ACCURACY OF THE APLS FORMULA, THE APLS NORMAL RANGE METHOD AND THE BROSELOW PAEDIATRIC TAPE IN ESTIMATING THE BODY WEIGHT OF MALAYSIAN CHILDREN

by

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In the name of Allah, the Most Gracious and the Most Merciful

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LIST OF ABBREVIATIONS

APLS	Advance Paediatric Life Support
HUSM	Hospital Universiti Sains Malaysia
IPPT	Institut Perubatan dan Pergigian Termaju
USM	Universiti Sains Malaysia
LOA	Limits of Agreement
MPD	Mean Percentage Difference

ABSTRAK

KETEPATAN FORMULA APLS, KAEDAH JULAT NORMAL APLS DAN PITA PEDIATRIK BROSELOW DALAM MENGANGGARKAN BERAT BADAN KANAK-KANAK MALAYSIA.

Latar Belakang:

Penentuan berat badan kanak-kanak dengan segera adalah penting untuk resusitasi kerana ia membolehkan pengiraan dos ubat-ubatan, jumlah cairan yang diperlukan dan juga kadar tenaga elektrik yang diperlukan. Berat sebenar tidak begitu praktikal untuk di timbang bagi kanak-kanak yang mengalami sakit kritikal. Kajian ini bertujuan untuk membandingkan ketepatan formula APLS, kaedah jadual julat normal APLS dan pita pediatrik Broselow.

Kaedah:

Peserta dipilih dari kanak-kanak berusia dari satu hingga lima perpuluhan sembilan tahun yang hadir di Jabatan Kecemasan dan Trauma dan juga klinik susulan pediatrik di Hospital Universiti Sains Malaysia, Kelantan dan yang hadir di klinik pediatrik dan klinik umum di Institut Perubatan dan Pergigian Termaju, Pulau Pinang. Maklumat demografi dicatatkan. Berat dan tinggi setiap kanak-kanak diukur menggunakan penimbang dan pita pengukur. Anggaran berat ditentukan pada waktu yang lain menggunakan formula APLS, jadual julat normal APLS dan pita pediatrik Broselow. Hasil utama adalah ralat tidak lebih dari 10% dari berat sebenar.

Keputusan:

Seramai 464 orang kanak-kanak telah menyertai kajian ini. Seramai 239(51.5%) adalah lelaki dan 225(48.5%) adalah perempuan. Ketiga-tiga kaedah telah terlebih anggar berat

badan kanak-kanak tersebut, dengan formula APLS telah terlebih anggar bagi 64.9%, jadual APLS 61.4% dan pita Broselow 62% dari jumlah kanak-kanak tersebut. Walau bagaimanapun, pita Broselow adalah yang paling tepat dengan 33% dari kanak-kanak tersebut berat badan anggaran mereka adalah dalam ralat 10% berbanding dengan berat sebenar, diikuti oleh jadual APLS 29.5% dan juga formula APLS 26.5%. Pita Broselow telah terlebih anggar dengan purata peratusan perbezaan 14.79% (had persetujuan 95% 47.1 hingga -17.5), jadual APLS 15.32% (had persetujuan 95% 54.8 hingga -24.2) dan formula APLS 17.48% (had persetujuan 95% 59.4 hingga -24.4).

Kesimpulan:

Ketiga-tiga kaedah secara konsisten telah menganggar berat dengan berlebihan. Pita Broselow adalah yang paling tepat daripada tiga kaedah ini. Rekomendasi kumpulan APLS yang terbaru, jadual APLS adalah lebih tepat dari formula APLS.

ABSTRACT

ACCURACY OF THE APLS FORMULA, THE APLS NORMAL RANGE METHOD AND THE BROSELOW PAEDIATRIC TAPE IN ESTIMATING THE BODY WEIGHT OF MALAYSIAN CHILDREN.

Background:

Rapid establishment of children body weight is crucial for resuscitation as it enables calculation of drug doses, amount of fluid to be administered, and amount of energy to be applied. Actual weight is impractical to measure in a critically ill child. This study aims to compare the accuracy of Advanced Paediatric Life Support (APLS) formula, APLS normal range table and the Broselow Paediatric Tape.

Methods:

Participant were selected from children from one to five point nine years old attending the Accident and Emergency department and Paediatric follow up clinic in Hospital University Sains Malaysia, Kelantan, and Paediatric and general clinics in Institut Perubatan dan Pergigian Termaju, Penang. Demographic characteristics were obtained. Weight and height of each child were measured using a calibrated scale and measuring tape. Estimated weights were later determined by using the APLS formula, the APLS table and the Broselow tape. The primary outcome was the accuracy within 10% of the measured weight.

Results:

The number of children included in this study were 464. There were 239(51.5%) boys and 225(48.5%) girls. All three methods overestimated the weight of the children with the APLS formula overestimating 64.9%, the APLS table 61.4% and the Broselow tape

62% of them. However, the Broselow tape is the most accurate tool with 33% of the estimation within 10% of the actual weight, followed by the APLS table (29.5%) and the APLS formula (26.5%). The Broselow tape overestimated the weight with a mean difference of 14.79%(95% limits of agreement 47.1 to -17.5), the APLS table with 15.32%(95% limits of agreement 54.8 to -24.2) and the APLS formula with 17.48%(95% limits of agreement 59.4 to -24.4).

Conclusions:

The three methods consistently overestimated the weight. The Broselow tape appeared to be the most accurate out of them. The more recent APLS group recommendation, APLS table is more accurate than the APLS formula.

CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction and Literature Review

When it comes to resuscitating critically ill paediatric patients one of the most crucial information that need to be established early on are the patients' weight. Rapid establishment of the patients' body weight are crucial for resuscitation as it enables calculation of drug doses, amount of fluid to be administered to correct hypovolemic shock, and amount of electricity to be applied in ventricular fibrillation and other arrhythmias.

Weighing the patients on a calibrated scale is the gold standard, however, in most cases patients' present weight is not known and often a calibrated weighing scale is not within reach. The patients themselves usually are too ill to be moved for weighing. Therefore, various formulae and methods have been established to estimate their weight.

One could argue that in an emergency setting where the child is too ill to be weighed a weight estimate by either the parents or an experienced physician would be fairly accurate.

However, studies had showed conflicting evidence. One study found that weight estimate by either physician, nurses or even parents were unreliable, even in a developed country such as the United States[1]. Some other study found the opposite, in Australia, Thailand and Israel; parents seemed to estimate their child's weight more accurately[2, 3].

One of the widely used formula for weight estimation in Malaysia is the Advance Paediatric Life Support (APLS) formula. The latest iteration of the formula was published in the 5th edition of the APLS manual[4].

This is the recommended weight estimation formula by the Malaysian paediatric protocol[5]. This formula uses the child's age as a variable to calculate the estimated weight. Some concern has been raised about the applicability of the APLS formula to modern day children, with several studies finding that the APLS formula tends to underestimate weight[6].

In 2016, the APLS group published the 6th edition APLS textbook[7]. This new edition introduces the APLS normal range table for children weight estimation and is meant to replace the APLS formula as the recommended method to estimate children's weight. This table still uses the children's age as a variable to estimate their weight. As of writing, there has yet to be a study that verify this new normal range table published.

Another widely used method to estimate weight is by using the Broselow pediatric tape. This validated tape estimates weight of the supine child based on length[8, 9]. The Broselow tape also lists drug doses and equipment sizes for resuscitation[8]. By comparing the child's height against the Broselow paediatric tape, one can determine the child's estimated weight. There is increasing evidence that methods based on the length of the child are more accurate than aged-based formulae[10, 11].

Some deem this method as superior compared to the APLS formula as it eliminates the need to memorize the formula and for calculation. There has been evidence to suggest that the multiple formulae of APLS for different ages are difficult to recall and the calculations that follows may not be the most practical approach in an emergency[12]. The obvious disadvantage however, of the Broselow paediatric tape is that it is not easily available in Malaysia and rather expensive.

It is generally accepted that Asians have smaller builds compared to Caucasians and many of these formulae were not only derived in the western pediatric populations, but thereafter they were subjected to validation locally[10, 13-15] before their use in those countries[2].

The nutritional state of different children population plays a big role. For example, a study done in South Sudan found that the Broselow tape overestimates the weight of a child, which it attributed to the general state of widespread malnutrition in the area[16].

A rise in the incidence of childhood obesity put the accuracy of these methods into question. Childhood obesity is a growing problem. The World Health Organization has called it a global

pandemic and considers it to be a new chronic disease that overshadows all other pediatric diseases[17-19]. A 2013 Malaysian study found that 1/5 of Malaysian children is overweight[20].

An accurate estimation of a child's weight is important as the effectiveness of emergent intervention and development of adverse event is dependent on it. Previous studies that looked at the accuracy of these weight estimation methods and formulae in various populations showed variable accuracy.

A search of the literature performed on PubMed on September 20th 2016 by the principal investigator did not reveal any published literature on the accuracy of any of the weight estimating method or formula for Malaysian children.

It is the aim of this study to compare the APLS formula, the APLS normal range method and the Broselow paediatric tape to determine which of these formula or methods is more accurate in estimating children's weight in Malaysia.

CHAPTER 2: OBJECTIVES OF THE STUDY

2.1 General Objective

This study aims to compare the accuracy of the APLS formula, APLS normal range method and The Broselow Paediatric Tape in estimating the weight of Malaysian children.

2.2 Specific Objectives

- This study aims to measure the accuracy of the APLS formula in estimating the body weight of Malaysian children.

- This study aims to measure the accuracy of the APLS normal range method in estimating the body weight of Malaysian children.

- This study aims to measure the accuracy of the Broselow paediatric tape in estimating the body weight of Malaysian children.

- This study aims to compare the accuracy of the APLS formula, APLS normal range method and the Broselow pediatric tape in estimating children's weight in each age groups of one to five years old and in the overall group.

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CHAPTER 3: MANUSCRIPT

3.1 TITLE PAGE

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Running title

APLS FORMULA VS APLS TABLE VS BROSELOW TAPE

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3.2 ABSTRACT

Background and Aims:

Rapid establishment of children body weight is of paramount importance during resuscitation as it enables accurate calculation of drug doses, amount of fluid, and amount of current delivered during defibrillation. However, the actual weight is impractical to be measured during resuscitation of a critically ill child. This study aims to compare the accuracy of Advanced Paediatric Life Support (APLS) formula, APLS normal range table and the Broselow Paediatric Tape.

Subject and Methods:

Participant were recruited among children from one to five point nine years old who attended the Accident and Emergency department and Paediatric follow up clinic in Hospital Universiti Sains Malaysia, Kelantan, and Paediatric and general clinics in Advanced Medical and Dental Institute, Penang. Demographic characteristics were obtained. Weight and height of each child were measured using a calibrated scale and a measuring tape. Estimated weights were subsequently determined by using the APLS formula, the APLS table and the Broselow tape. The primary outcome of interest was the accuracy within 10% of the measured weight.

Results:

Four hundred and sixty four children were included in this study. There were 239(51.5%) boys and 225(48.5%) girls. All three methods overestimated the weight of the children with the APLS formula overestimating 64.9%, the APLS table 61.4% and the Broselow tape 62%. However, the Broselow tape is the most accurate with 33% of the estimation fell within 10% of the actual weight, followed by the APLS table (29.5%) and the APLS formula (26.5%). The Broselow tape overestimated the weight with a mean difference of 14.79%(95% limits of

agreement 47.1 to -17.5), the APLS table with 15.32%(95% limits of agreement 54.8 to -24.2) and the APLS formula with 17.48%(95% limits of agreement 59.4 to -24.4).

Conclusions:

All three methods consistently overestimated the children's weight. When used to calculate drug and fluid dosages, this may lead to over-resuscitation of a critically ill child. The Broselow tape appeared to be the most accurate tool among the three investigated methods.

Keywords:

APLS, Broselow, Malaysia, Paediatric, Weight

3.3 INTRODUCTION

When it comes to resuscitating critically ill paediatric patients, one of the most crucial information that needs to be established early on is the patients' weights. Rapid establishment of the patients' body weight is crucial for resuscitation as it enables the calculation of drug doses, amount of fluid to be administered to correct hypovolemic shock, and amount of energy required in defibrillating shockable cardiac rhythms.

Weighing the patients on a calibrated scale is the gold standard method of weight measurement, however, in most resuscitation scenarios, it is not practically possible to place the patient on a calibrated weighing machine. Therefore, various formulae and methods have been suggested to estimate children's weight.

One could argue that in an emergency setting where the child is too ill to be weighed, a weight estimation by either the parents or an experienced physician would be fairly accurate.

However, studies showed conflicting evidence. One study found that weight estimations by either physicians, nurses or even parents were unreliable, even in a developed country such as the United States[1]. Nevertheless, some other studies found the opposite, where in Australia, Thailand and Israel; parents seemed to estimate their child's weight more accurately[2, 3].

The most widely used formula for weight estimation in Malaysia is the Advance Paediatric Life Support (APLS) formula. The latest iteration of the formula was published in the 5th edition of the APLS manual[4]. This is the recommended weight estimation formula by the Malaysian paediatric protocol[5]. This formula uses the child's age as a variable to calculate the estimated weight. Some concerns have been raised regarding the applicability of the APLS formula on modern day children, with several studies finding that the APLS formula tends to underestimate weight[6].

In 2016, the APLS group published the 6th edition APLS textbook[7]. This new edition introduces the APLS normal range table for children's weight estimation and is meant to replace the APLS formula as the recommended method to estimate children's weight. This table still uses the children's age as a variable to estimate their weight. There has yet to be a study that verifies this new normal range table published.

Another common method to estimate children's weight is the Broselow pediatric tape. This validated tape estimates weight of a child based on height[8, 9]. The Broselow tape also lists drug doses and equipment sizes for resuscitation[8]. By comparing the child's height against the Broselow paediatric tape, one can determine the child's estimated weight. There is increasing evidence that methods which are based on the height of the child are more accurate than aged-based formulae,[10, 11].

Some, deem the Broselow paediatric tape as superior compared to the weight-estimating formulae as it eliminates the need to memorize the formula and for calculation[12]. There has been evidence suggesting the multiple formulae of APLS for different ages are difficult to be recalled and the calculations that follows may not be the most practical approach in an emergency[13].

It is generally accepted that Asians have smaller builds compared to Caucasians and many of these formulae were not only derived in the western paediatric populations, but they were also subjected to local validation[10, 14-16].

The different nutritional state of children population plays a big role in determining their weight. For example, a study done in South Sudan found that the Broselow tape overestimated the weight of a child, which it attributed to the general state of widespread malnutrition in the area[17].

Also, a rise in the incidence of childhood obesity put the accuracy of these methods into question. Childhood obesity is a growing problem. The World Health Organization has called it a global pandemic and considers it to be a new chronic disease that overshadows all other paediatric diseases[18-20]. A 2013 Malaysian study found that 1/5 of Malaysian children is overweight[21].

An accurate estimation of a child's weight is important as the effectiveness of emergent intervention and development of adverse event are dependent on it. Previous studies that studied the accuracy of these weight estimation methods and formulae in various populations showed variable accuracy.

This study aims to compare the APLS formula, the APLS normal range method and the Broselow paediatric tape to determine which of these formulae or methods is more accurate in estimating children's weight in Malaysia.

3.4 SUBJECT AND METHODS

- **Study design and setting**

  This is a cross-sectional study. Children attending the accident and emergency department, the paediatric clinic of Hospital Universiti Sains Malaysia (HUSM) Kelantan and the paediatric and general clinics in Institut Perubatan dan Pergigian Termaju (IPPT) Pulau Pinang were recruited for this study. The choice of the study area and population were made based on convenience of accessibility, and ease of getting healthy children to participate in the research.

- **Study population and sampling method**

  Children aged 1 year to 5.9 years were the target population of this study. Children who had major physical abnormality or dysmorphism, who were too ill to be weighed, who

were taller than the length of the Broselow paediatric tape (145 cm) or whose age could not be verified were excluded from this study.

- **Sample size determination**

  Sample size calculator for two dependent means was used[22]. Means and standard deviations were derived from previous study[2] which compared weights obtained using various formulae with the actual weights in a population of Nigerian children. The means ± standard deviations were 10.7 ± 1.7, 13.2 ± 1.9, 14.3 ± 2.0, 16.5 ± 2.3 and 18.5 ± 2.9 for the 1 year old to 5 years old age groups respectively. The sample size yielded was 470, inclusive of 10% rate of refusal or dropout.

- **Data collection**

  The study was conducted from April 2017 to July 2017. Once a potential participant was identified, information leaflets and consent forms were given to the parents or the legal guardian of the child. Verbal explanation and clarification regarding the study was also given to the parents or legal guardians. Upon consent, the participant's demographic data was recorded on the data-collecting sheet. The dates of birth of the children were verified using their mykid (Malaysian identification card for children) or their birth certificates. Their ages were calculated from the day the measurements were taken to the nearest year.

  The children's estimated weights using the APLS normal range method were determined by comparing their age to the APLS normal range table. Their weight estimates using the APLS formula were obtained by substituting the age into the formula.

  The children's height was measured using a measuring tape to the nearest 0.1 cm. Height measurements were taken either with the participants in standing position or in

supine position depending on their cooperativeness and ability to stand. The measured heights were compared to the Broselow paediatric tape to get the weight estimates.

Actual weights of the children were determined using a battery-powered Bayers B-16i digital scale. Weight was measured in kilograms to the nearest 0.1 kg. If the children were uncooperative or unable to stand, subtraction method, in which the weight of the child was determined by subtracting the weight of the parent or legal guardian from the combined weight of the parent or legal guardian carrying the child.

- **Data analysis**

Data was analysed using SPSS for Windows version 22.0 with the level of statistical significance set at $p = 0.05$. The children were classified into five age groups; 1 year old (1.0-1.9 years), 2 years old (2.0-2.9 years), 3 years old (3.0-3.9 years), 4 years old (4.0-4.9 years) and 5 years old (5.0-5.9 years). The estimated weights of the children were calculated by substituting their ages to the nearest year (A) into the equation of the APLS formula[4]: for ages 1-5 years old, estimated weight in kg= (2 x A) +8 and for age 6-12 years old, estimated weight in kg = (3 x A) +7.

Using the APLS normal range method the estimated weights were determined by comparing the ages to the nearest year to the APLS normal range table[7].

For the Broselow pediatric tape the estimated weights were determined by comparing height of the children taken to the nearest one decimal place(cm) to the Broselow pediatric tape.

Pairwise comparison of the measured and estimated weights by age were made using paired sample t-test.

Pearson's correlation was used to determine the relationship between the values. The closer the correlation value is to 1, the stronger the correlation is. A positive correlation indicates that the values are moving in tandem.

In order to compare the weights estimated using the different methods and formula with the measured weight, the mean percentage difference [(estimated weight minus measured weight) / measured weight x 100] and the absolute difference (estimated weight minus measured weight) were calculated.

Bland-Altman plots were displayed for each method for each age group and for overall sample, to graphically present the bias and 95% limits of agreement. The percentage differences between the estimated and measured weights were plotted on the y-axis while the average of the two were plotted on the x-axis. The dotted lines represent the limits of agreement (LOA) showing the degree of reliability while the spread of the scattered points depict the extent of agreement. For each graph, the smaller width of LOA indicates better reliability and the closer the scattered points to the line of no difference the better the agreement is. The accuracy of each weight-prediction method was assessed and defined as having a predicted weight within ± 10% of the child's actual weight.

- **Ethical consideration**

  The study protocol was reviewed and approved by the Universiti Sains Malaysia (USM) Human Research Ethics Committee, reference number USM/JEPeM/16110480. Written and/or verbal consent were obtained from the parents or appointed guardians before measurements were taken.

3.5 RESULTS

- **Characteristics of study participants**

  Four hundred and sixty-four children participated in this study. Among them 225(48.5%) were females and 239(51.5%) were males. The age distribution of the participants by gender was shown in table 1. Most of the participants were Malay (97.2%). Racial distribution is summarised in table 2.

- **Pairwise comparison of measured and estimated weight by age**

  The differences between the means of measured and estimated weights of the participants in each age groups were as shown in table 3. Weights estimated using the APLS formula, the APLS normal range method and the Broselow paediatric tape were all significantly higher than the measured weights in all the age groups including in the overall participants.

- **Relationships between height, age, measured weight with the estimated weight**

  Pearson's correlation was used to examine the relationships between height and measured weight and between age and measured weight for all the children. Both showed positive correlations, however height and actual weight showed a stronger correlation, $r= 0.80$ ($p<0.001$) compared to age and measured weight, $r= 0.69$ ($p<0.001$).

  The relationship between height and estimated weight using the Broselow paediatric tape showed positive correlation, $r=0.99$ ($p<0.001$).

  The Pearson's correlations between age and both the APLS method and APLS formula were also positive with $r=0.98$ ($p<0.001$) and $r= 0.92$ ($p<0.001$) respectively. The correlation between age and the APLS method was stronger as compared to the APLS formula.

  Looking at the correlations between the measured weights and the estimated weights using the various methods, the strongest correlation was between the measured weight and the estimated weight using the Broselow paediatric tape, $r=0.81$ ($p<0.001$), followed by the APLS method, $r=0.67$ ($p<0.001$) and the APLS formula, $r= 0.63$ ($p<0.001$).

- **Performance comparisons of estimated and measured weights**

Table 4 describes the mean percentage difference (MPD) between the measured weights and the estimated weights using the various methods for all participants and age groups of 1 to 5 years old. MPD being a measure of deviation from the measured weight, for the different methods of weight estimation, exhibited that all the methods showed overestimation of the children's weights. These methods overestimated the body weight by 11.72% and up to 23.80% depending on age groups. The MPDs for all methods across all age groups and overall participants were more than the ±10% value taken as a measure of accuracy. The Broselow paediatric showed the smallest MPDs for all participants, 14.79% (95% CI bias = -17.52 to 47.10, SD = 16.48) and in all age groups except in the 4 years old age group where the APLS method and APLS formula had the smallest MPDs, 12.32% (95% CI bias = -26.15 to 50.79, SD = 19.63). The APLS Formula and APLS method MPDs were identical for age groups of 2, 3 and 4 years old. In the age groups of 1 year old, 5 years old, and overall participants the APLS method had lower MPDs compared to the APLS formula.

- **Precision of the estimated weights**

The accuracy of each weight-prediction method was defined as having a predicted weight within ± 10% of the child's measured weight. Precision was determined by calculating the proportion of children estimated within ± 10% of their body weight. In the 1 year old age group, the APLS method was the most precise, estimating 33.3% of the children within 10% of the measured weight compared to the Broselow paediatric tape, 31.9% and the APLS formula 23.6%.

Meanwhile, in the age groups of 2, 3 and 4 years old, the Broselow paediatric tape was the most precise, estimating 34.8%, 39.3% and 29.5% of the children respectively

within 10% of the measured weight. The APLS method and APLS formula were identical, estimating 28.7%, 30.4% and 26.1% of the children in these age groups within 10% of the measured weight.

In the 5 years old age group, the APLS method once again was the most precise as it estimated 29.9% of the children in this age groups within 10% of the measured weights, followed by the Broselow paediatric tape, 26% and the APLS formula 20.8%.

Overall, the Broselow paediatric tape appeared to be the most precise as it estimated 33% of the children within 10% of their measured weight, followed by the APLS method ,29.5% and the APLS formula 26.5%.

- **Agreements between measured and estimated weights**

Bland-Altman plots for assessing the agreement of weights obtained using the different methods with measured weights were displayed in figures 1 to 18. The solid line at 0 represent the line of agreement (line of no difference). The dotted line at the centre represents the mean percentage difference and the dotted line above and below represents the upper and lower limits of agreement (LOA).

Figure 1 to 15 displayed the Bland-Altman plot for children aged 1, 2, 3, 4 and 5 years old and figure 16 to 18 represent the Bland-Altman plots for the overall children for the APLS method, APLS formula and the Broselow paediatric tape.

Observation that can be made from the figures was that most of the scattered points for all methods appeared to be above the line of no difference, suggesting that these methods tended to overestimate the weights of children in all age groups and as a whole. The number of scattered points outside of the LOA were similar for all age groups and all methods.

With the exception for 4 years old age group, the Broselow paediatric tape consistently demonstrated the smallest mean percentage difference compared to the APLS method and APLS formula. The Broselow paediatric tape consistently have the narrowest LOA for all age groups and overall children.

The Bland-Altman plots for APLS method and APLS formula for the 2, 3 and 4 years old age groups were identical. For age groups 1 and 5 years old, the APLS method appeared to demonstrate smaller mean percentage differences and narrower LOA compared to the APLS formula.

It is of note that more points were on the line of no difference in the Bland-Altman plots for the Broselow paediatric tape in all groups and in the all of the children. This suggested that the Broselow paediatric tape had a better agreement between the estimated and measured weight compared to the other two methods.

3.6 DISCUSSION

The study has shown that the three common methods of body weight estimation in Malaysian children were not very precise nor accurate. The only thing that was consistent with these methods was their tendency to overestimate the weights of the children.

This maybe explained by the fact that these weight-estimating methods were derived and validated in western children population. Studies has shown that there are significant differences in children's body weight and composition in different population[23, 24], with Asians having smaller build compared to Caucasians.

The overestimation was clearly demonstrated in the Bland-Altman plots figure 1 to 18, where most of the plots were above the line of no difference. The Bland-Atman plots also suggested that the Broselow paediatric tape is the most accurate out of the three methods as it consistently demonstrate the narrowest limit of agreement in each age group and as a whole. More points

were plotted on the line of agreement in the Bland-Altman plots for Broselow paediatric tape compared to the other two methods.

The mean percentage difference of weights in age groups of 1 to 5 years old and the overall group for all weight estimation methods were significantly above the set accuracy limit of ±10% of the measured weight. All in all, the Broselow tape was the most accurate method overall with a mean percentage difference of 14.79%, followed by the APLS method with 15.32% and then 17.48% for the APLS formula.

Looking at each age groups, the Broselow paediatric tape consistently displayed the lowest mean percentage difference, except in the 4 years old age group. This is the age group where both the APLS method and APLS formula showed the highest level of accuracy, sharing a mean percentage difference of 12.32% compared to the Broselow paediatric tape with 15.5%. The Broselow paediatric tape was most accurate in the 5 years old age group with a mean percentage difference of 11.72%.

On the whole, the Broselow paediatric tape was the most precise, estimating 33% of the children within 10% of their measured weight, followed by the APLS method with 29.5% and the APLS formula with 26.5%.

Looking at each age groups however, the APLS method was the most precise in 1 year old and 5 years old age group, estimating 33.3% and 29.9% of the children respectively within 10% of the measured weight. Consistently, the APLS formula was the least accurate and precise out of all these three methods.

There was no literature as to why there were differences in precision of the weight estimates in different age groups, however it was postulated that the difference may be due to the different growth rates in each age group.

Height and measured weight showed a stronger positive correlation, r= 0.80 ($p<0.001$) compared to age and measured weight, r= 0.69 ($p<0.001$). This suggests that height is the better variable in estimating weight.

All methods of weight estimation showed significant($p<0.001$) strong positive correlation with the measured weight. The Broselow paediatric tape with r= 0.805, the APLS method with r= 0.665 and the APLS formula with r= 0.625. The Broselow paediatric tape showed the strongest correlation to the measured weight out of the three.

The use of the APLS formula to calculate weight in children is a very popular. The Malaysian paediatric protocol also recommend using it for the purpose body weight estimation in children [5].

The APLS normal range table was introduced in 2016 in the latest APLS manual. It was meant to be an update for the APLS formula which was recommended in the previous edition of the manual. At of the time of writing, there has yet been a study that validates the APLS table for weight estimation in any population. Comparing it to the APLS formula, the APLS table is meant to be a quicker method as it eliminates the need for doing any calculation. It was also meant to be more accurate as it was based on the latest available data derived from western children.

However, the APLS table mostly differs from the APLS formula in the estimation of children aged less than 2 years old and more than 6 years old. For children in the age groups between 2 to 5 years old, the APLS table weight estimates were the same as the APLS formula's.

The Broselow paediatric tape was a great advancement in standardizing paediatric resuscitation since its introduction. It reduced the amount of memorization, estimation and calculations needed during critical emergency situations. It is also compact, easy to carry and to deploy.