titirangi School	10	236
Sherwood School (Auckland)	10	228	Torbay School	10	237
St Ignatius Catholic School (St Heliers)	10	229	Vauxhall School	10	238
			Victoria Avenue School	10	239
St John's School (Mairangi Bay)	10	230	Westmere School (Auckland)	10	240
			Woodlands Park School	10	241
St Michael's Catholic School (Remuera)	10	231	Point View School	10	242
			Pinehill School (Browns Bay)	10	243
St Thomas School (Auckland)	10	232	Kohia Terrace School	10	244
			Upper Harbour Primary School	10	245
Stanley Bay School	10	233			

Appendix E – Researcher Training

Anthropometry Level I Certificate

ISAK

International Society for the Advancement of Kinanthropometry

This is to certify that

Sally Britnell

has attended an ISAK training course at the

Sport Performance Research Institute
New Zealand (SPRINZ) laboratories
AUT University -Millennium Campus,
Auckland NEW ZEALAND
03/05/13 – 05/05/13

and has met all requirements for accreditation as a

LEVEL ONE ANTHROPOMETRIST

(TECHNICIAN - RESTRICTED PROFILE)

Accreditation valid until
2nd September 2017

Professor H. de Ridder
President ISAK

Dr. C. Hencken
Secretary-General ISAK

Appendix F – Study Protocols

Prior to arrival at selected School

Step	Method	Notes
1	Information about the study sent to each school	Phone or email
2	Confirmation of agreement to participate in the study.	Phone
2	Negotiation with selected school around suitable day and time for data collection, discussion arranging information and consent forms being sent to the parents and collected by the school.	Phone or email
3	Photocopied parent information sheets, consent forms and demographics surveys sent to the school for distribution.	Post ***
4	Confirmation the day before with school staff.	Phone
*** One school sent out their own parent consent form prior to receiving my form 4 days later. They did use the information sheet I supplied but their own parent consent and demographic information form. When I discussed this after the fact the assistance principle felt that the parents would not related well to the AUT form.		

On arrival at a selected school

Step	Method	Notes
1	Report to the school main office	
2	Collect parental consent forms	
3	Collect class list	
4	Collect map of school or ask for a tour of the school	
5	Discuss the best way to set up room with research assistants.	
6	Setup room and assemble equipment. Standiometer Broselow-Luten Tape Scales (on heard surface) Table and chairs for children to colour in assent forms and wait. Check in table	

Beginning of each day

Step	Method	Notes
1	Assign roles to assistants (check in, assent and explanation and scribe / body habitus rater.	
2	Sort the parental consent alphabetically in classroom sets	
3	Number the consent forms sequentially with unique numbers	This became their study ID.
4	Attach a child assent form to each consent form and number with the same unique study ID on the consent form.	
5	Setup admin desk with pens, folders, hole punch, stapler	
6	Start a folder for the school to house completed consent / assent forms	
7	Setup childrens table with colouring pens for assent forms.	
8	Decide the order to call children in groups of 8	

Check in Process and Assent Process

Step	Method	Notes
1	Check in Process: Child presents to the check in desk Name and age are checked against the school roll and consent form assent form is issued (with a matching number to their consent form) Child sent to table with form for explanation of the study	
2	A group of up to 8 children assembled	
3	Child Greeted by assistant and an explanation of the process of the study given. This included: Introduction to the team (Researcher and Assistance) Explanation of rationale for study What we would like them to do How this will occur	Assistance with reading was given by a research assistant if necessary care was taken to not influence child's decision to participate.
4	Child asked to: Research assistant to read through the information and child assent sheet Child asked to read the assent form and fill in name, age, class and school. Child asked to colour in the faces on the form corresponding to their decision to participate. Yes No Maybe – I have questions	Assistance with writing and spelling was offered to children who had not yet learned to write.
5	Children able to use colouring books and paper while they wait for their turn to be weighted and measured.	Children who did not assent stayed colouring until their group was ready to go back to class.

Weighing each child

Step	**Method**	**Notes**
1	Ensure scale is flat and on a hard surface	
2	Weighing process explained to child – answer any questions the child has	
3	Scales turned on wait until they read zero	
4	Child asked to step on the scales and stand up tall	
5	Scribe records the weight in "weight 1" field	This is not said aloud so as not to stigmatise the child.
6	Child asked to step off the scale	
7	Ask child to step off the scale and wait for scale to read zero	
8	Child asked to step on the scale and stand tall	
9	Scribe records the weight in "weight 2" field	This is not said aloud so as not to stigmatise the child.
10	Ask child to step off the scale and wait for scale to read zero	
11	Child asked to step on the scale and stand tall	
12	Scribe records the weight in "weight 3" field	This is not said aloud so as not to stigmatise the child.
13	Ask child to step off the scale and wait for scale to read zero	
14	Thank the child and go on to the next measure	

Measuring Height of each child

Step	**Method**	**Notes**
1	Ensure that the stadiometer is put together properly	

	with guides against the wall for stability.	
2	Height measurement process explained to child – answer any questions the child has	
3	Child asked to step on to the stadiometer with their back to the measuring post	
4	Child asked to stand up tall. Researcher then checks that the head is level and child is standing straight.	
5	Researcher the moves the head plate to the top of the child's head and calls out the height to the scribe who puts this in the "Height 1" field	
6	Child asked to step off the stadiometer	
7	Child asked to step on to the stadiometer with their back to the measuring post	
8	Child asked to stand up tall. Researcher then checks that the head is level and child is standing straight.	
9	Researcher the moves the head plate to the top of the child's head and calls out the height to the scribe who puts this in the "Height 2" field	
10	Child asked to step off the stadiometer	
11	Child asked to step on to the stadiometer with their back to the measuring post	
12	Child asked to stand up tall. Researcher then checks that the head is level and child is standing straight.	
13	Researcher the moves the head plate to the top of the child's head and calls out the height to the scribe who puts this in the "Height 3" field	
14	Thank the child and go on to the next measure	

Broselow-Luten Tape Measure

Step	Method	Notes
1	Ensure that the Broselow-Luten Tape is laid flat on the ground	
2	Broselow-Luten Tape measurement process explained to child – answer any questions the child has	
3	Child asked to lay down flat with their head in neutral position and feet at 90 degrees (heels and toes aligned)	
4	Child asked to stay still. Researcher then checks that the head is level with the top of the Broselow-Luten Tape and adjusts if necessary.	
5	Researcher measures the Broselow-Luten weight as per tape instructions and the scribe records this in the "Broselow 1" field	
6	Child asked get up / move around and lie back down flat with their head in neutral position and feet at 90 degrees (heels and toes aligned)	
7	Child asked to stay still. Researcher then checks that the head is level with the top of the Broselow-Luten Tape and adjusts if necessary.	
8	Researcher measures the Broselow-Luten weight as per tape instructions and the scribe records this in the "Broselow 2" field	
9	Child asked get up / move around and lie back down flat with their head in neutral position and feet at 90 degrees (heels and toes aligned)	
10	Child asked to stay still. Researcher then checks that the head is level with the top of the Broselow-Luten Tape and adjusts if necessary.	
11	Researcher measures the Broselow-Luten weight as	

	per tape instructions and the scribe records this in the "Broselow 3" field	
12	Thank the child and go on to the table and choose a sticker	

Appendix G - Return Rates

The following page is a breakdown of return rates and inclusion in the study. It shows total school roll, class child is in using information collected from each school on the day of data collect.

School	Class	Consent Returned			Total School Roll			Percentages Returned			Absent		Declined		Over 10 years	Included
		Female	Male	Total	Female	Male	Total	Female	Male	Total	Female	Male	Female	Male		
Decile 5 School	1	1	3	4	12	16	28	8.33%	18.75%	14.29%					1	3
	2	7	2	9	12	15	27	58.33%	13.33%	33.33%		1				8
	3	1	0	1	5	4	9	20.00%	0.00%	11.11%	1					0
	4	0	0	0	8	8	16	0.00%	0.00%	0.00%						0
	5	1	3	4	10	14	24	10.00%	21.43%	16.67%						4
	6	3	3	6	8	11	19	37.50%	27.27%	31.58%			2			4
	7	0	1	1	4	7	11	0.00%	14.29%	9.09%		1				0
	8	1	0	1	14	12	26	7.14%	0.00%	3.85%						1
	9	2	0	2	12	5	17	16.67%	0.00%	11.76%						2
	10	2	1	3	9	18	27	22.22%	5.56%	11.11%						3
		18	13	31	94	110	204	19.15%	11.82%	15.20%	1	2	2	0	1	25
Decile 8 School	1	0	6	6	9	16	25	0.00%	37.50%	24.00%						6
	2	4	1	5	12	11	23	33.33%	9.09%	21.74%						5
	3	2	3	5	12	13	25	16.67%	23.08%	20.00%					1	4
	4	1	0	1	10	13	23	10.00%	0.00%	4.35%						1
	6	5	2	7	12	15	27	41.67%	13.33%	25.93%						7
	7	3	5	8	9	15	24	33.33%	33.33%	33.33%				2		6
	8	5	2	7	10	17	27	50.00%	11.76%	25.93%						7
	9	1	1	2	7	7	14	14.29%	14.29%	14.29%						2
	10	5	2	7	11	6	17	45.45%	33.33%	41.18%						7
	11	4	4	8	9	10	19	44.44%	40.00%	42.11%				1		7
	13	5	1	6	13	7	20	38.46%	14.29%	30.00%						6
	14	12	8	20	12	8	20	100.00%	100.00%	100.00%			1	1		18
	16	6	4	10	10	8	18	60.00%	50.00%	55.56%						10
	17	3	8	11	7	13	20	42.86%	61.54%	55.00%						11
		56	47	103	143	159	302	39.16%	29.56%	34.11%	0	0	1	4	1	97

Decile 1 Scool	1	4	4	8	10	17	27	40.00%	23.53%	29.63%					1	7
	2	3	2	5	11	15	26	27.27%	13.33%	19.23%						5
	3	5	3	8	13	15	28	38.46%	20.00%	28.57%					1	7
	4	3	6	9	5	16	21	60.00%	37.50%	42.86%						9
	5	4	1	5	13	9	22	30.77%	11.11%	22.73%						5
	6	0	2	2	7	13	20	0.00%	15.38%	10.00%						2
	7	3	5	8	13	12	25	23.08%	41.67%	32.00%					2	6
	8	0	3	3	6	14	20	0.00%	21.43%	15.00%				1		2
	9	5	2	7	10	14	24	50.00%	14.29%	29.17%				1		6
	10	2	0	2	11	14	25	18.18%	0.00%	8.00%						2
	12	8	6	14	10	14	24	80.00%	42.86%	58.33%		1		1	1	11
	13	2	6	8	7	18	25	28.57%	33.33%	32.00%						8
	14	3	0	3	10	11	21	30.00%	0.00%	14.29%			1			2
	15	0	2	2	9	9	18	0.00%	22.22%	11.11%						2
	16	2	3	5	12	14	26	16.67%	21.43%	19.23%						5
	18	0	0	0	10	16	26	0.00%	0.00%	0.00%						0
	19	1	0	1	12	13	25	8.33%	0.00%	4.00%						1
	20	2	2	4	9	12	21	22.22%	16.67%	19.05%						4
	23	5	0	5	10	11	21	50.00%	0.00%	23.81%						5
	27	5	2	7	17	10	27	29.41%	20.00%	25.93%						7
	28	1	0	1	13	10	23	7.69%	0.00%	4.35%						1
	29	0	0	0	13	5	18	0.00%	0.00%	0.00%						0
		58	49	107	231	282	513	25.11%	17.38%	20.86%	0	1	1	3	5	97
Decile 10 School	2	7	8	15	9	13	22	77.78%	61.54%	68.18%			2	2		11
	3	2	3	5	8	13	21	25.00%	23.08%	23.81%						5
	5	10	8	18	13	15	28	76.92%	53.33%	64.29%				1		17
	9	1	0	1	13	13	26	7.69%	0.00%	3.85%						1
	11	6	4	10	15	12	27	40.00%	33.33%	37.04%						10
	12	9	6	15	17	10	27	52.94%	60.00%	55.56%			2			13
	13	3	1	4	13	13	26	23.08%	7.69%	15.38%						4
	15	2	0	2	16	15	31	12.50%	0.00%	6.45%						2
	16	5	2	7	15	14	29	33.33%	14.29%	24.14%		1				6
	17	11	7	18	17	14	31	64.71%	50.00%	58.06%	1					17
	18	2	0	2	16	14	30	12.50%	0.00%	6.67%					1	1
	21	1	1	2	16	14	30	6.25%	7.14%	6.67%						2
		59	40	99	168	160	328	35.12%	25.00%	30.18%	1	1	4	3	1	89

Decile 5 School	1	7	5	12	23	4	27	30.43%	125.00%	44.44%						12
	2	7	4	11	12	13	25	58.33%	30.77%	44.00%						11
	3	12	9	21	15	18	33	80.00%	50.00%	63.64%			1	1		19
	7	6	5	11	12	9	21	50.00%	55.56%	52.38%						11
	8	4	1	5	15	14	29	26.67%	7.14%	17.24%					1	4
	9	6	5	11	15	12	27	40.00%	41.67%	40.74%						11
	10	0	0	0	14	14	28	0.00%	0.00%	0.00%						0
	11	0	1	1	17	15	32	0.00%	6.67%	3.13%					1	0
		42	30	72	123	99	222	34.15%	30.30%	32.43%	0	0	1	1	2	68