Research Article   Open Access

Comparison of Actual and Estimated Body Weight Using Mid Upper Arm Circumference, Broselow Tape and Advanced Pediatric Life Support (APLS) Formula Among Children Age 1 to 12 Years Old

Ana Kristina Lizo Garcia* and **Rebecca Abiog Castro**

Department of Pediatrics, University of Santo Tomas Hospital, Philippines

*Corresponding author: Ana Kristina Lizo Garcia, Department of Pediatrics, University of Santo Tomas Hospital, Manila, Metro Manila 1800, Philippines, Tel: 6329228830464; E-mail: tingarciamd@gmail.com

Abstract

Background: Medications and fluids used among pediatric patients are computed based on weight. The Broselow tape and the Advanced Pediatric Life Support (APLS) formula are currently being used to predict the actual weight, however, studies have shown that when used on patients of different ethnicity and varying body mass index (BMI), it over/underestimates the weight. Studies done among Chinese and Indian children as well as elderly patients made use of a formula using Mid Upper Arm Circumference (MUAC): (MUAC-10) × 3 to predict weight. As of this time, there is no published literature on methods for approximating weight among Filipino children.

Objectives: This study aims to determine which of the methods can be used among Filipino children aged 1 to12 years old to predict the weight.

Methodology: Patients seen at University of Santo Tomas Outpatient Department were weighed using a mechanical beam scale, length determined using Broselow Tape and the MUAC using a standard tape measure and recorded.

Results: Three hundred sixty participants were included and grouped according to sex, age and BMI. The results showed that the three methods had a positive correlation and were comparable to the actual weight. Of the three methods tested, MUAC had the strongest independent relationship, and seen to be more accurate and precise compared to Broselow and APLS formula.

Conclusions: Any of previously mentioned methods may be used among Filipino children age 1 to 12 years old, with the MUAC formula being the most accurate and precise in estimating weight. Another advantage of using the MUAC formula is its reproducibility, since the material used for measurement is readily available and that it is easy to do.

Keywords: Weight estimation; Broselow

Abbreviations:

APLS: Advanced Pediatric Life Support; MUAC: Mid Upper Arm Circumference

Introduction

Medications, intravenous fluids, even equipment sizes (endotracheal tube etc.) used on pediatric patients are computed based on weight. Ideally all pediatric patients should be weighed; however, this may not be possible at all times, as in cases of emergency, trauma etc. With this, different methods have been used to estimate weight, each with its own advantage and disadvantages.

One of the most widely used method would be the Broselow-Luten color coded tape designed to estimate the body weight, medication doses and endotracheal tube sizes based on body length among children aged 1 to 12 years old [1,2]. This method was discussed in the American Heart Association Pediatric Advanced Life Support courses and widely used in the United States as well as in European countries. However, recent studies show that it may underestimate weight among obese children [2,3]. Another disadvantage of this method is that it sometimes underestimates the weight when used among children of different race and ethnicity since Broselow Tape was developed on the basis of the 50th percentile or ideal body weight of the pediatric population in the United States [4].

Another method used to predict the weight is the Advanced Pediatric Life Support Formula or the APLS formula. The formula would differ depending on the age group the patient belongs to:

Years old: weight in kg=2 × AGE+8

6-12 years old: weight in kg=3 × AGE+7

As with length based estimation tools, body habitus is also not considered [5-7]. This kind of estimating tool may have variable results on patients who are on extremes of nutritional status (undernourished or obese).

Because of these limitations, we are always finding better ways to estimate weight. One of the most commonly proposed method is by

making use of the mid upper arm circumference (MUAC). The mid upper arm circumference is already being used as a screening tool to determine nutritional assessment, especially for monitoring of improvement among malnourished children. Because of its correlation to weight, a study has been done among elderly patients, made use the mid upper arm circumference and generated a formula that can be used to estimate the weight. The formula of

Weight=(MUAC-10) × 3 to estimate weight

Was also tested using the pediatric population in a hospital in India and China, and results showed that it can be an alternative method to estimate weight.

As of now, there has been no published literature on available methods for estimating weight among Filipino children.

Review of Related Literature

In pediatrics, determination of weight is important since most medications and fluids would require weight for appropriate dosage. However, as previously mentioned, this may not be done at all times. Different styles have been used each with its strengths and weaknesses. Since Broselow was derived using the Western population, they are more likely to overestimate weight when applied to a population of a developing country like India [8]. Recent studies have shown that Broselow is only accurate to only 48.9% [6]. Aside from having inconsistencies among varying ethnicities and body compositions, the Broselow Tape has its limitations, one of which would be when a patient exceeds the length of the tape.

The APLS formula is a well-known method of estimating weight using age. Several studies have showed that this method tends to underestimate the actual weight and the margin of error increases with age. Another limitation of this method is that it uses different formula depending on the patient's age [5,6]. Since body habitus is not a factor, there may be an overestimation o underestimation of estimated weight of children who are underweight, overweight or obese [9].

Lastly, the MUAC has long be used as a screening tool or indicator for undernourishment or malnutrition [5,10]. Because of this, it has been proposed that it has a direct correlation with actual weight, with the patients BMI as an important factor in estimation. This method has already been used in some parts of Asia, both developed and developing countries, particularly in China and India, as well as among geriatric patients who have difficulty in ambulating [11].

Objectives

General:

To compare the actual weight of children age 1 to 12 years old to the estimated weight using mid upper arm circumference, Broselow Tape and APLS Formula.

Specific:

To determine patient characteristics as follows:

1. Demographic data-age and sex.
2. Anthropometric measurements-weight, height, body mass index.

To compare the 3 methods in terms of the accuracy and precision in estimating weight.

Method

Study design

This is a prospective, cross-sectional study conducted at the Pediatrics Outpatient Department of the University of Santo Tomas Hospital, Clinical Division.

Inclusion criteria

Filipino children aged 1 to 12 years old seen at Pediatrics Outpatient Department of the University of Santo Tomas Hospital Clinical Division who gave their informed consent was included in the study.

Exclusion criteria

1. Children with height of >145 cm.
2. Children with weight >55 kg.
3. With apparent upper limb deformities.
4. Children >2 years old who cannot stand upright.

Withdrawal criteria

As participation was entirely voluntary, the parents were free to withdraw from the study at any time.

Procedures

All subjects who met the inclusion criteria took part in the study. Patient information sheet which includes basic information such as patient's name, age and gender was answered by the relative or primary caregiver. The patients' actual weight was taken using a calibrated mechanical beam scale (Detecto®) for children ≥ 2 years old, and for those <2 years old, an infant weighing scale (Detecto®). The patients were weighed wearing nothing but light clothing and no foot wear. Results are rounded off to nearest 0.2 kg. Length was measured using the Broselow Tape and the MUAC was measured using a standard measuring tape, with the child's left arm relaxed in a 90 degree angle, the midpoint between the acromion and olecranon will be marked, and the tape wrapped around the arm, making sure that the tape lies flat against the skin. Results were rounded off to the nearest 0.1 cm.

Statistical analysis

Statistical analysis was performed using SPSS (version 21; SPSS Inc., Chicago, IL USA) software considering 95% confidence interval in demographic data analyses. The demographic profile of patients and the significant difference between the actual weight and the estimated body weight using mid upper arm circumference, Broselow tape and APLS formula, were displayed using cross tabulation and Chi square test. Pearson's correlation coefficients were calculated for the three variables (age, height and mid upper arm circumference) and a logistic regression analysis was performed to determine which of these variables have the strongest independent relationship. Comparison of different methods in terms of accuracy and precision was reflected by the using Bland Altman plot.

Results

Three hundred sixty (360) respondents were included in the study and grouped according to age, sex and BMI. The collected data on gender and BMI were cross tabulated in terms of age and was

computed and presented in chi-square, frequency and percentage. The data presented in Table 1 showed that 53% (192) are males while the remaining 37% (168) are females with a gender ratio of approximately 1:1. The gender of the respondents was equally distributed in all age groups except in the 10 years old group. Moreover, the chi-square value of 7.50 and p-value of 0.757 was not statistically significant. This result implied that the frequency of male and female were comparable when grouped according to age. The BMI was interpreted based on z-scores.

According to the collected data, there were 120 children (33%) who had normal BMI. From remaining 240 respondents, ninety four (26%) respondents were classified as wasted, eighty four (23%) respondent were overweight, twenty four (7%) respondents were severely wasted and thirty eight (11%) respondents were obese. However, the distribution of BMI p-value was 0.821, thus, BMI classification was not significant based on age group.

Description	Frequency Age (years)													X2-value	p-value	Remarks
	1	2	3	4	5	6	7	8	9	10	11	12	Total			
Gender																
Female	16	13	12	16	15	14	17	14	16	9	14	12	168 (47%)	7.50	0.757	Not Significant
Male	14	17	18	14	15	16	13	16	14	21	16	8	192 (53%)			
BMI																
SW	2	1	2	2	3	4	0	1	1	4	2	2	24 (7%)	35.34	0.821	Not Significant
W	8	9	8	8	5	6	10	9	9	6	8	8	94 (26%)			
N	10	10	10	10	10	10	10	10	10	10	10	10	120 (33%)			
OW	5	3	4	8	9	6	8	8	6	7	10	10	84 (23%)			
O	5	7	6	2	3	4	2	2	4	3	0	0	38 (11%)			
BMI: Body Mass Index; SW: Severely Wasted; W: Wasted; N: Normal; OW: Overweight; O: Obese																

Table 1: Cross tabulation of demographic profile.

Description	Mean ± SD	r-value	p-value p=0.05	Remarks
Actual weight*	23.88 ± 11.84	0.821	0.000	Significant
Broselow predicted weight	22.15 ± 8.25			
Actual weight*	23.88 ± 11.84	0.977	0.000	Significant
MUAC predicted weight	23.93 ± 11.76			
Actual weight*	23.88 ± 11.84	0.728	0.000	Significant
APLS predicted weight	25.67 ± 11.04			

Table 2: Correlation between actual weight and broselow, MUAC and APLS.

The correlation between each method and actual weight was assessed and the results were summarized in Table 2. The average of actual weight was greater than the average of Broselow weight which implies that the predicted Broselow weight was underestimated. Contrary, the average actual weight was less than MUAC and APLS predicted weight, thus, the two methods were overestimated. It was clear from the results that there is a strong positive correlation between the three methods and the actual weight (Broselow, r =0.821; MUAC, r=0.977; APLS, r=0.728) of the three methods presented, the predicted weight determined by MUAC has the highest r-value and implicated the strongest relationship among paired variables.

Description	Beta	t-value	p-value p=0.05	Remarks	R2 value	Sig.F change	Remarks
Constant	-0.995	-2.704	0.007	Significant	0.960	0.000	Significant
Broselow	0.135	2.627	0.009	Significant			
MUAC	0.897	49.227	0.000	Significant			
APLS	0.017	0.526	0.600	Not Significant			

Table 3: Linear regression of broselow, MUAC and APLS predicted weights.

Table 3 illustrates the most important predictors among the three methods in predicting weights of children age 1 to 12 years old. The logistic regression analysis revealed that MUAC predicted weight (t-value=49.227; p=0.000) and Broselow predicted weight (t-value=2.627; p=0.009) were the significant variables compared to actual weight. The APLS predicted weight showed no significant difference with p-value of 0.600. The predictor analysis showed that constant and MUAC were the primary predictors with Beta values of -0.995 and 0.897, respectively. This result implied that MUAC has the strongest independent relationships with the actual weight.

	Description	Mean ± SD	Mean difference	r-value	p-value p=0.05	Remarks
Below normal weight	Actual weight *	17.67 ± 6.44	-4.36	0.987	0.000	Significant
	Broselow predicted weight	22.03 ± 8.33				
	Actual weight*	17.67 ± 6.44	-0.24	0.940	0.000	Significant
	MUAC predicted weight	17.91 ± 6.86				
	Actual weight*	17.67 ± 6.44	-8.13	0.941	0.000	Significant
	APLS predicted weight	25.80 ± 11.11				
Normal weight	Actual weight*	20.82 ± 8.25	-0.28	0.965	0.000	Significant
	Broselow predicted weight	21.10 ± 7.69				
	Actual weight*	20.82 ± 8.25	0.35	0.982	0.000	Significant
	MUAC predicted weight	20.47 ± 8.18				
	Actual weight*	20.82 ± 8.25	-4.85	0.908	0.000	Significant
	APLS predicted weight	25.67 ± 11.07				
Above normal weight	Actual weight*	32.91 ± 13.40	9.60	0.970	0.000	Significant
	Broselow predicted weight	23.31 ± 8.62				
	Actual weight*	32.91 ± 13.40	-0.24	0.970	0.000	Significant
	MUAC predicted weight	33.15 ± 12.90				
	Actual weight*	32.91 ± 13.40	7.37	0.931	0.000	Significant
	APLS predicted weight	25.54 ± 11.02				
Combined	Actual weight*	23.88 ± 11.84	1.73	0.821	0.000	Significant
	Broselow predicted weight	22.15 ± 8.25				
	Actual weight*	23.88 ± 11.84	-0.05	0.977	0.000	Significant
	MUAC predicted weight	23.93 ± 11.76				
	Actual weight*	23.88 ± 11.84	-1.79	0.728	0.000	Significant
	APLS predicted weight	25.67 ± 11.04				

Table 4: Correlation betwee actual weight and broselow, MUAC and APLS in terms of below normal weight, normal weight and above normal weight.

Methods	Limit of Agreement				Difference between Methods	
	Lower	CL 95%	Upper	CL 95%	Mean Difference	SD Bias
Actual weight* Broselow weight	-11.11	-13.11 to -10.65	15.28	14.11 to 16.56	1.73	6.91
Actual weight* MUAC weight	-4.97	-5.44 to -4.55	4.87	4.45 to 5.34	-0.05	2.51
Actual weight* APLS weight	-18.38	-19.95 to -16.95	14.81	13.38 to 16.39	-1.78	8.46

Table 5: Bland-Altman comparison of broselow, MUAD and APLS predicted weights.

Table 4 illustrates the correlation between the weight of different methods and actual weight across different BMI. MUAC has the smallest mean difference as compared to the different methods when compared among different BMI. From this we can say that it has the closest approximation of predicted weight from the actual.

Table 5 describes the Bland-Altman plot statistics for the Broselow, MUAC and APLS estimated weight compared to actual weights of the patients. The MUAC weight estimation differed from actual weight by -0.05, (95% CI, -4.97 to 4.87), Broselow weight estimation, on average, by 1.73 (95% CI, -11.11 to 15.28) and APLS weight estimation, on average, by -1.78 (95% CI, -18.38 to 14.81). The MUAC got the smallest mean difference and showed the closer range in terms of limit of agreement. A positive average was noted between Broselow and actual weight while negative average bias for MUAC and APLS. The results indicated that Broselow methods was overestimated over actual weight and underestimated for MUAC and APLS method. The better SD bias was shown on MUAC (2.51) followed by Broselow (6.91) and APLS (8.46).

Discussion

Estimation methods are often based on age (example: APLS formula) or height (Broselow Tape). In the Philippine setting, rapid pediatric weight estimation methods among children 1 to 12 years of age in the emergency setting have not been evaluated. This study included three hundred sixty (360) respondents grouped by thirty based on age group from 1 to 12 years old. The gender of the respondents was equally distributed in all age groups with almost 1:1 ratio and statistically comparable when grouped according to age. BMI classification was also significantly comparable based on age group.

All methods of weight estimation had a strong positive relationship with measured weight (Pearson's correlation r=0.728-0.977), with the MUAC method having a very strong positive relationship (r=0.977). Subsequently, all of the methods showed statistically significant result

thus comparable to actual weight. Generally, the derived weight-estimation formula based on mid-arm circumference: weight=(MAC-10) × 3 outperformed the Broselow tape and the APLS age-based formula. In similar study, Carroll found a strong linear correlation of weight with MAC r-value of 0.91 less than the r-value of the present study with r-value of 0.977.

The predictor analysis showed that constant and MUAC were the primary predictors which imply that MUAC method has the strongest independent relationship with the actual weight.

The mean differences of Broselow, MUAC and APLS method compared to actual weight were 1.73, -0.05 and -1.78, respectively. The MUAC got the smallest mean difference followed by Broselow and APLS method. This is similar to study of Cattermole which showed that MUAC is superior to the Broselow tape, subsequently, Broselow tape was better than APLS method [12].

Weight-estimation tools for emergency situations should be both simple and reliable. Reliability involves both accuracy and precision. Accuracy is a measure of the average deviation of an estimation rule from reality, and reflected by the Bland Altman bias12. Based on Bland-Altman plot analysis (Figure 1), it displayed the difference of means between predicted weights of three methods and actual weight. Figure 1B revealed that MUAC has the smallest SD bias and has consistent variability compared to other methods. This implicates that MUAC has the most accurate estimates of weight compared to the other methods.

Precision on the other hand, is a measure of the scatter, and is reflected by the limits of agreement. The limits of agreement of MUAC, Broselow, and APLS were 95% CI, -4.97 to 4.87, 95% CI, -11.11 to 15.28 and 95% CI, -18.38 to 14.81, respectively. The MUAC showed the closer range in terms of limit of agreement which entails that of the three methods; it is the most precise in predicting weight. Generally, the actual weight correlates more strongly with MUAC than with Broselow and APLS predicted weight to children age 1 to 12 years old.
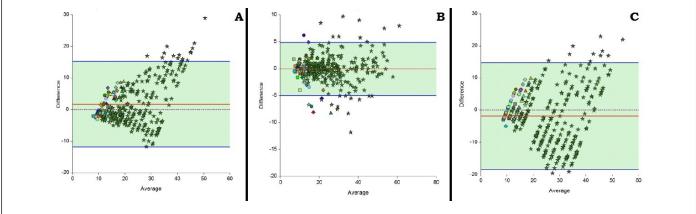

Figure 1: Bland-Altman plot analysis; **A.** Method 1: Actual weight, Method 2: Broselow weight; **B.** Method 1: Actual weight, Method 2: MUAC weight; **C.** Actual weight, Method 2: APLS weight.

Conclusion and Recommendations

In conclusion, all three of the weight estimation methods have a positive correlation to actual weight and are comparable in predicting weight among Filipino children aged 1 to 12 years old. MUAC proves to have the strongest relationship and correlation to weight as compared to other methods. Based on results stated above, it also

proves to be the most accurate and precise in predicting the weight regardless of BMI. This method is not only reliable, but because it only makes use of a measuring tape, it is readily available and easy to use.

This study only included children seen at the Outpatient Department of Pediatrics, at the University of Santo Tomas and is relatively of good health. A population that includes the critically ill

may be of significance, as well as including children age 13 years old and above.

Acknowledgement

References

1. Hofer CK, Ganter M, Tucci M, Klaghofer R, Zollinger A (2002) How reliable is length-based determination of body weight and tracheal tube size in the pediatric age group? The Broselow reconsidered. Br J Anaesth 88: 283-285.

2. Rosenberg M, Greenberger S, Rawal A, Latimer-Pierson J, Thundiyil J (2011) Comparison of Broselow tape measurements versus physician estimations of pediatric weights. Am J Emerg Med 29: 482-488.

3. Argall JA, Wright N, Mackway-Jones K, Jackson R (2003) A comparison of two commonly used methods of weight estimation. Arch Dis Child 88: 789-790.

4. Jang H, Shin S, Ho Kwak Y (2007) Can the Broselow tape be used to estimate weight and endotracheal tube size in Korean children? Acad Emerg Med 14: 489-491.

5. Abdel-Rahman S, Ridge A, Kearns G (2014) Estimation of body weight in children in the absence of scales: a necessary measurement to insure accurate drug dosing. Arch Dis Child 99: 570-574.

6. Graves L, Chayen G, Peat J, O'Leary F (2014) A comparison of actual to estimated weights in Australian children attending a tertiary children's hospital, using the original and updated APLS, Luscombe and Owens, best Guess formulae and the Broselow tape. Resuscitation 85: 392-396.

7. Luscombe M, Owens B (2007) Weight estimation in resuscitation: Is the current formula still valid? Arch Dis Child 92: 412-415.

8. Ramarajan N, Krishnamoorthi R, Strehlow M, Quinn J, Mahadevan SV (2008) Internationalizing the Broselow Tape: How reliable is weight estimation in Indian children. Acad Emerg Med 15: 431-436.

9. Luscombe M, Owens B (2007) Weight estimation in resuscitation: Is the current formula still valid? Arch Dis Child 92: 412-415.

10. Bern C, Nathanail L (1995) Is mid upper arm circumference a useful tool for screening in emergency settings? The Lancet 345: 631-633.

11. Jung MY, Chan MS, Chow VS, Chan YT, Leung PF, et al. (2004) Estimating geriatric patient's body weight using the knee height caliper and mid-arm circumference in Hong Kong Chinese. Asia Pac J Clin Nutr 13: 261-264.

12. Cattermole GN, Leung PY, Mak PS, Graham CA, Rainer TH (2010) Mid-arm circumference can be used to estimate children's weights. Resuscitation 81: 1105-1110.