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A Study to Assess the Accuracy of Emergency Weight Estimation Methods in Children at a Tertiary Care Hospital

Dr Rajat Basavaraj Gadagi[1], Dr Nikitha Raj S N[2], Dr Premalatha R[3]

[1] Junior Resident, Department of Pediatrics, MVJMC & RH, Bengaluru rural, Karnataka.
[2] Assistant Professor, Department of Pediatrics, MVJMC & RH, Bengaluru rural, Karnataka.
[3] Professor, Department of Pediatrics, MVJMC & RH, Bengaluru rural, Karnataka.

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Corresponding Author:

Dr Rajat Basavaraj Gadagi
Junior Resident, Department of Pediatrics, MVJMC & RH, Bengaluru rural, Karnataka.

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ABSTRACT

Background: Accurate weight estimation is vital in pediatric emergency care, as most medications and resuscitation interventions are weight based. When direct weighing is not feasible, reliable weight estimation tools become essential.
Objective: To assess and compare the accuracy of Broselow pediatric emergency tape, Indian Pediatric Weight Estimation Tool (IPWET), PAWPER XL-on-a-page tape, and the Mercy method in estimating pediatric weight.
Methods: An observational study was conducted among children attending the department of pediatrics of a tertiary care hospital. Actual weight measured using a calibrated weighing scale was considered the reference standard. Estimated weights obtained using Broselow pediatric emergency tape, IPWET, PAWPER XL-on-a-page tape & Mercy method were compared with actual weight. Statistical analysis included paired t-test, Pearson's correlation, and Bland–Altman analysis.
Results: All four methods demonstrated strong positive correlation with actual weight. Broselow tape and IPWET showed the closest agreement with actual weight and the least variability, indicating better accuracy and precision. PAWPER XL-on-a-page tape demonstrated minimal bias but comparatively greater variability. The Mercy method showed a tendency towards underestimation and comparatively lower agreement. No significant difference was observed between actual weight and estimates obtained using Broselow pediatric emergency tape, IPWET & PAWPER XL-on-a-page tape.
Conclusion: Broselow pediatric emergency tape and IPWET were the most reliable pediatric weight estimation methods in the present study population and may improve the safety and accuracy of pediatric emergency management. These findings support the use of context appropriate pediatric weight estimation tools to optimize emergency drug dosing, fluid administration, and resuscitation practices.

Keywords: *Pediatric emergency care, Weight estimation, Broselow pediatric emergency tape, Indian Pediatric Weight Estimation Tool, PAWPER XL-on-a-page tape, Mercy method.*

INTRODUCTION

Accurate weight estimation in pediatric emergencies is a critical determinant of safe and effective clinical care, as it directly influences therapeutic interventions and ultimately, patient outcomes. Nearly all life-saving measures, including drug dosing, fluid resuscitation, equipment selection, and defibrillation energy, are weight-dependent, making timely and precise weight determination vital in emergencies [1]. However, in critically ill children, actual weight is often unknown, and measurement becomes impractical and unwise due to time constraints, hemodynamic instability, ongoing resuscitation, and the risk of delaying critical interventions.

Healthcare staff's subjective weight estimations are misleading, and so are parental weight estimations. Currently available formulae to predict weight based on age or anthropometric measures lack global accuracy and fail to account for variations

in body habitus, particularly in obese individuals [1]. Furthermore, most commonly used estimation methods are length-based and are unsuitable for children with special needs. As these children are undernourished and often have severe joint contractures or neurological defects, resulting in diverse morphologies, body types, and compromised traits [2]. Hence, these inaccuracies in weight estimation in diverse group of children often lead to erroneous medication doses, resulting in sub-therapeutic or supra-therapeutic levels. Therefore, a reliable, quick, precise, and valid weight estimate is crucial for managing pediatric emergencies.

The challenge is further amplified in the Indian context, where a unique "dual burden of malnutrition" exists. This is characterized by the simultaneous presence of undernutrition and an increasing prevalence of childhood overweight and obesity. This heterogeneity in body composition significantly restricts the applicability of weight estimation tools developed for homogeneous populations. The most commonly used weight estimation systems are "one-dimensional," which fail because a single variable cannot adequately account for the biological variability of weight-for-age and weight-for-length. More promising and accurate methods are the "two-dimensional" systems, which incorporate two variables in the estimation process, such as length (or a surrogate like humerus length) and habitus (or a surrogate like mid-arm circumference). In emergency situations, healthcare providers may also need to employ multiple approaches to weight estimation, and these should be evidence-based alternatives [3].

Several methods, including Broselow pediatric emergency tape, Indian Pediatric Weight Estimation Tool (IPWET), Pediatric Advanced Weight Prediction in the Emergency Room Tape extra-long (PAWPER XL-on-a-page) and Mercy method have been proposed and validated across different settings. However, their comparative accuracy in Indian children remains inadequately explored, particularly in real-world tertiary care environments. The Broselow pediatric emergency tape often overestimates weight in malnourished Indian children, risking over-resuscitation and dosing errors [1]. To address this, the IPWET improves accuracy by aligning weight ranges with Broselow colour zones, addressing the overestimation often found in Indian children weighing over 10 kg [4]. Because of the non-linear relationship between weight and age or length, two-dimensional approaches like PAWPER XL and the Mercy method tend to offer better precision. The PAWPER XL tape, though effective, is not commercially distributed, limiting international access. In contrast, the PAWPER XL-on-a-page option provides downloadable, printable sheets that allow users to assemble their own tapes, providing a near-accurate and cost-effective weight estimation system [5]. Meanwhile, the Mercy method can be applied in Indian children without any modification, making it versatile and extending its use beyond Western populations [6].

The present study aims to systematically compare the accuracy of Broselow pediatric emergency tape, IPWET, PAWPER XL-on-a-page, and the Mercy method in estimating pediatric weights in a tertiary care hospital. By identifying the most reliable approach for emergency use, the research aims to support evidence-based decision-making, enhance clinical protocols, and improve the safety and effectiveness of pediatric emergency care, particularly in settings where timely and precise weight assessment is crucial.

AIMS & OBJECTIVES

1. To evaluate the accuracy of emergency weight estimation methods—Broselow pediatric emergency tape, IPWET, PAWPER XL-on-a-page, and Mercy method—in children aged 1 month to 12 years presenting to a tertiary care hospital.
2. To compare the accuracy of Broselow pediatric emergency tape, IPWET, PAWPER XL-on-a-page, and Mercy method in estimating weight with the actual measured weight in children aged 1 month to 12 years.

METHODOLOGY

A cross-sectional observational study was conducted at the Department of Pediatrics, MVJMC & RH, a tertiary care hospital, over a period of 18 months. Children aged 1 month to 12 years of either gender presenting to the hospital were consecutively enrolled. Eligible participants included apparently healthy children attending the outpatient department for consultation, follow-up, or immunization. Children with known or apparent limb deformities, length <46 cm, height >146 cm, or weight >36 kg (beyond Broselow tape limits), as well as those who were severely malnourished, dehydrated, acutely ill, or requiring emergency care, were excluded. Children with underlying pathological conditions or on medications affecting body composition (e.g., chronic diseases, steroid therapy, immunosuppressants, nephrotic syndrome, tuberculosis) were also excluded.

The sample size was calculated at a 5% level of significance with 80% power to detect a mean difference of 5 kg between estimated and actual weights [7]. Using the formula, $N = \{ 2SD^2 (Z_{\alpha/2} + Z_\beta)^2 \} / d^2$ the sample size was estimated to be 87 children per colour zone. Since the chart comprises nine colour zones, the total sample size calculated was 783 children. Therefore, a total of 800 children were included in the study. The study was conducted after obtaining approval from the Institutional Ethics Committee of MVJMC & RH, Hoskote, Bengaluru Rural District (Ref. No. IEC-54/2024). Informed written consent was obtained from parents or legal guardians before enrolment.

Data collection began with a detailed case pro-forma. This pro-forma was used to gather demographic data, clinical history, a head-to-toe examination, and anthropometric measurements from each participant. A calibrated standard weighing scale was used to measure the actual body weight of each child as the reference value. Calibrated digital baby weighing scale with an accuracy of 0.1 kg were used for infants and younger children, while digital standing weighing scales were used for older children. Children were weighed wearing light clothing, and heavy outer clothing and shoes were removed before measurement. Trained personnel performed the weight measurements to ensure accuracy and consistency. This measured weight served as the gold standard for comparing all estimated weights.

For each child, several other anthropometric parameters were recorded as per the various weight estimation methods. The PAWPER XL-on-a-page method required additional measurements, including a visual assessment of the child's body habitus and scoring using the habitus score system, which ranged from HS1 (Thin) to HS7 (Severely obese). HS2 indicated Lean, HS3 represented Optimum, HS4 signified Slightly overweight, HS5 stood for Overweight, and HS6 represented Obese [5]. Similarly, the Mercy method also involved extra measurements, where the humeral length was measured from the upper edge of the posterior border of the acromion process down the posterior surface of the arm to the tip of the olecranon process, with the arm positioned at the child's side and the elbow flexed at 90 degrees. Using a non-stretchable measuring tape, the mid-upper arm circumference was then measured at the midpoint of the humeral length, and all measurements were recorded in centimeters with one decimal place precision [7].

Weight estimation for each child was done using four methods: Broselow pediatric emergency tape, IPWET, PAWPER XL-on-a-page, and the Mercy method. All measurements and estimations followed standard techniques for each tool.

Broselow pediatric emergency method: The child was supine on a flat examination bed. The Broselow tape was placed beside the child, with the red end at the crown. Two pieces of cardboard held the tape taut against the child's length. One was perpendicular to the tape at the crown, and the other at the heel. The predicted weight for the heel's crossing of the tape was read from the tape and recorded. The colour zone was also documented [8].

IPWET: The child's length was measured using the same technique as the Broselow pediatric emergency method. A remodeled Broselow tape for the Indian population (IPWET) with colour zones adjusted to a new height range of 50–150 cm and weight range of 4–36 kg was used to estimate the child's weight. The measured height was then used to identify the appropriate colour zone on the IPWET and the corresponding estimated weight was recorded [4].

PAWPER-XL-on-a-page Method: The child's length was measured using the PAWPER-XL-on-a-page tape. Then, their body habitus was visually assessed and scored using the habitus score system, guided by reference images. The ideal body weight was determined and adjusted based on the child's habitus score, which ranged from HS1 to HS7 [5].

Mercy Method: The two anthropometric measurements, humeral length and mid-arm circumference, were measured. Using the Mercy method chart of partial weights, a "partial weight" value was obtained for each anthropometric measurement. Adding these two values gave the total body weight estimate, recorded as the Mercy method estimated weight.

Statistical analysis: Data were entered into a structured database and analyzed using appropriate statistical software. Continuous variables were summarized as mean (standard deviation) or median (interquartile range), and categorical variables as frequencies and percentages. Estimated weights obtained by each method were compared with actual measured weight. Accuracy was assessed using Bland–Altman analysis to determine mean bias and limits of agreement. Paired samples t-test was used to compare mean differences between estimated and actual weights, and Pearson correlation coefficient was used to assess the strength of association. A p-value of <0.05 was considered statistically significant.

RESULTS

The study included 800 children aged 1 month to 12 years, of whom 412 (51.5%) were male and 388 (48.5%) were female. The majority of children were aged 2–5 years (42.1%), followed by 5–10 years (38.5%). With respect to body habitus, 64.6% of children had normal body habitus, while 34.4% were overweight

Table 1: Descriptive statistics of Actual and Estimated weight across methods

Weight estimation method	Mean (kg)	Standard Deviation	Minimum (kg)	Maximum (kg)
Broselow Pediatric Emergency Tape	0.024	0.963	-2.60	3.10
IPWET	-0.001	1.143	-3.80	3.60
PAWPER XL-on-a-page Tape	-0.010	1.454	-5.00	4.90
Mercy Method	-0.413	1.052	-4.00	2.40

Table 1 summarizes the performance of the four weight estimation methods. IPWET and the Broselow pediatric emergency tape demonstrated mean differences closest to zero with relatively lower standard deviations, indicating superior accuracy

and consistency. The Mercy method showed a negative mean difference, indicating underestimation, whereas PAWPER XL tape, despite minimal bias, exhibited greater variability.

Table 2: Paired t-test comparison between Estimated and Actual weight

Weight estimation method	Mean difference (kg)	t- value	p- value	95% CI Lower	95% CI Upper
Broselow Pediatric Emergency Tape	0.024	-0.690	0.490	-0.090	0.043
IPWET	-0.001	0.025	0.980	-0.078	0.080
PAWPER XL-on-a-page Tape	-0.010	0.185	0.853	-0.091	0.110
Mercy Method	-0.413	11.112	0.000***	0.340	0.486

Paired t-test analysis (Table 2) showed no statistically significant difference between estimated and actual weights for the Broselow pediatric emergency tape (p=0.490), IPWET (p=0.980), and PAWPER XL tape (p=0.853), indicating absence of systematic bias and good clinical reliability. In contrast, the Mercy method demonstrated a statistically significant difference (p<0.001), with a mean underestimation of 0.413 kg.

Table 3: Pearson correlation between Estimated and Actual weight

Weight estimation method	Correlation Coefficient (r)	p-value	Interpretation
Broselow Pediatric Emergency Tape	0.988	< 0.001***	Very Strong
IPWET	0.983	< 0.001***	Very Strong
PAWPER XL-on-a-page Tape	0.973	< 0.001***	Very Strong
Mercy Method	0.985	< 0.001***	Very Strong

Pearson correlation analysis (Table 3) revealed strong positive relationships between actual weight and all four estimation methods. The correlation coefficients ranged from 0.973 to 0.988, all with p-values less than 0. 001.The Broselow pediatric emergency tape showed the strongest correlation, followed by the Mercy method, IPWET, and the PAWPER XL tape. These excellent correlations (r>0.97) confirm the validity of all four methods as pediatric weight estimation tools.

Table 4: Accuracy and Bland-Altman Agreement analysis of weight estimation methods

Weight estimation method	Upper LOA (kg)	Lower LOA (kg)	Agreement Range (kg)	PW10 (%)	PW20 (%)
Broselow Pediatric Emergency Tape	1.91	-1.85	3.76	100	100
IPWET	2.22	-2.23	4.45	92.3	98.7
PAWPER XL-on-a-page Tape	2.83	-2.85	5.68	82.8	98.2
Mercy Method	1.645	-2.471	4.116	92.5	97.2

The proportion of estimates within 10% (PW10) and 20% (PW20) of actual weight is shown in Table 2. Broselow pediatric emergency tape achieved 100% accuracy for both PW10 and PW20. IPWET and the Mercy method also showed high accuracy (92.3%/98.7% and 92.5%/97.2%, respectively), while PAWPER XL demonstrated a lower PW10 (82.8%) but a high PW20 (98.2%).

Bland–Altman analysis (Table 4, Figure 1) showed the narrowest limits of agreement (LOA) for the Broselow pediatric emergency tape, followed by IPWET, indicating better agreement with actual weight. The Mercy method demonstrated moderate LOA with negative bias, while PAWPER XL showed the widest LOA reflecting lower reliability. On graphical assessment, Bland–Altman plots for Broselow pediatric emergency tape and IPWET showed clustering of differences around the mean with relatively uniform spread across the measurement range. The Mercy method demonstrated a downward shift of differences, consistent with underestimation, while PAWPER XL showed wider scatter, indicating increased variability without a clear systematic trend.

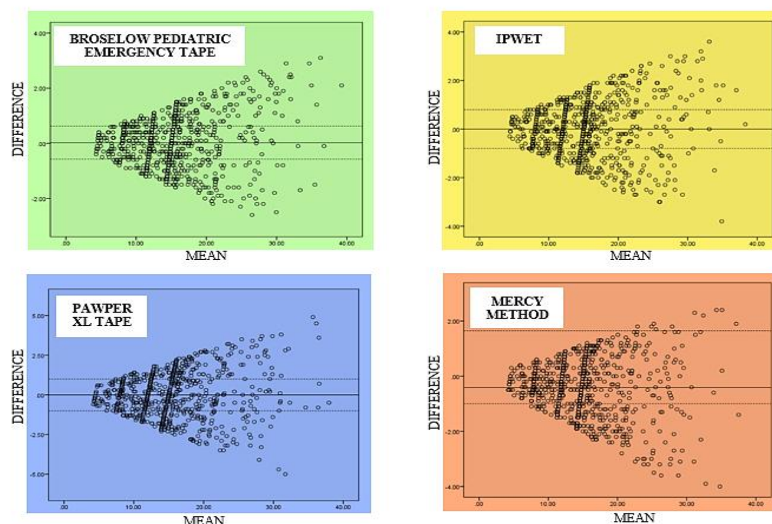

Figure 1: Bland- Altman Plots of all four weight estimation methods

DISCUSSION

This study evaluated four commonly used pediatric weight estimation methods in a large cohort of 800 children aged 1 month to 12 years. The study population was balanced in terms of gender and predominantly comprised children aged 2–10 years, reflecting the age group most frequently encountered in pediatric emergency settings. Notably, 34.4% of children were overweight, highlighting the growing dual burden of malnutrition in Indian children. Inclusion of children across a range of body habitus enhances the applicability of the findings, as anthropometric variation is known to influence the accuracy of weight estimation methods [9].

Accurate weight estimation is critical in pediatric emergency care, as most interventions are weight-based. In the present study, all four methods demonstrated excellent correlation with actual weight (r=0.973–0.988), confirming their overall validity. However, differences in agreement, bias, and precision were observed, highlighting that correlation alone does not necessarily imply clinical accuracy. Bland–Altman analysis therefore provided a more robust assessment of agreement than correlation or PW10/PW20 metrics alone. Despite inclusion of overweight children, Broselow tape and IPWET maintained good agreement and reliability in the present study. Overall, Broselow tape and IPWET demonstrated superior agreement and consistency, supporting the importance of population-specific validation in Indian emergency settings.

The Broselow tape demonstrated the best overall performance in the present study, with negligible bias (+0.024 kg), narrow limits of agreement, and the strongest correlation with actual weight (r=0.988), indicating excellent reliability. In contrast, several published studies have reported only moderate accuracy. Singh TK et al. [10] reported an overall PW10 of 61.2% for the Broselow tape, which dropped significantly to 9.8% in overweight children. In contrast, Shrestha et al. [7] reported PW10 and PW20 values of 63.2% and 91.5%, respectively. Similarly, Asskaryar et al. [4] observed overestimation of weight by the original Broselow tape in Indian children, leading to the development of IPWET. Meta-analyses by Wells et al. also showed modest Broselow performance, with a PW10 value of 55.6% and a PW20 value of 81.2% [3]. In comparison, the present study demonstrated substantially higher accuracy, with PW10 and PW20 of 100%, possibly due to exclusion of children with extreme anthropometric variations and the predominance of children with normal body habitus.

IPWET demonstrated excellent performance in the present study, with near-zero bias, low variability, and narrow limits of agreement, closely paralleling the Broselow tape. These findings are comparable to those reported by Asskaryar et al.,[4] who developed IPWET after observing that the original Broselow tape consistently overestimated weight in Indian children by 5–15%. In their study, the modified Indian Pediatric Weight Estimation Tool improved accuracy across Broselow colour zones and showed better agreement with actual weight in Indian children. The findings of the present study further support the usefulness of population-specific modifications such as IPWET in improving the reliability of pediatric weight estimation in Indian settings.

The PAWPER XL tape demonstrated minimal bias and strong correlation with actual weight in the present study, with no statistically significant difference from actual weight. However, it showed wider limits of agreement, indicating greater variability in individual estimates. Previous studies by Singh TK et al.,[10] Cosmos Yakubu et al.,[11] and Shrestha et al. [7] have reported high PW10 and PW20 accuracy for PAWPER XL, often outperforming the Broselow tape. Meta-analyses by Wells et al. also demonstrated consistently high accuracy across diverse populations. In contrast, the greater variability observed in the present study may be related to subjective habitus assessment and anthropometric differences in Indian children.

The Mercy method demonstrated a statistically significant underestimation in the present study, despite showing strong correlation with actual weight. Similar findings were reported by Shrestha et al.,[7] who observed lower accuracy of the Mercy method compared with PAWPER XL. In contrast, Dicko et al. [12] reported high accuracy of the Mercy method across diverse populations. Studies by Singh TK [10] et al. and Cosmos Yakubu et al. [11] also demonstrated good PW10 and PW20 values, although performance varied across populations. The underestimation observed in the present study may be related to anthropometric differences and variability in mid-arm circumference and humeral length measurements in Indian children.

Overall, this study shows that Broselow pediatric emergency tape, IPWET, and PAWPER XL-on-a-page tape are reliable methods for Pediatric weight estimation methods. They have good agreement with actual body weight, while the Mercy method was less accurate in the studied group. These findings support using accurate, population-appropriate weight estimation tools to improve emergency drug dosing, resuscitation safety, and overall pediatric patient care.

Strengths: This study evaluated multiple commonly used pediatrics weight estimation methods in a large cohort of children across a wide pediatric age range. Standardized anthropometric measurements and direct comparison with actual weight improved the reliability of the findings.

Limitations: Being a single-center study, the findings may not be generalizable to all populations. Subgroup analysis based on nutritional status and age categories was limited, and inter-observer variability was not assessed.

CONCLUSION

In the present study, Broselow pediatric emergency tape and IPWET emerged as the most reliable methods for estimating a child's weight. While PAWPER XL-on-a-page tape exhibited greater variation, the Mercy method tended to underestimate weight. Overall, Broselow pediatric emergency tape and IPWET provided the best balance of accuracy, precision, and agreement with actual weight.

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