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Research paper

Credibility of the caregivers as a source of information on the weight of a pediatric patient in emergencies. Estimating body weight using age-dependent formulas

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Abstract

Introduction: The child's body weight is very important in the proper pharmacotherapy in emergency situations.

Aim: The aim of the study is to assess the reliability of information on the current body weight of a pediatric patient obtained by taking history in emergencies. Additionally, the effectiveness of commonly used age-dependent weight formulas for children was analysed.

Material and methods: The study was retrospective. We have collected 1103 cases of pediatric patients admitted to the Emergency Department in the second half of 2018, in whom data on body weight were obtained by history taking and by weighing the patient. Subsequently, based on the patient's age, their weight was estimated using 13 different formulas.

Results and discussion: Parents, caregivers or teenagers are reliable sources of information about the patient's actual weight. In 86% of cases the data from the medical history were within the range defined as acceptable (±10% in comparison with the actual body weight). Underestimating body weight was a more frequent mistake than its overestimation. None of the formulas gave half as accurate results as medical history data. Of all the formulas, the best results were reported for the Park formula, however, only 42% of the estimates were within the acceptable range.

Conclusions: Weight information obtained from children and their parents or caregivers is more reliable in terms of determining the child's actual body weight than any formula for body weight estimation. If it is necessary to use any of the formulas for approximate body weight, it is most preferable to use the Park formula.

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1. INTRODUCTION

The body weight of a pediatric patient is the key to implementing effective and safe dosing of drugs and fluids.[1] It is important for the safe prescription of medicines – both commonly used over-the-counter (OTC) drugs and those used in medical rescue and hospital treatment.[2] Determining a patient's weight is not time consuming, costly or difficult. On the contrary, it is simple to do (even by non-medical personnel) and widely available.

In pediatric emergency medicine, body weight-based dosing is not only necessary in pharmacotherapy, but also in many others: in fluid therapy, electrotherapy, selecting of the size of certain supraglottic airway devices, determining of ventilation parameters, any calculations needed for blood, and blood components or determining the appropriate dose of coagulation factor concentrates. Body weight should be measured in the emergency department, both from a practical and health promotion point of view.[3,4]

All healthcare professionals, as well as patients and caregivers, use body weight as a tool for determining the appropriate treatment for the patient on a daily basis.

Body weight is commonly used both in routine medical practice and emergencies, i.e. in emergency medical aid. Many methods of calculating the approximate body weight exist. In practice, miniaturized scales and special formulas are often used to determine the right doses of drugs and the size of rescue equipment. Professional mobile applications dedicated to this are gaining popularity as well.

Observation reveals that medical personnel often does not verify the body weight value indicated by the patient or their caregiver. Additionally, in the conditions of emergency medical service (EMS) and events in public places – it is often not possible at all.

Experience shows that the patient or their caregiver often do not know what the patient's current weight is. Frequently they will provide an approximate body weight or will guess. This may confuse medical staff and potentially introduce error in the implemented treatment.

2. AIM

The main objective of the study is to determine the difference between the declared and actual body weight of a minor patient and to verify whether the information obtained in history taking can be considered reliable. An important element of the study is the comparison of the reliability of data provided by individual sources of information about pediatric patient's body weight: mother, father or caregiver.

Broselow tape is not found in Polish hospital emergency departments, therefore it is not subjected to research analysis. The aim of the study is to answer a clinical question: which of the available methods of estimating body weight is the most beneficial.

3. MATERIAL AND METHODS

This retrospective study was conducted in the Emergency Department (ED) of the Pediatric Teaching Clinical Hospital of the University Clinical Centre of the Medical University of Warsaw in the second half of 2018. The study consisted of checking whether the patients and/or their caregivers know the current body weight value, and in the subsequent verification of this information against the actual current body weight of the patient. In addition, the actual body weight value is compared to the approximate body weight calculated by using the formulas provided for this purpose, indicating the most useful ones. Hence, allowing to determine a body weight value close to the actual one. In total, 20 865 copies of individual medical records of patients admitted to the ED were analyzed to select those that meet the following criteria:

(1) The patient was a minor (less than 18 years of age).
(2) The patient's declared weight was stated in the records.
(3) The source of weight information (mother, father, patient, other caregiver) was recorded.
(4) Body weight measurement was performed by ED personnel using standardized medical scales and the value was recorded in the medical records.

We have collected 1103 cases which meet all previously stated criteria. The data was then anonymized and compiled into a statistical block, which was further analyzed.

Additionally, the body weight of each case was estimated based on available and used formulas intended for this purpose:[5–11]

(1) PALS formula for ages from 1 to 10 = (age + 4) × 2 or (age × 2) + 8;
(2) Luscombe and Owens formula for ages from 1 to 14 = (age × 3) + 7;
(3) Argall formula for ages from 1 to 10 = (age + 2) × 3;
(4) Theron formula for ages from 1 to 10 = e [(0.175571 × age) + 2.197099];
(5) CWAR formula for ages from 1 to 6 = (age × 3)+ 5;
(6) Lefller formula for infants = (age in months / 2) + 4;
Lefller formula for ages from 1 to 10 = (age × 2) + 10;
(7) Shann formula for ages from 1 to 9 = (age × 2) + 9;
Shann formula for ages from 10 to 14 = age × 3;
(8) Park formula for infants = (age in months + 9) / 2;
Park formula for ages from 1 to 4 = (age × 2) + 9;
Park formula for ages from 5 to 14 = (age × 4) – 1;
(9) Nelson formula for infants = (age in months +9) / 2;
Nelson formula for ages from 1 to 6 = (age × 2) + 8;
Nelson formula for ages from 7 to 12 = [(age × 7) – 5] / 2;
(10) Best Guess formula for infants = (age in months + 9) / 2;
Best Guess formula for ages from 1 to 4 = (age + 5) × 2;
Best Guess formula for ages from 5 to 14 = age × 4;
(11) Resuscitation Council UK formula for infants = (age in months × 0.5) + 4;
Resuscitation Council UK formula for ages from 1 to 5 = (age × 2) + 8;
Resuscitation Council UK formula for ages from 6 to 12 = (age × 3) + 7;

(12) NZ Resuscitation Council formula for ages from 1 to 9 = (age + 4) × 2;
NZ Resuscitation Council formula for ages from 10 to 14 = age × 3.3;
(13) Janus-Młodawska formula for ages from 1 to 10 = (age × 2) + 7.

Separate groups of data were distinguished for each method of body weight estimation due to the different age ranges of patients for whom a given formula is acceptable.

For each case within the course of statistical work on the obtained data, we have calculated a percentage of error (PE) which occurred in the estimation of the actual body weight using the following formula: percentage of error (PE) = 100 × (estimated weight-actual weight / actual weight), analogous to the formula used by Badeli (2015).[12] To be able to determine with certainty which of the methods of estimating body weight provide the greatest safety for patients, it was decided to follow foreign scientific literature and consider results that deviate from the actual body weight by 10% acceptable. In pediatric patients, dosing is done using body weight and an error in estimating the patient's weight of up to 10% should not have a critical impact on the patient's health. Values deviating by more than 10% should be considered above the maximum risk.[13] Significant differences were accepted for all analyses at the level of $P < 0.05$.

Excel 2016 software with extensions and Statistica 13 package were used to process the results. The obtained results are presented in the form of tables, charts and diagrams in the Results section.

4. RESULTS

The group of 1103 patients consisted of 616 boys and 487 girls. The average age of a child is 7.72 years (SD 4.9). The average body weight is 33.22 kg (SD 21.15). The age distribution of patients was uneven, as shown by the ED admission statistics, and is presented in Figure 1.

Body weight information was most often obtained from the patients' mothers (58%), less frequently from the patients themselves (23%) or the fathers (18%) and sporadically from the caregivers (10 patients – 1%). In the analyzed group, in 401 cases the reason for reporting to ED was trauma, whereas in 702 cases there were other reasons.

Age-based body weight estimation formulas have specific limitations defined by their authors or subsequent researchers. The distribution of the number of cases by the chosen method of estimating body weight is presented in Table 1.

Based on information obtained from the parents, from the patient or from caregivers who accompany the patient, the mean error (mean PE) was only –2%. The largest underestimation of body weight, with the error of –52%, was the case of a 4-year-old boy weighing 33 kg, whose mother suspected a weight of 16 kg. The biggest overestimation of body weight, with the error of 30%, was the case of an 8-year-old boy weighing 27 kg, whose mother determined his weight to be 35 kg. The mean error was calculated for each of the individual formulas for estimating body weight and these data are shown in Table 1.

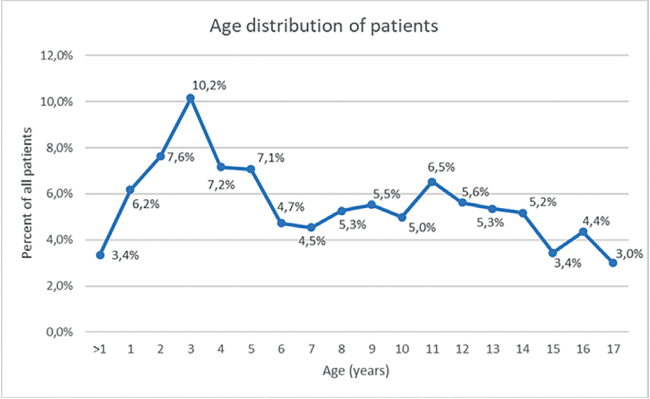

Figure 1. Age distribution of patients selected for the study.

Data obtained in history taking indicated on average a small error. However, the Lus-combe and Owens formula and the Park formula were on average more effective, because the average error was very close to 0. Nonetheless, what significantly distinguishes the effectiveness of weight assessment is not only the average data correspondence, but also the matter of small dispersion. Data from the patient, parents or other caregivers accompanying the patient indicate a small SD, i.e. less than 8%. This means that while on average parents can give slightly less accurate results, the data obtained from them are very likely to be close to the correct body weight. Quite the opposite will be the case for the Luscombe and Owens formula, where the SD totals 21%, or the Park formula, where the SD is 20% (Figure 2).

Table 1. Number of cases, mean weight estimation error, minimum value, maximum value and standard deviation.

Source of the weight value	*N*(%)	Mean PE	Minimum	Maximum	SD
Medical history	1103(100)	–2.06	–51.52	29.63	7.69
PALS formula	697(63)	–13.45	–64.78	42.86	15.50
Luscombe and Owens formula	947(86)	–0.45	–53.46	72.22	20.94
Argall formula	697(63)	–2.37	–54.72	66.67	19.03
Theron formula	697(63)	10.21	–44.93	103.67	25.14
CWAR formula	473(43)	–10.08	–50.92	53.85	17.92
Janus-Młodawska formula	629(57)	–18.70	–66.04	30.77	14.65
New Zealand Resuscitation Council formula	947(86)	–13.56	–58.49	45.20	17.14
Shann formula	947(86)	–12.25	–62.26	57.14	18.70
Leffler formula	734(67)	–2.00	–62.26	100.89	19.13
Park formula	984(89)	–0.20	–50.94	100.89	20.43
Best Guess formula	984(89)	4.12	–49.69	100.89	20.91
Nelson formula	868(79)	–10.91	–59.12	100.89	17.71
Resuscitation Council United Kingdom formula	868(79)	–3.87	–53.46	100.89	20.22

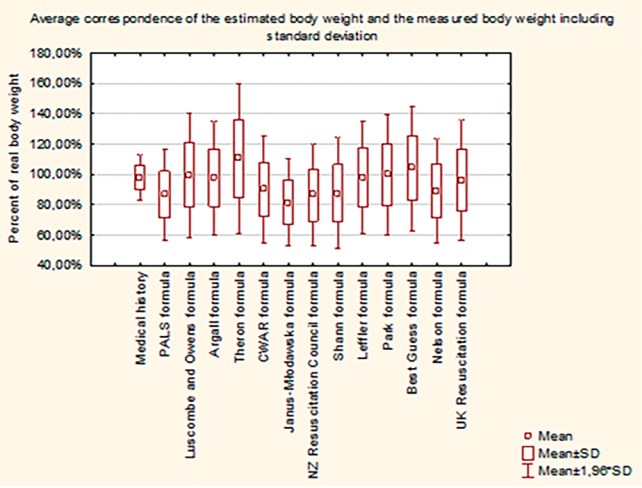

Figure 2. A box plot showing the average correspondence of the estimated body weight and the measured body weight including standard deviation.

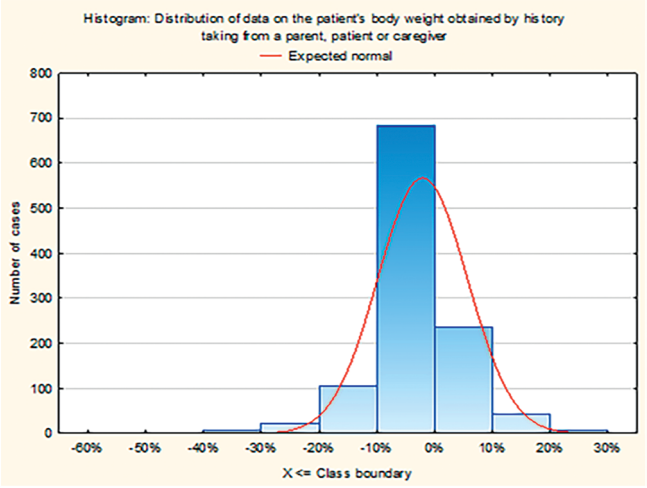

Figure 3. Distribution of data on the patient's body weight obtained by history taking from a parent, patient or caregiver.

For each body-weight estimating methods, it was checked how many results are within ±10% range. The resulting data is presented in Table 2.

It was decided to examine the distribution of data obtained by history taking to assess whether the data is more underestimated or overestimated in terms of the declared body weights. For this purpose, a histogram including a normal distribution curve was used. Figure 3 is shifted to the left, which is related to the most common underestimation of the weight of a child.

Based on the Kruskal-Wallis ANOVA rank analysis, it was found that there are no statistically significant differences ($P > 0.05$) between the data from medical history concerning body weight and the source of this data ($H_{3,N=1103} = 3.408329$, $P = 0.3328$) (Figure 4).

Table 2. Percentage of acceptable body weight estimates by method.

Source of the weight value	*N*	Mean, %	Number of acceptable	Percent of acceptable
Medical history	1103	98	928	84
PALS formula	697	87	251	36
Luscombe and Owens formula	947	100	341	36
Argall formula	697	98	274	39
Theron formula	697	110	249	36
CWAR formula	473	90	168	36
Janus-Młodawska formula	629	81	162	26
New Zealand Resuscitation Council formula	947	86	307	32
Shann formula	947	88	353	37
Lefller formula	734	98	323	44
Park formula	984	100	414	42
Best Guess formula	984	104	395	40
Nelson formula	868	89	318	37
Resuscitation Council United Kingdom formula	868	96	330	38

In the study of the statistical relationship between the knowledge of body weight and the cause of reporting to the ED, it was noted that the average value of estimated body weight in the group of nontraumatic patients was closer to the actual value (98% for nontraumatic patients vs. 97% for traumatic patients). A Mann-Whitney *U* test was performed to assess the significance of these results ($U = 127432.5$, $Z = 2.61700381$, $P = 0.00887095139$). This difference was considered statistically significant ($P < 0.05$). Additionally, a difference in age and mean weight was observed between the groups. Among nontraumatic children, the average age was 7 years old, with an average weight of 30.32 kg, compared to 9 years of age and 38.39 kg, respectively.

5. DISCUSSION

There are many methods for determining a child's body weight. The simplest ones include measurement using scales or asking the caregiver for this piece of information.[12,13] In the situation when it is not possible to obtain certain informa-

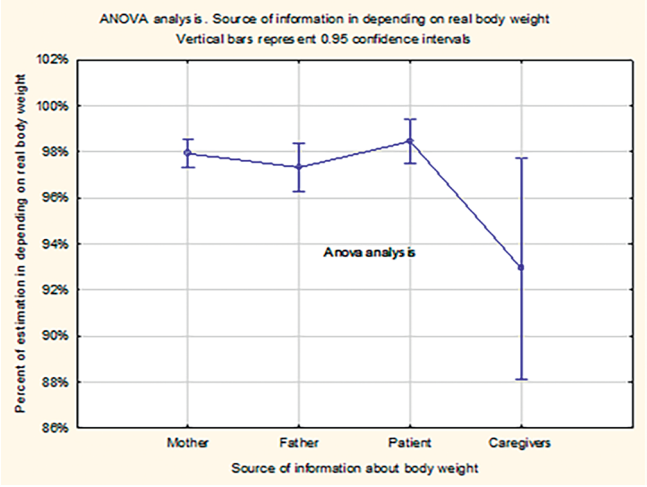

Figure 4. Source of information vs. truthfulness of body weight data. ANOVA analysis.

tion, modern medicine has equipped us with various validated support tools, such as body weight estimation formulas,[5–10] special Broselow tape[5,8,9,14] or smartphone applications.[15] An assessment based on the experience and knowledge of medical personnel is also possible.[12,13]

The presented results confirm that from a statistical point of view the mother, father, caregiver, as well as the patient themselves (depending on age and degree of development) is a valid source of information about body weight. These results are consistent with the collected data on information obtained from parents.[12,13] No statistically significant differences were observed between the information obtained from the mother and that obtained from the father of the child. We did observe something new: individuals who are not parents, but care-givers of the pediatric patients may also serve as a valid source of information on body weight. Figure 4 shows observations, including the interesting larger statistical range of information obtained from caregivers, which still remains within the expected range (±10% in comparison with actual body weight). The limitation of this part of the study is that the group of caregivers is small ($n = 10$).

The quality of the information received from the parents was also analyzed and most frequently the data provided by them constituted an underestimation of body weight (Figure 3), as indicated by the meta-analysis by Lundahl et al. (2014).[16]

A statistically significant difference in accuracy of estimated body weight provided by caregivers or patients was observed between trauma and non-trauma groups. More accurate data was obtained from non-traumatic patients. The hypothesis adopted by the researchers is that this statistically significant difference may be caused by the fact that in the case of illness, patients more often go to primary health care facilities where it is quite common to measure body weight. The obligation to take such measurements is imposed on primary health care medical personnel, nurses and school hygienists pursuant to the provisions of the Polish law.[17] Another hypothesis, related to age and weight of traumatic and non-traumatic patients, should not be ruled out, as the children who suffered from trauma were on average 2 years older than the children who fell ill. A possible factor explaining the phenomenon of better knowledge on body weight in children without trauma may be a greater interest of parents in the body weight of young children and a decrease in this interest as the child grows older.

Thirteen different formulas for body weight estimation on the basis of the pediatric patient's age were analyzed. None of them provided more reliable data than the data obtained from the patient, parents or caregivers (Table 2), which is also reflected in the scientific literature.[12] None of the formulas were effective in estimating the patient's body weight within the range of ±10% of the actual body weight in more than half of the cases. The most effective formulas (reaching more than 40% of results within the correct range) include the Leffler formula (44%), the Park formula (42%) and the Best Guess Formula (40%). At the same time, it was shown that on average, the Park and Luscomb-Owens formulas provide results very close to the correct body weight, but with very large data dispersion. While the PE was close to 0, the SD above 20 indicates inaccuracy of the data obtained (Table 1). Given that the Leffler formula is only applicable for up to 10 years of age ($n = 734$ in the study) and the Park formula – up to 14 years of age ($n = 984$ in the study), the Park formula appears to have the best parameters and the highest efficacy.

A well-collected interview within the ED plays a key role, which will enable obtaining the most accurate information about the child's body weight. Also, collecting information about height may be considered to calculate a BMI parameter that may indicate multiple medical conditions in pediatric patients.[18,19]

6. CONCLUSIONS

(1) Information on body weight obtained from children and their parents or caregivers is more reliable in determining the child's actual weight than any of the formulas intended for that purpose. This information may not be perfectly accurate when obtained in this way, but its use for therapeutic purposes is likely to be within the acceptable range.
(2) The most reliable estimates can be obtained using the Park formula, which on average provides very good results. However, the dispersion of results in relation to the actual weight of the child is quite large. Only 42% of the results obtained using the Park method fall within the therapeutically acceptable range, which is still the highest accuracy of all the formulas for estimating the child's body weight.
(3) If necessary, when it is impossible to take medical history or to determine the body weight, we recommend the use of the Park formula to medical personnel as it provides the highest probability of obtaining results close to the actual values.

Conflict of interest
None declared.

Funding
None declared.

Ethics
The retrospective study based only on medical records without contact with the patient does not require approval of the bioethics committee in accordance with Polish law. Despite this, our study was planned in accordance with all the rules of the Helsinki declaration and ensures full anonymization of data and respect for patient privacy.

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