Surface Area In Children: A Simple Formula

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We retrospectively compared body surface area (BSA) using the Mosteller formula $\sqrt{H \times \frac{W}{3600}}$ and a simple weight-based BSA formula ($[4W_{kg}+7]/ [90+W_{kg}]$). The participants were 363 children who underwent cardiac surgery from 1991 to 2000. Their age ranged from 5 days to 18 years, weight ranged from 1.2 kg to 98 kg and height ranged from 38 cm to 178 cm. There was excellent correlation (r^2=0.991) between Mosteller formula and the new formula (P <0.001). We propose that the weight-based formula is easy to use and accurate. It can safely replace Mosteller formula and dispense the need for time-consuming calculations.

Key Words: *Body surface area, Bodyweight, Child, Mosteller formula*.

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Measurement of body surface area (BSA) is important in determining the basal metabolic rate, blood volume, cardiac output and renal clearance(1-5). It is also frequently used for calculating drug dosages and parenteral fluid requirements(6). While the direct measurement of BSA is cumbersome, a number of formulae have been developed for its estimation based on height and bodyweight(7-12). The bi-exponential nature of these formulae requires the need for a scientific calculator or computer, which might not be always possible. Of the formulae available, the Mosteller equation is commonly used because of its accuracy. Though, this equation is simpler than other height and weight based equations, it cannot be calculated by a standard calculator because of the requirement of square-root function. Besides mathematical complexity, all these equations require measurement of height. Pediatricians are aware of problems faced in measuring accurate height or supine length in children, and acknowledge the non-reproducible nature of this variable, especially when the situation is emergent. Bodyweight is conveniently measured even in less sophisticated health facilities. The purpose of this study was to calculate BSA from a formula based primarily on bodyweight(12) and compare it with that calculated using the Mosteller formula(10).

METHODS

We retrospectively reviewed records of children who underwent cardiac surgery during 1991-2000 at Children's Hospital Illinois, University of Illinois, and College of Medicine at Peoria. This data was maintained by our perfusionist. We included children (newborn to 18 years) who required cardiopulmonary bypass for cardiovascular surgery. The following variables were recorded: age (months), weight (kg) and height (cm). The BSA (m^2) values in patient records using Mosteller formula were listed as Group A. A second value of BSA (m^2) for each patient was also calculated using a new weight based equation (Group B). The Institutional Review Board of University of Illinois, College of Medicine Peoria approved this study.The formulae for calculating BSA were as follows:

Group A BSA (m^2) = $\sqrt{H \times \frac{W}{3600}}$

Group B BSA (m^2) = (4 × W + 7) ÷ (90 + W)

Where height (H) is measured in cm and weight (W) is measured in kg.

We divided the study population in to four weight categories: (*i*) 0-9 kg; (*ii*) 10-19 kg; (*iii*) 20-29 kg and (*iv*) ≥30 kg. Data were entered and analyzed in SPSS version 14.0. We calculated the mean BSA for each weight category in both groups along with standard error of means. We also computed the Pearson correlation coefficient for each weight category; significance between groups was determined by *t*-test. Pearson correlation was also applied to all BSA values in both groups regardless of weight. The Bland- Altman analysis was used to determine the mean difference and 95% limits of agreement between Mosteller and new formula for BSA(13).

RESULTS

The study included 373 subjects. Their ages ranged from 5 days to 18 years, weight from 1.2 to 98 kg and height from 38 to 178 cm. Body surface areas of study subjects varied from 0.11 to 1.88 m^2 by Mosteller formula and 0.13 to 1.90 m^2 by the weight-based formula. ***Table* I** shows the number of children in each weight category and their estimated BSA values by both the formulae along with Pearson correlation. The mean±standard error BSA by the Mosteller formula was 0.58±0.23 m^2. The mean± standard error BSA by the study formula 0.59±0.24 m^2. There was excellent correlation between BSA values from both formulae (*P*<0.001) (***Fig.* 1**). Bland-Altman plot of differences between the two formulae, versus their respective averages, showed that the mean bias was 0.01 m^2 and limits of agreement were between -0.2 to 0.2, *i.e.* extremely narrow band (means excellent agreement) (***Fig.* 2**).

TABLE I BODY SURFACE AREA (MEAN ± STANDARD ERROR) BY DIFFERENT WEIGHT CATEGORIES USING THE TWO FORMULAE

Wt (kg)	No	Group A	Group B	Pearson correlation	*P*
0-9	199	0.28± 0.01	0.29 ± 0.01	0.99	<0.001
10-19	88	0.60 ±0.01	0.60± 0.01	0.89	<0.001
20-29	26	0.90± 0.01	0.87± 0.02	0.84	<0.001
30 +	59	1.42± 0.03	1.43± 0.03	0.93	<0.001

Group A: Mosteller formula; Group B: New formula.

DISCUSSION

Measurement of BSA is still a cumbersome task. BSA nomogram and web-based BSA calculators are frequently used in clinical practices instead of measuring BSA directly.

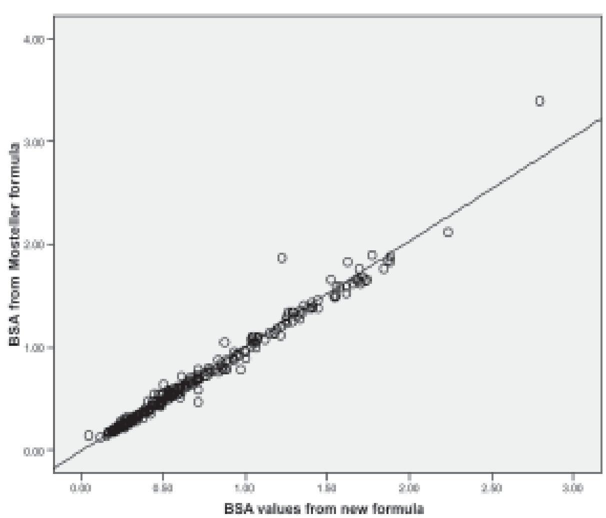

FIG. 1 *Correlation between body surface area (BSA) comparing Mosteller and new formula.*

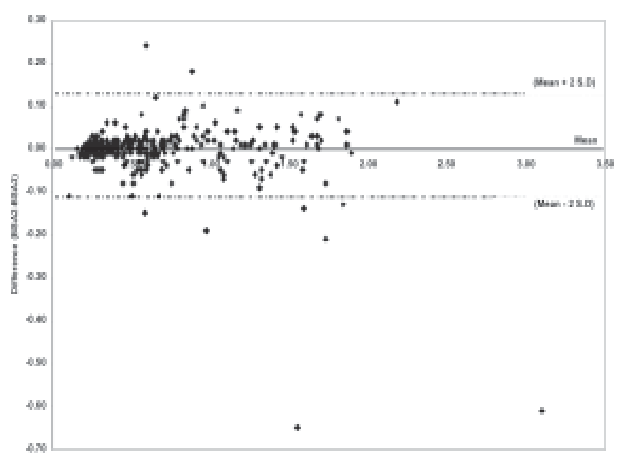

FIG. 2 *Bland-Altman plot showing average of Mosteller formula (BS-A) and new formula (BSA-B) on X-axis and differences of Mosteller formula (BS-A) and new formula (BSA-B) on Y-axis.*

Benefits of using the weight-based formula are manifold. Not only does it dispense with the hassle of exponential complexities, it also circumvents the difficulties of measuring accurate height in very small or sick children for incorporation in Mosteller formula. Our finding of an excellent correlation between these two formulae (r^2=0.99) establishes the accuracy of the weight-based formula besides highlighting its user-friendliness. This easy formula with its impressive correlation and agreement, can potentially replace the Mosteller formula in pediatric population especially in emergent situations where ease of calculation is more important than accuracy. Further studies are needed to validate the clinical application of this formula.

There are several limitations in this study. The study is retrospective, and a single center based. The weight-based formula may have the same limitations as Mosteller formula since both give similar BSA values. We did not compare the study formula with the Mosteller formula in population other than pediatric nor did we account for variations in weight (normal versus underweight versus obese subjects) in the same age groups.

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