Anthropometric Prediction of Total Body Water in Children Who Are on Pediatric Peritoneal Dialysis

Bruce Z. Morgenstern,* Elke Wühl,† K. Sreekumaran Nair,‡ Bradley A. Warady,§ and Franz Schaefer†

*Division of Pediatric Nephrology, Phoenix Children's Hospital, Phoenix, Arizona; †Division of Pediatric Nephrology, University Hospital for Pediatric and Adolescent Medicine, University of Heidelberg, Heidelberg, Germany; ‡Division of Endocrinology, Department of Internal Medicine, Mayo Clinic College of Medicine, Rochester, Minnesota; and §Section of Pediatric Nephrology, Children's Mercy Hospital, Kansas City, Missouri

Accurate estimation of total body water (TBW) is a critical component of dialysis prescription in peritoneal dialysis (PD). Gold-standard isotope dilution techniques are laborious and costly; therefore, anthropometric prediction equations that are based on height and weight are commonly used to estimate TBW. Equations have been established in healthy populations, but their validity is unclear in children who undergo PD, in whom altered states of hydration and other confounding alterations in normal physiology, particularly retarded growth and pubertal delay, may exist. TBW was measured by heavy water (H_2O^{18} or D_2O) dilution in 64 pediatric patients who were aged 1 mo to 23 yr and receiving chronic PD in the United States and Germany to establish and validate population-specific anthropometric TBW prediction equations and to compare the predictive power of these equations with formulas that have been established in healthy children. The best-fitting equations are as follows: For boys, $TBW = 0.10 \times (HtWt)^{0.68} - 0.37 \times weight$; for girls, $TBW = 0.14 \times (HtWt)^{0.64} - 0.35 \times weight$. The height × weight parameter also predicts body surface area (BSA). These equations can be simplified, with slightly less precision, to the following: For boys, $TBW = 20.88 \times BSA - 4.29$; for girls, $TBW = 16.92 \times BSA - 1.81$. TBW is predicted without systematic deviations and equally well in boys and girls, North American and European, obese and nonobese, growth-retarded and normally sized, and pre- and postpubertal children. In contrast, previous anthropometric equations that were derived from healthy children systematically overpredicted TBW and were less precise in this pediatric PD population. In summary, a new set of anthropometric TBW prediction equations that are suited specifically for use in pediatric PD patients have been provided.

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The accurate determination of total body water (TBW) is a critical component of the dialysis prescription and measurement of the delivered dialysis dose. Urea kinetic modeling is a key underpinning to dialysis prescription. An estimate of the urea distribution space (V) is required to calculate normalized urea clearance, *i.e.*, Kt/V (1) for patients who are on peritoneal dialysis (PD) using these models. The urea distribution space, V, is assumed to be the same as TBW. Accurate measurement of TBW requires sophisticated measurement techniques, such as isotope dilution measurements (2), which are costly and time-consuming and, hence, not suitable for routine clinical practice. TBW therefore usually is estimated from anthropometric measurements.

The Kidney Disease Outcomes Quality Initiative PD adequacy guidelines recommend the use of the formulas of Mellits and Cheek (1) to estimate V in children who are on PD. These formulas are based on heavy water dilution studies that were performed in healthy children and estimate TBW using a child's height, weight, and gender (3). Recently, isotope dilution–derived TBW data that were obtained in healthy neonates and infants were added to the original data set of Mellits and Cheek, and a new set of anthropometric prediction equations were proposed (4). In these equations, a new anthropometric parameter height times weight (HtWt) that correlates linearly with TBW when both values are log-transformed was introduced (4). Estimates from the newer formulas are somewhat more accurate for infants but are still based on data that were obtained in healthy children.

In the PD population, disorders of growth and body composition are common and superimposed on large variations of fluid status. Because direct measures of TBW in children who are on PD using the "gold standard" assays involving heavy water have not been reported in large cohorts of children (5,6), it is unknown whether the anthropometric prediction equations that have been established in healthy children hold true in this population. Hence, the objectives of this study were to (*1*) measure TBW in children incident to maintenance PD using heavy water, (*2*) develop and validate population-specific (*i.e.*, children on PD) formulas to estimate TBW on the basis of

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B.Z.M. and E.W. contributed equally to this work.

Address correspondence to: Dr. Bruce Z. Morgenstern, Division of Pediatric Nephrology, Phoenix Children's Hospital, 1919 East Thomas Road, Phoenix, AZ 85016. Phone: 602-546-4700; Fax: 602-546-4701; E-mail: bmorgenstern@mayo.edu

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anthropometric measurements, and (3) compare the accuracy and the precision of the formulas with those of prediction equations that have been established in healthy children.

Materials and Methods

Patients

This study represents a collaboration between the Pediatric Peritoneal Dialysis Study Consortium (PPDSC), a multicenter organization of pediatric PD centers (centers listed at the end of the article) and the University of Heidelberg School of Medicine (Heidelberg, Germany). Infants, children, and adolescents were eligible. The US cohort of children was studied within 90 d of initiation of PD. The German children had been on PD for a mean of 28.8 ± 32.4 mo. All patients were in a stable state of hydration at time of assessment without overt edema. In no case was the study performed within 30 d of an episode of peritonitis.

The study protocol was designed in adherence to the declaration of Helsinki and approved by local Institutional Review Boards or Ethical Committees. Written informed consent was obtained from all parents, and informed consent or assent was obtained from the patients as appropriate.

Heavy Water Dilution Studies

For the PPDSC cohort, H_2O^{18} (Isotec; Sigma-Aldrich, St. Louis, MO) was used to determine TBW, and D_2O (Merck, Darmstadt, Germany) was used in the study that was performed in Heidelberg. H_2O^{18} was administered as a 10% solution in a volume equal to the square root of the patient's weight divided by 70 kg, multiplied by 30.4 (the volume of a 10% solution needed for a 70-kg individual). In the Heidelberg cohort, 1 g of D_2O (purity 99.9%) per kilogram of body weight was administered. The children then drank another 30 ml of water out of the glass or bottle that was used to administer the dose to ensure complete delivery of the heavy water. Blood samples were obtained immediately before and 4 h after administration. Plasma H_2O^{18} concentration was determined at the Mayo Clinic Core Biomedical Mass Spectrometry Laboratory by mass spectrometry, and plasma D_2O was determined by vacuum distillation and Fourier-transformed infrared spectroscopy as described previously (5). The coefficient of variation (CV) of both methods is <0.5%. TBW was calculated by the plasma enrichment of heavy water relative to the mass administered, with a correction factor of 1.01 for the H_2O^{18} space and of 1.04 for the D_2O space to account for isotope sequestration (7,8). Because heavy water has previously been demonstrated to equilibrate fully with the intraperitoneal volume over 4 h (5), the intraperitoneal volume was subtracted from the TBW calculated to yield the final result.

Statistical Analyses

The PPDSC sample was used to establish the principal relationship between height and weight and TBW. Log-transformed TBW data were regressed against the log-transformed anthropometric parameter, HtWt, which correlates linearly in studies that have been performed on healthy children (4). A linear relationship between HtWt and TBW was also found in this population. The residuals in the best fitting single-term equation were analyzed for remaining systematic effects by anthropometric variables or gender. This analysis disclosed the need for constructing gender-specific equations with inclusion of a linear correction factor accounting for body mass. The PPDSC and the Heidelberg samples were pooled into a single cohort to enhance the validity of the resulting gender-specific equations.

The resulting final prediction equations were internally cross-validated by separate reapplication to population subsets—The North American and the German patients, boys and girls, growth-retarded (height SD score [SDS] <-2) *versus* patients of normal height, patients with increased (>1) *versus* normal BMI SDS—and, finally, to random subsets that comprised two thirds and one third of the entire cohort, respectively. Height and body mass index SDS (BMI *z* scores) were calculated using nation-specific norms (9,10). BMI SDS were calculated using the LMS method, to account for the non-Gaussian distribution of BMI in the population (11).

The precision of the prediction equations was expressed by the root mean square error (RMSE), *i.e.*, the square root of the sum of squared differences between the observed and the predicted values divided by the number of patients studied. The smaller the RMSE, the greater is the accuracy of the equation. There is no absolute criterion value for an RMSE that indicates successful (12) validation. Because a wide range of TBW was studied, the RMSE was also expressed by the CV, *i.e.*, RMSE divided by the mean value of the dependent variable. The accuracy of the prediction was expressed by the mean difference between calculated and measured TBW values.

In addition, regression analyses were performed and Bland-Altman plots were generated to quantify the residual error inherent in the different anthropometric prediction methods available. Apart from the new formulas established here, estimates examined were TBW = 0.6 × body weight (13), the Mellits and Cheek equations (1), and the newer series of anthropometric predictive equations described earlier (hereinafter called "New Healthy") (4).

Finally, because the HtWt parameter appears as a parameter in a common formula that is used to estimate body surface area (BSA = $[(HtWt)/3600]^{0.5}$) (14), the relationships between TBW formulas and BSA were explored, and the accuracy of that relationship was similarly assessed.

Statistical analysis was performed using Microsoft Excel version 11.1.1 (Microsoft Corp., Redmond, WA) and SAS version 8.2 (SAS, Cary, NC). Pearson product moment correlation coefficients were calculated for univariate analysis of associations between continuous variables and paired *t* test for comparison of between-group differences. The best fitting formula for TBW was obtained by the NLIN procedure in the SAS package.

Results

Demographics

Table 1 shows the basic clinical characteristics of the patients who were studied in the PPDSC centers and in Heidelberg. Thirty-four children (16 girls, 18 boys) who were new to maintenance PD were studied in the United States. The children had mean age of 8.2 yr (range 1.5 mo to 19 yr). The 30 children from Heidelberg comprised nine girls and 21 boys, with a mean age of 12.6 yr (range 14 mo to 23 yr). The German children were older ($P < 0.01$), were taller ($P < 0.05$), and had a lower BMI *z* score ($P < 0.0001$) than the PPDSC group (Table 1).

The mean (±SD) TBW for the groups was 16.9 ± 9.5 L (range 2.4 to 40.5 L). The TBW averaged 56.8% (±10.1%) of body weight (Table 1). The percentage of body weight representing TBW was inversely related to age ($r = -0.29$, $P < 0.05$), height ($r = -0.35$, $P = 0.005$), weight ($r = -0.49$, $P < 0.0001$; Figure 1), and BMI ($r = -0.57$, $P < 0.0001$). Whereas % TBW did not differ in boys and girls who were younger than 10 yr, adolescent girls had significantly less body water per unit of weight (49.2 ± 10.3%) than adolescent boys (56.1 ± 5.6%; $P < 0.05$).

Table 1. Basic demographics of the patient cohorts used for validation of prediction equation[a]

	PPDSC Sample	German Sample	Total Population
n	34	30	64
Age (yr)	8.2 ± 6.2[b]	12.6 ± 5.9	10.2 ± 6.4
% male	53	69	61
Height (cm)	116.0 ± 41.4[b]	136.5 ± 27.2	125.6 ± 36.7
Height SDS	−1.7 ± 2.2	−2.2 ± 1.7	−2.0 ± 2.0
BSA (m^2)	0.98 ± 0.54	1.12 ± 0.37	1.03 ± 0.47
BMI (kg/m^2)	18.7 ± 4.3[b]	16.4 ± 3.0	17.6 ± 3.9
BMI SDS	0.8 ± 1.3[b]	−0.8 ± 1.5	−0.02 ± 1.6
TBW (L)	15.1 ± 10.4	19.0 ± 8.1	16.9 ± 9.5
TBW (% body wt)	54.6 ± 12.4[b]	59.4 ± 5.8	56.8 ± 10.1

[a]Appropriate national standards applied. PPDSC, Pediatric Peritoneal Dialysis Study Consortium; SDS, SD score; BSA, body surface area; BMI, body mass index; TBW, total body water.
[b]Significant difference between US and German children ($P < 0.05$).

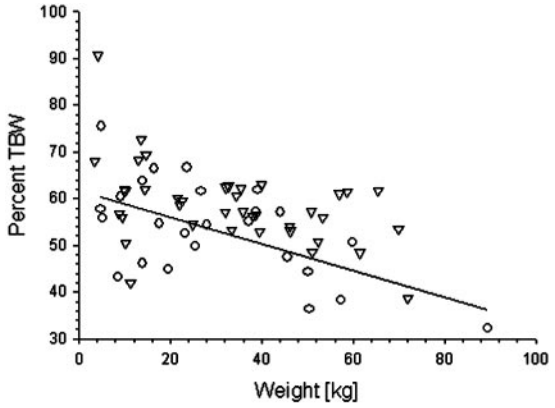

Figure 1. Variation of tissue hydration (percentage of total body water [% TBW]) in 64 pediatric peritoneal dialysis (PD) patients who were aged 1 mo to 23 yr. [utrif], boys; ○, girls. % TBW was inversely related to body mass ($r = -0.49$, $P < 0.0001$).

Development and Validation of TBW Prediction Equation

The 34 patients of the PPDSC cohort were used to establish a best fitting anthropometric prediction equation. Regression analysis verified a tight linear relationship of the log-transformed measured TBW values with the log-transformed Ht × Wt product ($R^2 = 0.96$, $P < 0.0001$). Back-transformation of this relationship yielded the following allometric equation:

$$TBW = 0.11 \times (HtWt)^{0.61} \quad \text{[Equation 1]}$$

The RMSE of the estimates based on Equation 1 was 3.02 L relative to the measured data (CV 20.1%). Inclusion of the Heidelberg sample in the validation cohort confirmed the close log-linear relationship between HtWt and TBW ($R^2 = 0.93$, RMSE 2.60, CV 15.4%, $P < 0.0001$).

Bland-Altman analysis of the residual variation in the relationship between measured and predicted TBW disclosed that the predictive accuracy and precision were inversely related to absolute body mass, with systematic overestimation of TBW in pubertal boys and underestimation in pubertal girls. Therefore, gender-specific prediction equations were established. Inclusion of a linear correction factor for body mass further improved the goodness of fit for both genders. All patients were used to determine the coefficients resulting in the following best fitting equations:

$$\text{Boys: } TBW = 0.10 \times (HtWt)^{0.68} - 0.37 \times \text{weight} \quad \text{[Equation 2a]}$$

$$\text{Girls: } TBW = 0.14 \times (HtWt)^{0.64} - 0.35 \times \text{weight} \quad \text{[Equation 2b]}$$

By these equations, TBW was predicted with $R^2 = 0.95$, a mean (±SD) difference(estimated − expected TBW) of 0.001 ± 2.15 L, and an RMSE of 2.17 L (CV 12.8%; Figure 2, Table 2). Equations 2a and 2b were reapplied to estimate TBW in the US and the German cohorts, in randomly selected subsets that comprised two thirds and one third of the total cohort, in boys and girls as well as in subsets that comprised patients with high *versus* low BMI SDS or low *versus* normal height SDS (Table 2). TBW was predicted equally well in all selected subpopulations, without any systematic deviations or imprecisions. Equations 2a and 2b are arithmetically complex relationships. Nomograms for children of different genders and body sizes based on these equations are presented in Appendix 1.

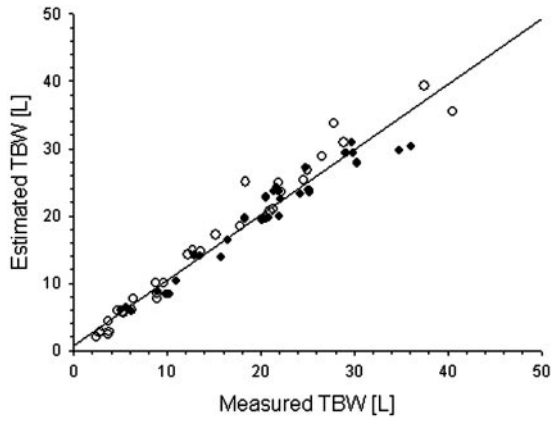

Figure 2. Comparison of calculated TBW by new anthropometric equations (Equations 2a and 2b) with measured TBW ($R^2 = 0.95$, $P < 0.0001$). ○, US children; ●, German children.

Table 2. Accuracy and precision of anthropometric TBW prediction by Equations 2a and 2b in subsets of validation cohort[a]

	Measured TBW (L)	Calculated TBW (L)	Difference Estimated from Measured TBW (L)	RMSE (L)	CV (%)
Total population	16.9 ± 9.5	16.9 ± 9.2	0.001 ± 2.15	2.17	12.8
PPDSC subset	15.1 ± 10.4	15.5 ± 10.4	0.40 ± 2.36	2.38	15.7
Heidelberg subset	19.0 ± 8.1	18.6 ± 7.5	−0.45 ± 1.81	1.82	9.6
Random 2/3 subset	15.8 ± 9.3	15.7 ± 9.2	−0.04 ± 2.46	2.46	15.6
Random 1/3 subset	18.8 ± 9.7	18.9 ± 9.2	0.07 ± 1.61	1.62	8.6
Boys	18.2 ± 10.0	18.2 ± 9.9	−0.02 ± 1.89	1.92	10.5
Girls	14.9 ± 8.4	14.9 ± 8.0	0.04 ± 2.54	2.59	17.4
BMI SDS >1	14.9 ± 11.1	14.7 ± 11.2	−0.17 ± 2.69	2.75	18.5
BMI SDS <1	17.6 ± 8.9	17.7 ± 8.4	0.06 ± 1.94	1.96	11.1
Height SDS <−2	15.5 ± 8.2	15.2 ± 7.7	−0.31 ± 2.13	2.16	13.9
Height SDS >−2	18.6 ± 10.7	18.9 ± 10.5	0.35 ± 2.15	2.19	11.8

[a]RMSE, root mean square error; CV, coefficient of variation.

Effect of Hydration on Anthropometric TBW Prediction

Alterations of hydration status are an inevitable source of error in anthropometric TBW prediction using only height and weight. To assess the effect of altered hydration on the precision of our prediction model, we categorized the cohort into fractional TBW quintiles (Figure 3). Patients with a trend toward overhydration will cluster in the top quintile (*i.e.*, those 20% of patients with the highest TBW content relative to body weight), and those with relative fluid depletion will cluster in the bottom quintile. TBW prediction was not affected systematically in the second, third, and fourth quintiles but tended to be low in the highest and high in the lowest quintile. The median prediction error was −16.9% in the top quintile and 9.8% in the bottom quintile, suggesting a moderate bias to TBW prediction at the extremes of hydration.

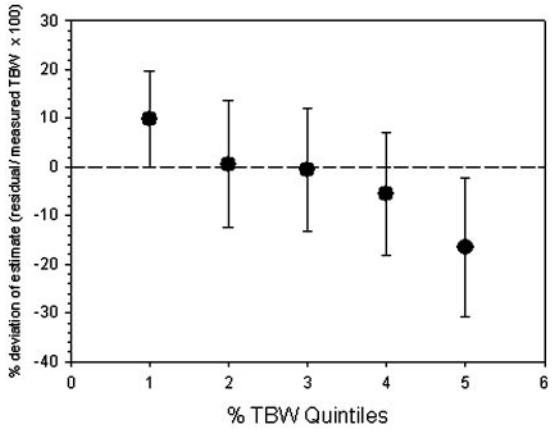

Figure 3. Relative estimation error (expressed as regression residual divided by measured TBW) of Equations 2a and 2b according to % TBW quintiles. "1" denotes bottom, "5" top quintile of fractional TBW within the cohort. Dot and error bars denote mean ± SD.

Predictive Accuracy and Precision of Anthropometric Equations in Children on PD

The comparative analysis of the new PD-specific pediatric prediction equations with two published anthropometric prediction equations that were derived from healthy children and another common approximation assuming TBW as a constant fraction of 60% of body weight is given in Table 3 and Figure 4. The three alternative equations had an inferior predictive precision in this pediatric PD cohort, with RMSE ranging from 2.37 to 3.4 L (CV 13.9 to 20.2%). Moreover, TBW was systematically overestimated with each of the equations ($P < 0.0001$ for each comparison).

Relationship of TBW to BSA

The TBW estimates using Equation 1 correlated linearly with BSA estimates using the Gehan (15) formula ($BSA = 0.02350 \times height^{0.42246} \times weight^{0.51456}$); the correlation led to the following formulas:

$$\text{Boys: } TBW = 20.88 \times BSA - 4.29 \quad \text{[Equation 3a]}$$

$$\text{Girls: } TBW = 16.92 \times BSA - 1.81 \quad \text{[Equation 3b]}$$

where BSA is in m^2 ($r^2 = 0.94$, $P < 0.0001$). These equations estimate TBW with a mean (SD) difference of −0.16 (2.3) L. The RMSE is 2.36 L, which corresponds to a CV of 13.9%. Using the simplified BSA formula ($BSA = [(HtWt)/3600]^{0.5}$) (14), the resulting correlations are similar:

$$\text{Boys: } TBW = 20.75 \times BSA - 3.88$$

$$\text{Girls: } TBW = 16.96 \times BSA - 1.57$$

Discussion

In this article, we have established a pair of population-specific equations that allows one to predict with acceptable accuracy and precision TBW in boys and girls on who are chronic PD. The equations should prove useful in standardiz-

Table 3. Accuracy and precision of different anthropometric equations in predicting TBW.

	Mean ± SD (L)	Difference Estimated TBW − Measured TBW (L)	RMSE (L)	CV (%)
Measured TBW	16.9 ± 9.5	—	—	—
Equations 2a and 2b	16.9 ± 9.2	0.001 ± 2.15	2.17	12.8
Equations 3a and 3b	16.9 ± 9.2	−0.001 ± 2.33	2.36	13.9
Mellits & Cheek	19.0 ± 11.3[a]	2.04 ± 3.17	2.37	14.0
New Healthy	21.1 ± 13.5[a]	4.19 ± 4.99	2.45	14.5
0.6 × Wt	18.9 ± 11.9[a]	1.96 ± 4.53	3.40	20.2

[a]Significant differences from measured TBW, $*P < 0.0001$.

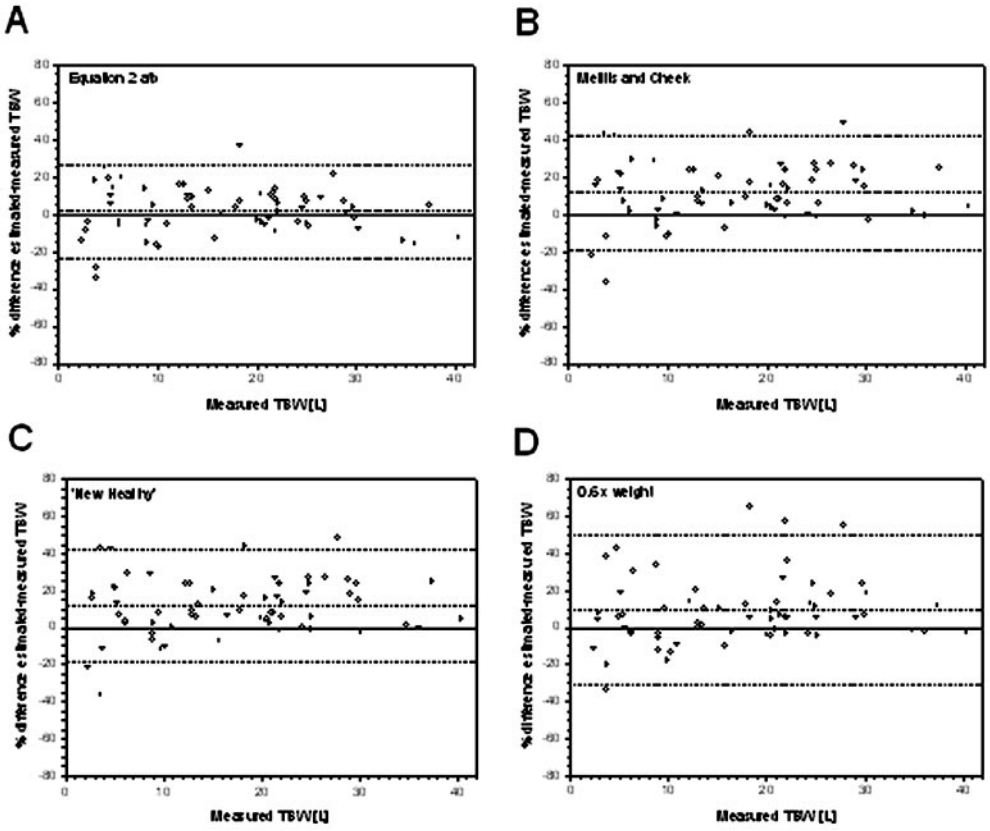

Figure 4. Bland-Altman plots of measured TBW *versus* difference between measured and estimated TBW using Equations 2a and 2b (A), Mellits and Cheek equations (B), the "New Healthy" equations (C), and 0.6 × body weight (D).

ing PD prescription according to the size of the distribution space of urea and other small molecules.

An accurate determination of TBW in patients who are on dialysis is necessary to assess fluid status and to calculate delivered dialysis dose by Kt/V and has been used in adult and pediatric studies to assess body composition and nutritional status (12,16,17). Estimation of TBW by simple formulas, such as 0.6 times body weight, or by formulas that are based on data derived from healthy patients is inaccurate, with an inferior predictive precision accounting for approximately 10% wider error ranges than prediction derived with the new population-specific equations. Such errors may have clinical relevance in the pediatric PD population (18).

The importance of using an adequate TBW approximation procedure is illustrated by the wide range of the TBW fraction observed in the pediatric PD population in this and previous studies (5,6). This wide variability is explained by both physiologic (developmental) changes and disease-related alterations of hydration: The TBW fraction decreases across childhood, particularly during the infant years (13). During puberty, differential changes of body composition are induced by male and female sex steroid production (19). Whereas boys experience a marked increase in lean body mass, girls tend to accumulate more fat than lean tissue, resulting in reciprocal changes of the water compartment. These changes held through in the pediatric PD population studied here; fractional TBW was inversely

correlated with age and was consistently lower in female compared with male adolescents.

Disorders of hydration and nutritional status, which may be disease related, are superimposed on these physiologic/developmental causes of TBW variability in childhood. These are related in part to the difficulty of maintaining a neutral fluid balance in children who are on PD, whose capacity to excrete water is altered and where fluid retention and excessive fluid losses commonly occur. Alterations of the nutritional state are common in these children as well, including malnutrition or obesity. In fact, children who are on supplemental tube feeding are frequently suspected to have both increased fat tissue deposition and wasting of lean body mass. The combined effects of alterations in fluid and metabolic balance may have little overall impact on body weight or the BMI but major effects on the distribution of hydrated and nonhydrated tissue compartments.

While none of the patients in this study displayed signs and symptoms of grossly altered hydration, subclinical disorders of fluid status could not be ruled out. We attempted to quantify the effect of abnormal hydration on anthropometric TBW prediction by defining % TBW quintiles. TBW tended to be underpredicted in the top quintile and to be overpredicted in the lowest quintile of fractional TBW distribution. This was expected because anthropometric prediction is based on the assumption of a constant proportion of water and water-free tissues. The prediction error at the ends of the hydration spectrum was moderate in quantitative terms, averaging at −16.9% in the 20% of patients with the highest fractional TBW and at 9.8% in the quintile with the lowest TBW content.

Tracer dilution studies are not likely to be performed as a routine in all children who are on maintenance PD because of the complexity of the procedure and the expense of the tracer. More precise TBW estimates can be achieved in children who are on PD by obtaining additional anthropometric information using bioelectrical impedance (BIA) or skinfold measurements (5). With either of these techniques, the CV of the TBW estimation can be reduced to approximately 8.5% as compared with 12.9% with the equations presented here. Studies in adult patients confirm the usefulness of BIA-based prediction equations in predicting TBW (12,16,17). However, because BIA is not available in most dialysis units, the anthropometric equations established here should serve as an acceptable compromise between optimal predictive power and routine clinical applicability.

The relationship between TBW and BSA has been noted before (4,20,21). In adult PD patients, this finding has been particularly relevant in obese patients (20). The finding has been explained by the fact that in most formulas to calculate BSA, an increase in weight with no change in height results in a proportionally smaller increase of BSA. The formulas for BSA therefore are less subject to the impact of overweight (22). Our previous reanalysis of data obtained in healthy children suggested that BSA may well be a better parameter than height or weight alone even on those who are not obese (4). Certainly, the linear relationship between TBW and BSA in children who are on PD described above (Equations 3a and 3b) facilitates an easier estimation of TBW compared with the more arithmetically complex Equations 2a and 2b. However, it must be pointed out that adopting the "easier" estimation of TBW from BSA will necessarily result in a slight loss of precision. The RMSE of Equations 3a and 3b is 2.36 L (CV 13.9%) compared with 2.18 L (CV 12.9%) using Equations 2a and 2b. To facilitate use of the more precise estimates, we have developed nomograms (see Appendix 1).

In this work, we took account of the complex changes in body composition during childhood by constructing gender-specific prediction equations that comprised an allometric height × weight term with an additional linear component. This strategy resulted in an improved quality of the anthropometric estimation. We were able to reduce RMSE to 2.18 L (CV 12.9%). This level of precision will result in a clinically acceptable error range of the ultimate Kt/V estimate; *e.g.*, in a 10-yr-old child with an estimated TBW of 17 L, a calculated weekly Kt/V urea of 2.0 will correspond to a "true" Kt/V between 1.8 and 2.2 (±1 SD) in 68% of the measurements. Internal cross-validation of the equations confirmed a very robust, reliable performance in subsets of the cohort. TBW was predicted equally well and without systematic deviations in obese and nonobese, tall and short, and North American and German children, as well as in randomly selected subsets of the cohort. Although the predictive power of the new equations was superior to previous anthropometric formulas that were derived in healthy children, it should be kept in mind that even with the optimized formula, the 95% confidence interval for TBW predictions is as high as ±4.4 L. Because of the physiologic and pathologic variability of body composition and fluid balance outlined above, it may be impossible to reduce further this residual variance of estimation if only height and weight data are available (20,23–25).

In summary, we have verified that anthropometric equations that are based on healthy individuals can provide only limited approximations of body composition in a diseased population, such as children who are receiving chronic PD; truly useful equations should be constructed and validated in the specific population of interest. We provide such a set of anthropometric TBW prediction equations, which permit superior precision and accuracy compared with previous formulas that were established in healthy children. The recommendation to use the equations of Mellits and Cheek (1) to determine TBW, or V, in children who are on maintenance PD is now able to be revised.

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Appendix

TBW Nomograms for children of typical heights and weights. Extremes of either height or weight have been eliminated. These data are based on Equations 2a and 2b (see text). For each gender, table a is for smaller children.

Male TBW nomogram

a

Weight (kg) \ Height (cm)	50	54	58	62	66	70	74	78	82	86	90	94	98	102	106	110	114
2	1.6	1.7	1.8	1.9													
3	1.9	2.1	2.2	2.4													
4	2.2	2.4	2.6	2.8	3.0												
5	2.4	2.7	2.9	3.1	3.3												
6	2.6	2.9	3.1	3.4	3.6	3.9	4.1										
7	2.8	3.1	3.4	3.6	3.9	4.2	4.4	4.7	4.9								
8	2.9	3.2	3.5	3.9	4.1	4.4	4.7	5.0	5.3	5.5	5.8						
9				4.0	4.4	4.7	5.0	5.3	5.6	5.9	6.2	6.5	6.7				
10				4.2	4.6	4.9	5.2	5.6	5.9	6.2	6.5	6.8	7.1	7.4	7.7		
11				4.4	4.8	5.1	5.5	5.8	6.2	6.5	6.8	7.1	7.5	7.8	8.1	8.4	8.7
12				4.5	4.9	5.3	5.7	6.0	6.4	6.8	7.1	7.5	7.8	8.1	8.5	8.8	9.1
13								63	6.6	7.0	7.4	7.8	8.1	8.5	8.8	9.2	9.5
14								6.5	6.9	7.3	7.7	8.0	8.4	8.8	9.2	9.5	9.9
15								6.7	7.1	7.5	7.9	8.3	8.7	9.1	9.5	9.9	10.2
16								6.8	7.3	7.7	8.1	8.6	9.0	3.4	9.8	10.2	10.6
17											8.4	8.8	9.2	9.7	10.1	10.5	10.9
18											8.6	9.0	9.5	9.9	10.4	10.8	11.2
19											8.8	9.3	9.7	10.2	10.6	11.1	11.5
20											9.0	9.4	9.9	10.4	10.9	11.3	11.8

b

Weight (kg) \ Height (cm)	106	110	114	118	122	126	130	134	138	142	146	150	154	158	162	166	170	174	178	182	186	190
20	10.9	11.3	11.8	12.3	12.7	13.2	13.6	14.0	14.5	14.9	15.3	15.7										
22	11.4	11.9	12.4	12.8	13.3	13.8	14.3	14.7	15.2	15.7	16.1	16.6										
24	11.8	12.3	12.9	13.4	13.9	14.4	14.9	15.4	15.9	16.4	16.8	17.3	17.8	18.3	18.7							
26	12.2	12.8	13.3	13.9	14.4	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5							
28	12.6	13.2	13.8	14.4	14.9	15.5	16.0	16.6	17.1	17.7	18.2	18.7	19.3	19.8	20.3	20.8	31.2					
30	13.0	13.6	14.2	14.8	15.4	16.0	16.6	17.1	17.7	18.3	18.8	19.4	19.9	20.5	21.0	21.6	22.1					
32	13.3	14.0	14.6	15.2	15.8	16.5	17.1	17.7	18.3	18.8	19.4	20.0	20.6	21.2	21.7	22.3	22.9	32.4	24.0			
34	13.6	14.3	15.0	15.6	16.3	16.9	17.5	18.2	18.8	19.4	20.0	20.6	21.2	21.8	22.4	23.0	23.6	24.2	24.7			
36	13.9	14.6	15.3	16.0	16.7	17.3	18.0	18.7	19.3	19.9	20.6	21.2	21.8	22.4	23.1	23.7	24.3	24.9	25.5	26.1	26.6	
38	14.2	14.9	15.7	16.4	17.1	17.8	18.4	19.1	19.8	20.4	21.1	21.8	22.4	23.0	23.7	24.3	24.9	25.6	26.2	26.8	27.4	
40			16.0	16.7	17.4	18.1	18.8	19.5	20.2	20.9	21.6	22.3	23.0	23.6	24.3	24.9	25.6	26.2	26.9	27.5	28.1	28.8
42			16.3	17.0	17.8	18.5	19.2	20.0	20.7	21.4	22.1	22.8	23.5	24.2	24.9	25.5	26.2	26.9	27.5	28.2	28.8	29.5
44			16.6	17.3	18.1	18.9	19.6	20.4	21.1	21.8	22.6	23.3	24.0	24.7	25.4	26.1	26.8	27.5	28.2	28.8	29.5	30.2
46			16.8	17.6	18.4	19.2	20.0	20.8	21.5	22.3	23.0	23.8	24.5	25.2	26.0	26.7	27.4	28.1	28.8	29.5	30.2	30.9
48			17.1	17.9	18.7	19.5	20.3	21.1	21.9	22.7	23.5	24.2	25.0	25.7	26.5	27.2	27.9	28.7	29.4	30.1	30.8	31.5
50			17.3	18.2	19.0	19.8	20.7	21.5	22.3	23.1	23.9	24.7	25.4	26.2	27.0	27.7	28.5	29.2	30.0	30.7	31.5	32.2
52						20.1	21.0	21.8	22.6	23.5	24.3	25.1	25.9	26.7	27.5	28.2	29.0	29.8	30.6	31.3	32.1	32.8
54						20.4	21.3	22.1	23.0	23.8	24.7	25.5	26.3	27.1	27.9	28.7	29.5	30.3	31.1	31.9	32.7	33.4
56						20.7	21.6	22.5	23.3	24.2	25.0	25.9	26.7	27.6	28.4	29.2	30.0	30.8	31.7	32.4	33.2	34.0
58						20.9	21.8	22.8	23.7	24.5	25.4	26.3	27.1	28.0	28.8	29.7	30.5	31.4	32.2	33.0	33.8	34.6
60						21.2	22.1	23.1	24.0	24.9	25.8	26.7	27.5	28.4	29.3	30.1	31.0	31.8	32.7	33.5	34.4	35.2
62						21.4	22.4	23.3	24.3	25.2	26.1	27.0	27.9	28.8	29.7	30.6	31.5	32.3	33.2	34.0	34.9	35.7
64						21.7	22.6	23.6	24.6	25.5	26.4	27.4	28.3	29.2	30.1	31.0	31.9	32.8	33.7	34.5	35.4	36.3
66									24.8	25.8	26.8	27.7	28.6	29.6	30.5	31.4	32.3	33.2	34.1	35.0	35.9	36.8
68									25.1	26.1	27.1	28.0	29.0	30.0	30.9	31.8	32.8	33.7	34.6	35.5	36.4	37.3
70									25.4	26.4	27.4	28.4	29.3	30.3	31.3	32.2	33.2	34.1	35.1	36.0	36.9	37.8
72									25.6	26.6	27.7	28.7	29.7	30.7	31.6	32.6	33.6	34.5	35.5	36.4	37.4	38.3
74									25.9	26.9	27.9	29.0	30.0	31.0	32.0	33.0	34.0	34.9	35.9	36.9	37.8	38.8
76									26.1	27.2	28.2	29.3	30.3	31.3	32.3	33.3	34.4	35.3	36.3	37.3	38.3	39.3
78									26.3	27.4	27.4	29.5	30.6	31.6	32.7	33.7	34.7	35.7	36.7	37.7	38.7	39.7
80									26.5	27.6	27.6	29.8	30.9	31.9	33.0	34.1	35.1	36.1	37.1	38.2	39.2	40.2

Female TBW nomogram

a

Weight (kg) \ Height (cm)	50	54	58	62	66	70	74	78	82	86	90	94	98	102	106	110	114
2	2.0	2.1	2.2	2.4													
3	2.4	2.6	2.8	2.9													
4	2.8	3.0	3.2	3.4	3.6												
5	3.1	3.3	3.5	3.8	4.0												
6	3.3	3.6	3.8	4.1	4.3	4.6	4.8										
7	3.5	3.8	4.1	4.4	4.8	4.9	5.2	5.5	5.7								
8	3.7	4.0	4.3	4.6	4.9	5.2	5.5	5.8	6.1	6.4	6.6						
9				4.9	5.2	5.5	5.8	6.1	6.4	6.7	7.0	7.3	7.6				
10				5.1	5.4	5.8	6.1	6.4	6.8	7.1	7.4	7.7	8.0	8.3	8.6		
11				5.3	5.6	6.0	6.4	6.7	7.1	7.4	7.7	8.1	8.4	8.7	9.0	9.3	9.6
12				5.4	5.8	6.2	6.6	7.0	7.3	7.7	8.0	8.4	8.7	9.1	9.4	9.7	10.0
13								7.2	7.6	8.0	8.3	8.7	9.1	9.4	9.8	10.1	10.4
14								7.4	7.8	8.2	8.6	9.0	9.4	9.7	10.1	10.5	10.8
15								7.6	8.0	8.5	8.9	9.3	9.7	10.0	10.4	10.8	11.2
16								7.8	8.3	8.7	9.1	9.5	9.9	10.3	10.7	11.1	11.5
17											9.3	9.8	10.2	10.6	11.0	11.4	11.8
18											9.6	10.0	10.5	10.9	11.3	11.7	12.2
19											9.8	10.2	10.7	11.1	11.6	12.0	12.5
20											10.0	10.4	10.9	11.4	11.8	12.3	12.7

b

Weight (kg) \ Height (cm)	106	110	114	118	122	126	130	134	138	142	146	150	154	158	162	166	170	174	178	182	186	190
20	11.8	12.3	12.7	13.2	13.6	14.0	14.5	14.9	15.3	15.7	16.1	16.5										
22	12.3	12.8	13.3	13.7	14.2	14.7	15.1	15.6	16.0	16.4	16.9	17.3										
24	12.8	13.3	13.8	14.3	14.8	15.2	15.7	16.2	16.7	17.1	17.6	18.0	18.5	18.9	19.4							
26	13.2	13.7	14.2	14.8	15.3	15.8	16.3	16.8	17.3	17.8	18.3	18.7	19.2	19.7	20.1							
28	13.6	14.1	14.7	15.2	15.8	16.3	16.8	17.3	17.9	18.4	18.9	19.4	19.9	20.4	20.9	21.3	21.8					
30	13.9	14.5	15.1	15.7	16.2	16.8	17.3	17.9	18.4	18.9	19.5	20.0	20.5	21.0	21.5	22.0	22.5					
32	14.3	14.9	15.5	16.1	16.6	17.2	17.8	18.4	18.9	19.5	20.0	20.6	21.1	21.7	22.2	22.7	23.2	23.7	24.3			
34	14.6	15.2	15.8	16.4	17.0	17.7	18.2	18.8	19.4	20.0	20.6	21.1	21.7	22.3	22.8	23.4	23.9	24.4	25.0			
36	14.8	15.5	16.2	16.8	17.4	18.1	18.7	19.3	19.9	20.5	21.1	21.7	22.3	22.8	23.4	24.0	24.5	25.1	25.6	26.2	26.7	
38	15.1	15.8	16.5	17.1	17.8	18.4	19.1	19.7	20.3	21.0	21.6	22.2	22.8	23.4	24.0	24.6	25.1	25.7	26.3	26.9	27.4	
40			16.8	17.4	18.1	18.8	19.5	20.1	20.7	21.4	22.0	22.7	23.3	23.9	24.5	25.1	25.7	26.3	26.9	27.5	28.1	28.6
42			17.0	17.7	18.4	19.1	19.8	20.5	21.1	21.8	22.5	23.1	23.8	24.4	25.0	25.7	26.3	26.9	27.5	28.1	28.7	29.3
44			17.3	18.0	18.7	19.5	20.2	20.9	21.5	22.2	22.9	23.6	24.2	24.9	25.5	26.2	26.8	27.4	28.1	28.7	29.3	29.9
46			17.5	18.3	19.0	19.8	20.5	21.2	21.9	22.6	23.3	24.0	24.7	25.3	26.0	26.7	27.3	28.0	28.6	29.3	29.9	30.5
48			17.8	18.5	19.3	20.0	20.8	21.5	22.3	23.0	23.7	24.4	25.1	25.8	26.5	27.2	27.8	28.5	29.2	29.8	30.5	31.1
50			18.0	18.8	19.6	20.3	21.1	21.8	22.6	23.3	24.1	24.8	25.5	26.2	26.9	27.6	28.3	29.0	29.7	30.4	31.0	31.7
52						20.6	21.4	22.1	22.9	23.7	24.4	25.2	25.9	26.6	27.4	28.1	28.8	29.5	30.2	30.9	31.6	32.2
54						20.8	21.6	22.4	23.2	24.0	24.8	25.5	26.3	27.0	27.8	28.5	29.2	29.9	30.7	31.4	32.1	32.8
56						21.1	21.9	22.7	23.5	24.3	25.1	25.9	26.6	27.4	28.2	28.9	29.7	30.4	31.1	31.9	32.6	33.3
58						21.3	22.1	23.0	23.8	24.6	25.4	26.2	27.0	27.8	28.5	29.3	30.1	30.8	31.6	32.3	33.1	33.8
60						21.5	22.4	23.2	24.1	24.9	25.7	26.5	27.3	28.1	28.9	29.7	30.5	31.3	32.0	32.8	33.5	34.3
62						21.7	22.6	23.4	24.3	25.2	26.0	26.8	27.7	28.5	29.3	30.1	30.9	31.7	32.4	33.2	34.0	34.8
64						21.9	22.8	23.7	24.6	25.4	26.3	27.1	28.0	28.8	29.6	30.4	31.3	32.1	32.9	33.6	34.4	35.2
66									24.8	25.7	26.5	27.4	28.3	29.1	30.0	30.8	31.6	32.4	33.2	34.1	34.9	35.7
68									25.0	25.9	26.8	27.7	28.6	29.4	30.3	31.1	32.0	32.8	33.6	34.5	35.3	36.1
70									25.2	26.1	27.0	27.9	28.8	29.7	30.6	31.5	32.3	33.2	34.0	34.9	35.7	36.5
72									25.4	26.4	27.3	28.2	29.1	30.0	30.9	31.8	32.7	33.5	34.4	35.2	36.1	36.9
74									25.6	26.6	27.5	28.4	29.4	30.3	31.2	32.1	33.0	33.9	34.7	35.6	36.5	37.3
76									25.8	26.8	27.7	28.7	29.6	30.6	31.5	32.4	33.3	34.2	35.1	36.0	36.8	37.3
78									26.0	27.0	27.9	28.9	29.9	30.8	31.7	32.7	33.6	34.5	35.4	36.3	37.2	38.1
80									26.2	27.2	28.1	29.1	30.1	31.1	32.0	33.0	33.9	34.8	35.7	36.7	37.6	38.5

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