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ORIGINAL ARTICLE

Weight estimation in two groups of Ghanaian children with chronic diseases using Broselow, Mercy, PAWPER XL and PAWPER XL-MAC tapes

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ABSTRACT

Introduction: The performance of various weight estimation methods in children with sickle cell disease (SCD) and heart disease (HD) has not been studied. We aimed to determine and compare the accuracies of the Broselow, Mercy, PAWPER XL and PAWPER XL-MAC tapes in Ghanaian children with no known chronic diseases (controls), SCD and HD.

Methods: We prospectively recruited 631 children (199 with HD, 209 SCD and 223 controls) from the Komfo Anokye Teaching Hospital (KATH). Their weights were estimated using the Broselow, Mercy, PAWPER XL and PAWPER XL-MAC tapes. These estimated weights were compared to measured weight using mean percentage error (MPE), the proportion of weight estimates within ±10% (P10) and ±20% (P20) of measured weight. Bland-Altman limits of agreement (LOA) were determined to assess the precision of weight estimation and agreement with measured weight.

Results: The PAWPER XL, Mercy and PAWPER XL-MAC were the most accurate in all groups of children studied. All methods except the Broselow tape (BT), which performed best in the control group, had their best performance among children with SCD with negligible critical error rates (proportion of children with weight estimates > 20% of their actual weight). The P20 in the various groups of children using the BT were 88.36%, 80.21% and 51.10% respectively in the control, SCD and HD groups. The Mercy, PAWPER XL and PAWPER XL MAC tapes were generally above 90% in all groups.

Discussion: The Mercy, PAWPER XL and PAWPER XL-MAC tapes performed significantly better than the BT in all groups of children studied. These methods of weight estimation performed best in children with SCD with very little critical error.

Introduction

It is sometimes necessary to base pediatric drug dose calculation and other medical interventions on an estimate of a child's weight when time, safety or logistics will not allow for the usual weighing of the child on a scale [1]. These weight estimates may be based on age [2,3], length [4], mid-arm circumference (MAC) [5] or a combination of length and habitus [6,7]. The most commonly used methods of weight estimation are age-based rules and the Broselow tape (BT) [8]. These methods overestimate the weight of children in low- and middle-income countries (LMICs) [9].

Newer methods of weight estimation using both length, or a surrogate such as humeral length, and a measure of body habitus (referred to as the 2 dimensional or 2D methods) have been shown to perform better than age-based and BT weight estimates in both low and high-income countries [10,11]. Most studies on weight estimation in the West African subregion have been conducted in children without chronic disease [12–14]. Sickle cell disease (SCD) affects up to 3% of newborn children in parts of Africa [15]. In Ghana, approximately 2% of newborns have SCD [16], while close to 1% of newborns globally are estimated to have congenital heart disease (CHD) [17]. These two groups of children form a significant proportion of children with underlying chronic diseases seen at our emergency. In 2021, 84 out of 2419 children (3.5%) presenting to the pediatric emergency center of the Komfo Anokye Teaching Hospital (KATH) were children with SCD. SCD is also the number one condition seen at our specialist outpatient clinics with cardiac diseases being the fifth (2021 Performance Review, KATH).

Children with SCD present with many acute complications including vaso-occlusive crises, acute chest syndrome and cerebrovascular accident, whilst children with heart disease are frequently admitted to the

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emergency center with cardiac failure and hypoxia making weighing on a scale inappropriate and potentially unsafe.

It is very important that when estimated weights are used in the computation of drug doses and fluid volumes, the most accurate method available is used to ensure correct resuscitation is performed [18]. Excessive fluid therapy can be problematic as it has been shown to result in poorer outcomes in children with septic shock in resource-poor settings [19].

No study in Ghana has looked specifically at the performance of the various weight estimation methods in children with SCD and HD. Children with SCD and HD may have abnormalities in their growth, development and nutritional state compared to other children without these chronic ailments [19,20] and so methods of weight estimation developed using data from normal healthy children like those from the World Health Organization (WHO) and the National Health and Nutrition Examination Survey (NHANES) may perform differently in these children. The original validation study of the BT intimated that the accuracy of the BT for patients with chronic cardiac and neurologic disorders did not significantly differ from that for healthy, acutely ill children [4]. It is, however, unclear if the study was powered enough to detect such a difference. A study of weight estimation in children with Down syndrome has shown that the accuracy of the Mercy method was low in children with the condition when compared to unaffected children [21].

This study seeks to determine and compare the accuracies of the 2017 BT, Mercy, Paediatric Advanced Weight Prediction in the Emergency Room Extra Large, Extra Long (PAWPER XL) and PAWPER XL-Mid Arm Circumference (MAC) tapes in children with SCD, HD and without any known chronic disease. We hypothesised that the weight estimation methods would perform better in children with no chronic disease compared to children with SCD and HD.

Methods

A cross-sectional study was conducted at KATH in Kumasi, the capital of the Ashanti region. It is the second largest hospital in Ghana with a total bed capacity of 1200 and a pediatric bed capacity of approximately 237 [22]. The Directorate of Child Health offers both inpatient and out-patient clinics, with 11 specialist outpatient clinics [23] which attend to children up to the age of 13 years.

We recruited 631 children from various units (209 with SCD, 199 with heart disease, and 223 without chronic disease). The sample size was determined using an assumed difference in the proportion of weight estimates within 20% of measured weight (P20) of 10%. Thus, to determine the sample size for P20 of 90% and 80%, a significance level of 0.05 and a power of 80%, a sample size for a McNemar test of at least 211 was required for each of the three groups of children. Recruitment was done to ensure equal representation of children from each age bracket.

Children were recruited from the pediatric outpatient department (OPD) and the main wards after obtaining written informed consent from the parents of the children. Ethical approval for the study was obtained from the KATH Institutional Review Board (KATH IRB/AP/126/20).

Age and gender were taken in completed years and months and weight was estimated using the BT, PAWPER XL, PAWPER XL-MAC tapes and the Mercy tape. In determining weight with the BT, the child lay supine on a bed and the tape was placed alongside the child from the crown of the head to the heel of the foot. The weight at the same horizontal level as the heel was taken as the BT estimated weight. The PAWPER XL tape was used similarly and placed from the crown of the head to the heel and the location of the tape at the heel was noted. Each child with their upper clothing removed was assigned a habitus score between 1 and 7 using figural reference images supplied with the tape and the appropriate estimated weight read from the tape at the assigned habitus score. The mid-upper-arm circumference (MUAC) of the child was then taken with the child seated or standing with the arm hanging by his/her side using the tape measure at the initial segment of the PAWPER XL-MAC tape or a vinyl tape measure. Using this MUAC the appropriate weight estimate from the PAWPER XL-MAC tape was read.

The 2D Mercy tape was then used to estimate weight by first placing the humeral length side of the tape from the edge of the acromion to the tip of the olecranon process to determine the humeral length fractional weight estimate. The mid-portion of the upper arm between the acromion and the olecranon process was then determined and the MUAC portion of the mercy tape was placed around the arm to determine the MUAC fractional weight estimate. These two fractional weight estimates were added up to give the Mercy Tape estimated weight. It was ensured that each weight estimate was determined independently without considering the results of the other methods and the actual weight of the child was unknown to the estimator.

Data were collected from November 2020 to December 2021. Data were entered into a case report form and subsequently entered into a database created using EpiData 4.4.2 (EpiData Association, Odense, Denmark). The complete dataset was exported to R statistical software version 4.03 [24] for further cleaning and analysis. Continuous numerical variables were summarised and presented as their mean and standard deviations when normally distributed and as their median and interquartile ranges when not. Categorical variables were presented as counts and percentages/proportions. To assess the performance of the various weight estimation methods the proportion of weight estimated by each method within ±10% (P10) and ±20% (P20) of the children's weight was determined. As a measure of bias/trueness, the weight differences between estimated weight and measured weight were determined and expressed as a percentage of the measured weight of the children (measured weight – estimated weight/measured weight X 100) and the average was determined as the mean percentage error (MPE). Bland-Altman limits of agreement (LOA) were determined as a measure of the precision of each method and to assess agreement between the weight estimates by the various methods and the scale-measured weights.

To compare the P10 and P20 of the various weight estimation methods, pairwise comparisons between the methods were done using the McNemar test with *p*-values corrected for multiple comparison using Holm's method. Furthermore, after stratifying the weight estimation methods, a pairwise proportion test was done for the P10 and P20 for the various disease conditions. The generated *p*-values were also corrected for multiple comparison using Holm's method. For all analyses, a *p*-value of <0.05 was considered statistically significant.

Results

We recruited 631 children. The characteristics of the children are shown in Table 1. The three groups differed significantly when categorised by weight, body mass index (BMI) and habitus categories with those in the HD group having a greater proportion of children in the lowest BMI and habitus categories. All the methods of weight estimation had their worst performance in this group with the BT being the least accurate. The BT predicted the weight of only half of the children with cardiac disease within 20% of their actual weight while the Mercy, PAWPER XL and PAWPER XL-MAC tapes predicted 90.95%, 92.46% and 92.96% respectively of the children's weight within 20% of their actual weight. The PAWPER XL-MAC and PAWPER XL tapes were the most precise methods as demonstrated by their narrow LOAs (Table 2). All the methods of weight estimation performed better in children with SCD and the control group compared to those with HD (supplementary Table 2). Some of these differences remained when children were divided into comparable habitus and BMI categories (supplementary Tables 3 and 4).

The 2D methods of weight estimation had high levels of accuracy in children with SCD, each estimating more than three-quarters of the children's weight within ±10% and almost all within ±20% of their actual weight. The BT had a P10 of 50.00% and a P20 of 80.21% among these children. Again, the PAWPER XL and PAWPER XL-MAC tapes had

Table 1
Descriptive analysis of the study participants.

	Control	Cardiac	SCD	Total	*p*-value
Total	223	199	209	631	
Categorised ages					0.183
< 1year	21 (9.4)	20 (10.1)	11 (5.3)	52 (8.2)	
1 to 5 years	74 (33.2)	68 (34.2)	61 (29.2)	203 (32.2)	
6 to 13years	128 (57.4)	111 (55.8)	137 (65.6)	376 (59.6)	
Gender of patient					0.387
Female	101 (45.3)	94 (47.2)	85 (40.7)	280 (44.4)	
Male	122 (54.7)	105 (52.8)	124 (59.3)	351 (55.6)	
Categorised weight					< 0.001
<10kgs	31 (13.9)	49 (24.6)	17 (8.1)	97 (15.4)	
10–25kgs	104 (46.6)	104 (52.3)	122 (58.4)	330 (52.3)	
>25kgs	88 (39.5)	46 (23.1)	70 (33.5)	204 (32.3)	
Categorised BMI					< 0.001
BMI < 5th percentile	13 (7.1)	69 (44.8)	33 (17.8)	115 (22)	
BMI 5th to 85th centile	126 (68.9)	80 (51.9)	144 (77.8)	350 (67)	
BMI > 85th percentile	44 (24)	5 (3.2)	8 (4.3)	57 (10.9)	
Categorised habitus score					< 0.001
<3	106 (47.5)	171 (85.9)	158 (75.6)	435 (68.9)	
3	70 (31.4)	21 (10.6)	41 (19.6)	132 (20.9)	
>3	47 (21.1)	7 (3.5)	10 (4.8)	64 (10.1)	

BMI – Body mass index.

Table 2
Distribution of accuracy estimates for the various estimation methods.

	Broselow (95%CI)	Mercy (95%CI)	Pawper XL (95%CI)	PawperXL-MAC (95%CI)
Control				
p10	59.26 (51.89, 66.34)	79.82 (73.94, 84.89)	80.27 (74.43, 85.28)	78.92(72.98, 84.09)
p20	88.36 (82.91, 92.56)	94.62 (90.79, 97.19)	96.41 (93.05, 98.44)	96.41 (93.05, 98.44)
MPE	3.92 (2.15, 5.70)	0.34 (−0.91, 1.59)	−0.75 (−1.84, 0.33)	1.47 (0.34, 2.60)
B(LoA)	3.12 (−20.81, 27.05)	−0.08 (−17.88, 17.71)	−1.10 (−17.28, 15.08)	1.10 (−15.32, 17.52)
Heart Disease				
p10	21.43 (15.70, 28.11)	65.83 (58.79, 72.39)	64.82 (57.75, 71.44)	67.34 (60.35, 73.80)
p20	51.10 (43.59, 58.57)	90.95 (86.08, 94.55)	92.46 (87.87, 95.72)	92.96 (88.48, 96.10)
MPE	18.30 (16.30, 20.29)	1.96 (0.13, 3.79)	5.21 (3.85, 6.58)	5.81 (4.56, 7.06)
Bias (LoA)	16.03 (−7.24, 39.30)	1.17 (−22.51, 24.84)	4.64 (−13.65, 22.94)	5.28 (−11.14, 21.71)
Sickle Cell Disease				
p10	50.00 (42.72, 57.28)	81.82 (75.91, 86.80)	87.56 (82.31, 91.71)	85.65 (80.15, 90.10)
p20	80.21 (73.86, 85.60)	99.52 (97.36, 99.99)	100.00 (98.25,100.00)	98.56 (95.86, 99.70)
MPE	10.33 (8.74, 11.92)	−2.16 (−3.19, −1.13)	−0.98 (−1.85, −0.12)	0.47 (−0.51, 1.44)
Bias (LoA)	9.29 (−10.46, 29.04)	−2.47 (−17.28, 12.35)	−1.19 (−13.69, 11.30)	0.22 (−13.61, 14.05)

Bias (LoA) – Bland-Altman Bias (lower and upper limits of agreement), MPE – Mean Percentage Error.

narrow LOAs while the BT and Mercy tapes had wide LOA (Table 2). The accuracy of the BT was greatest in the group of children without any chronic disease. The most precise method in this group was the PAWPER XL tape (Table 2).

Discussion

The main theme of this study is that the 2D methods of weight estimation were highly accurate among Ghanaian children with SCD and those without any chronic disease. The BT achieved lower levels of accuracy in all groups of children studied. The Mercy, PAWPER XL and PAWPER XL-MAC tapes had comparable performance but all performed significantly better than the BT in all groups of children studied (supplementary Table 1).

The BT has dominated weight estimation studies for the past three decades and is regarded as the gold standard length-based weight estimation tool [6]. Weight estimates are based on only length. By relying solely on length, it is not possible to adjust weight according to the build/habitus of a child. Thus, the weight estimates for an averagely built child, a thin child and an obese child would be the same. For this reason, the BT has been found to perform badly in populations with children who differ in any significant way from the average. It is therefore not surprising that the BT performed best in the control group. The performance of the BT among control and SCD children was significantly better than its performance in children with HD (Supplementary Table 2).

The BT performance is worse in children with cardiac disease who happen to be the most undernourished group. The findings in this study agree with those of a study in South Sudan which demonstrated that the more undernourished a population of children the greater the degree of overestimation of weight by the BT [25].

A study by Neiman et al. [18] in the USA suggested that the use of the BT can lead to the under-resuscitation of children because of its tendency to underestimate the weight of children in the first world. The developers of the BT have defended its continued use in the developed world by explaining that the BT was designed to predict ideal body weight which is probably adequate for drug dosing for most emergency medications. This may not apply in circumstances where ideal body weight exceeds actual weight such as in the undernourished. The developers of the BT further argue that since malnourished children are less frequently encountered in the USA and other developed countries it is still appropriate to use this device in those settings [26]. In low- and middle-income countries, however, where rates of undernutrition are high the continued use of the BT has been questioned. Some authors have suggested that underestimation of weight is probably potentially less dangerous than overestimation of weight [27]. When a child is underdosed it is possible to titrate the dose upwards to achieve a response but there is no mechanism for taking back an already administered dose of medication to avoid toxicity in the event of an overdose. The findings from this study show that the BT overestimates the weight of Ghanaian children, with an MPE ranging from 3.92% in controls to 10.33% and 18.3% in children with SCD and cardiac disease. A previous study in Ghana assessing the accuracy of the BT in a setting with considerably higher rates of undernutrition than in the current study showed that the BT was able to estimate 47.5% of the children's weight within 10% error and 82% within 20%, with MPE of 9.42% among children who had no chronic disease [12]. Clinicians who use this device in Ghana and similar countries should beware of its tendency to overestimate weight.

The Mercy tape performed well in all groups of children studied with its best performance in children with SCD and worst performance in those with HD. It had significantly better P10 in the control and SCD groups than in the HD group (Supplementary Table 2). We hypothesised that the various weight estimation methods would have lower degrees of accuracy in children with SCD because of findings in other studies that have demonstrated growth failure and undernutrition in children with SCD compared to those without SCD. It is apparent in this study that the Mercy tape performs better in children who are moderately underweight and not severely so, as demonstrated by its very good performance in children with SCD and bad performance in children with HD who were the most severely underweight. The performance of the Mercy tape is comparable to its performance in other studies [6,28,29].

Almost all children with SCD had their weights estimated by the Mercy tape within 20% of their actual weight. These represent the later generation of the PAWPER system of tapes [7]. These tapes have achieved some of the highest accuracies in many studies [30,31], a finding replicated in this study. The PAWPER XL tape had the highest P10 in all groups of children studied, closely followed by the PAWPER XL-MAC. The highest P10 was in children with SCD. The reason for this may be that it was easier to assign the correct body habitus to children with SCD who were moderately undernourished. Studies have shown that it is easier to identify the undernourished than it is to identify the overweight and obese. While 20.3% of control subjects were assigned habitus scores > 3, only 4.8% of SCD patients were assigned habitus scores > 3 and while 22.4% of controls had BMI > 85th percentile only 4.3% of children with SCD had BMI > 85th percentile. It is more difficult to assign correct habitus scores in overweight and obese populations as shown by the poor performance of the PAWPER tape in studies conducted among obese children in the USA [32,33]. The comparative accuracies of these tapes in the three groups of children mirror those of the Mercy tape (Supplementary Table 2).

An ideal weight estimation method should be accurate, easy to use across a wide range of ages, heights and body habitus, inexpensive and with a minimal tendency for error. It remains to be determined objectively what the desired level of accuracy of a weight estimation method should be. Wells et al. [11] have suggested a benchmark accuracy of 70% for P10 and 95% for P20 while Manirafasha et al. [34] have suggested that a P20 of 69% or better should be accepted in regions where more accurate methods are unavailable. The Mercy, PAWPER XL and PAWPER XL-MAC tapes meet the accuracy recommendations of Wells et al. in all the groups of children studied except in children with HD. It is our opinion that weight estimation should be taught comprehensively in medical education and as part of courses such as the Advanced Paediatric Life Support Course (APLS) so healthcare workers are able to choose the most accurate method to use, among available choices, while efforts are taken to ensure the availability of the current best methods.

The Mercy, PAWPER XL and PAWPER XL-MAC tapes were the most accurate in all groups of children studied with the best accuracies seen in children with SCD and the worst accuracies in children with cardiac disease. These tapes should be studied further and adopted for use in our setting.

Our study was not without limitations including no formal inter- and intraobserver reliability in the use of the various methods carried out. Also, the intended number of children to be recruited in children with HD and SCD was not attained. Only the 2017 edition of the BT was used in this study. Older versions of the tape have been shown to be more accurate than newer versions of the BT. Older versions of the BT may, however, not be available.

Dissemination of results

The results of this study were presented as an abstract at the Paediatric Society of Ghana Annual General and Scientific Meeting in February 2022.

Authors' contributions

R.C.Y. conceptualized the study, collected data and wrote the initail draft as well as reviewing the final article for important intellectual content. S.B.N. was involved in conceptualization of the study, data collection, performed the statistical analysis and reviewed the article for important intellectual content. V.P. was involved in study conceptualization, drafting the initial manuscript and critically reviewing it for important intellectual content.

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Declaration of Competing Interest

The authors have no conflicts of interest to declare concerning this publication.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.afjem.2023.04.003.

References

[1] Abdel-Rahman SM, Ridge A, Kearns GL. Estimation of body weight in children in the absence of scales: a necessary measurement to insure accurate drug dosing. Arch Dis Child 2014;99:570–4. doi:10.1136/archdischild-2013-305211.
[2] ALS Group Advanced paediatric life support: the practical approach. John Wiley & Sons; 2011.
[3] Argall JAW. A comparison of two commonly used methods of weight estimation. Arch Dis Child 2003;88:789–90. doi:10.1136/adc.88.9.789.
[4] Lubitz DS, Seidel JS, Chameides L, Luten RC, Zaritsky AL, Campbell FW. A rapid method for estimating weight and resuscitation drug dosages from length in the pediatric age group. Ann Emerg Med 1988;17:576–81. doi:10.1016/S0196-0644(88)80396-2.
[5] Cattermole GN, Leung PYM, Mak PSK, Graham CA, Rainer TH. Mid-arm circumference can be used to estimate children's weights. Resuscitation 2010;81:1105–10. doi:10.1016/j.resuscitation.2010.05.015.
[6] Abdel-Rahman SM, Paul IM, James LP, Lewandowski A. Evaluation of the Mercy TAPE: performance against the standard for pediatric weight estimation. Ann Emerg Med 2013;62:332–339.e6. doi:10.1016/j.annemergmed.2013.02.021.
[7] Wells M, Coovadia A, Kramer E, Goldstein L. The PAWPER tape: a new concept tape-based device that increases the accuracy of weight estimation in children through the inclusion of a modifier based on body habitus. Resuscitation 2013;84:227–32. doi:10.1016/j.resuscitation.2012.05.028.
[8] Young KD, Korotzer NC. Weight estimation methods in children: a systematic review. Ann Emerg Med 2016;68:441–451.e10. doi:10.1016/j.annemergmed.2016.02.043.
[9] Wells M, Goldstein LN, Bentley A. A systematic review and meta-analysis of the accuracy of weight estimation systems used in paediatric emergency care in developing countries. Afr J Emerg Med 2017;7:S36–54. doi:10.1016/j.afjem.2017.06.001.
[10] Wells M., Goldstein L.N. How and why paediatric weight estimation systems fail - a body composition study. Cureus n.d.;12. https://doi.org/10.7759/cureus.7198.
[11] Wells M, Goldstein LN, Bentley A. The accuracy of emergency weight estimation systems in children—a systematic review and meta-analysis. Int J Emerg Med 2017;10. doi:10.1186/s12245-017-0156-5.
[12] Yakubu RC, Nguah SB, Ayi-bisah N. Comparison of paediatric weight estimation methods at a tertiary hospital in Ghana. Afr J Emerg Med 2021;11:252–7. doi:10.1016/j.afjem.2021.03.005.
[13] Iloh ON, Edelu B, Iloh KK, Igbokwe OO, Ndu IK, Nduagubam OC, et al. Weight estimation in Paediatrics: how accurate is the Broselow-tape weight estimation in the Nigerian child. Ital J Pediatr 2019;45:146. doi:10.1186/s13052-019-0744-5.
[14] Omisanjo AO, Orimadegun AE, Akinbami FO. Accuracy of Nelson and best guess formulae in estimation of weights in Nigerian children population. Ann Ib Postgrad Med 2014;12:80–8 –88.
[15] Grosse SD, Odame I, Atrash HK, Amendah DD, Piel FB, Williams TN. Sickle cell disease in Africa: a neglected cause of early childhood mortality. Am J Prev Med 2011;41:S398–405. doi:10.1016/j.amepre.2011.09.013.

[16] Ohene-Frempong K, Oduro J, Tetteh H, Nkrumah F. Screening newborns for sickle cell disease in Ghana. Pediatrics 2008;121:S120.
[17] Behrman RE, Kliegman RM, Jenson HB. Nelson textbook of pediatrics. 17th ed. U S Am Hal B Jenson; 2004.
[18] Nieman CT, Manacci CF, Super DM, Mancuso C, Fallon WF. Use of the Broselow tape may result in the underresuscitation of children. Acad Emerg Med 2006;13:1011–19. doi:10.1197/j.aem.2006.06.042.
[19] Barden EM, Kawchak DA, Ohene-Frempong K, Stallings VA, Zemel BS. Body composition in children with sickle cell disease. Am J Clin Nutr 2002;76:218–25. doi:10.1093/ajcn/76.1.218.
[20] Bennett EL. Understanding growth failure in children with homozygous sickle-cell disease. J Pediatr Oncol Nurs 2011;28: 67–74. doi:10.1177/1043454210382421.
[21] Talib NJ, Rahm G, Abdel-Rahman SM. Estimating weight in children with down syndrome. Glob Pediatr Health 2015;2:2333794X14568450. doi:10.1177/2333794X14568450.
[22] Komfo anokye teaching hospital. Minist Health n.d. https://www.moh.gov.gh/komfo-anokye-teaching-hospital/[Accessed 29 January 2023].
[23] Our History. Komfo anokye teach hosp n.d. https://kath.gov.gh/our-history/[Accessed 29 January 2023].
[24] Administrator B R 4.0.3 now available | R-bloggers; 2020 https://www.r-bloggers.com/2020/10/r-4-0-3-now-available/ [Accessed 28 March 2021].
[25] Clark MC, Lewis RJ, Fleischman RJ, Ogunniyi AA, Patel DS, Donaldson RI. Accuracy of the Broselow Tape in South Sudan, "The hungriest place on earth.". Acad Emerg Med 2016;23:21–8. doi:10.1111/acem.12854.
[26] Luten RC, Zaritsky A, Wears R, Broselow J. The Use of the Broselow tape in pediatric resuscitation. Acad Emerg Med 2007;14:500–1. doi:10.1111/j.1553-2712.2007.tb01817.x.
[27] Anderson M. Underestimation potentially better than overestimation. Arch Dis Child 2007;92:937.
[28] Batmanabane G, Jena PK, Dikshit R, Abdel-Rahman S. Using the mercy method for weight estimation in indian children. Glob Pediatr Health 2015;2:2333794X14566625. doi:10.1177/2333794X14566625.
[29] Dicko A, Alhousseini ML, Sidibé B, Traoré M, Abdel-Rahman SM. Evaluation of the Mercy weight estimation method in Ouelessebougou, Mali. BMC Public Health 2014;14:270. doi:10.1186/1471-2458-14-270.
[30] Wells M, Goldstein L, Bentley A. A validation study of the PAWPER XL tape: accurate estimation of both total and ideal body weight in children up to 16 years of age. Trauma Emerg Care 2017;2. doi:10.15761/TEC.1000141.
[31] Georgoulas VG, Wells M. The PAWPER tape and the Mercy method outperform other methods of weight estimation in children at a public hospital in South. Africa 2016;106:7.
[32] Chavez H, Peterson RE, Lo K, Arel M. Weight estimation in an inner-city pediatric ED: the effect of obesity. Am J Emerg Med 2015;33:1364–7. doi:10.1016/j.ajem.2015.07.040.
[33] Garcia CM, Meltzer JA, Chan KN, Cunningham SJ. A validation study of the PAWPER (Pediatric Advanced Weight Prediction in the Emergency Room) tape–a new weight estimation tool. J Pediatr 2015;167:173–177.e1. doi:10.1016/j.jpeds.2015.04.006.
[34] Manirafasha A, Yi S, Cattermole GN. Estimating children's weight in a Rwandan emergency centre. Afr J Emerg Med 2018;8:55–8. doi:10.1016/j.afjem.2018.03.003.