Variability of \( k \) terms in bioelectrical impedance spectroscopy

Dear Sir:

Ellis et al described the validation of bioelectrical impedance spectroscopy (BIS) for measurement of volumes of intracellular water (ICW) and extracellular water (ECW) in healthy children (1). When they compared BIS with the dual-energy X-ray absorptiometry (DXA) and total body potassium (TBK) model, new \( k \) terms for the BIS computer model in children were derived. Their study is an important contribution to the field, but several issues need to be addressed.

The volume of ECW is arithmetically computed as total body water (TBW) minus ICW (from the DXA and TBK measurements, respectively). Comparison of the mean values for TBW minus ICW and ECW in Table 2 of the article should thus give only differences due to rounding errors. However, for African American males (14–18 y of age), Mexican American males (9–13 and 14–18 y of age), African American females (all age groups), and Mexican American females (9–13 y of age), much larger differences (up to 15 L) are present. Publication of the correct data for all ethnic age and sex groups would be helpful for comparison in future studies. The Bland-Altman comparisons between BIS and the other model are given for combined data of both sexes but not for the age groups. Quantitative data for the age groups in Table 3 would give the reader a sense of the effect of dependency of difference values on the average values. In the BIS results, the mean values for resistance from the Xitron BIS instrument readings would also be helpful for comparison with the authors’ previous data (2) and with future results.

The recalculated \( k \) terms for the BIS model, as reported by Ellis et al in the present study (eg, for males: \( k_{ECF} = 0.330 \) for the ECW constant and \( k_p = 3.05 \) for the ratio of resistivity of intracellular versus extracellular tissues), are different from the values reported by the same group of authors in their previous study (2) in which they compared the Xitron BIS instrument with dilution methods in subjects aged 3–29 y (\( k_{ECF} = 0.370 \) and \( k_p = 3.03 \), respectively). Ellis et al did not discuss whether these differences have any practical significance, which \( k \) terms for the BIS instrument under study should now be preferred in children, and whether the \( k \) terms were different between ethnic groups.

BIS has many advantages in children, including the absence of radiation exposure and the possibility of repeated measurements in the same individual. Elucidation of the issues raised above would be of great value for the users of this promising method in the fields of pediatrics and nutrition.

Kees de Meer
Departments of Pediatrics and Clinical Chemistry
Academic Hospital Free University
PO Box 7057
1007 MB Amsterdam
Netherlands
E-mail: k.demeer@azvu.nl

REFERENCES

Reply to K de Meer

Dear Sir:

We are pleased to see that our recent article (1) in the Journal received such a detailed examination by de Meer. The following is in response to his questions and requests.

We reexamined the data sets used to generate the mean values presented in Table 2. We found that 3 total body water (TBW) values were incorrect and we thank de Meer for bringing them to our attention. The correct values are given in the corresponding erratum. These errors were traced to a transposed entry and an incorrect age classification for one girl (13 y rather than 3 y). No other changes were found in the reanalysis of the remaining values presented in Table 2. When we calculated the mean extracellular water (ECW) values as the difference between the mean TBW and mean intracellular water (ICW) values, we found acceptable agreement after the above-noted corrections) when an uncertainty of only \( \pm 0.1 \) L was allowed for the mean TBW and ICW values, which is much less than the corresponding SEM for these values.

We did not provide resistance values in this article or in our previous article (2), partially because bioelectrical impedance spectroscopy (BIS), unlike single-frequency bioelectrical impedance analysis (BIA), generates an impedance locus plot that must be modeled. Furthermore, others have shown that the resistance values expressed in \( \Omega \) units can be instrument dependent; hence, we did not want to add to the confusion. However,
if one simply rearranges the terms in Eq 1, substitutes the values for weight and height from Table 1, $V_{ECF}$ from Table 3, and uses the $k_{ECF}$ constant provided with the Xitron instrument, a mean value for $R_e$ can be easily calculated. Likewise, if the appropriate values (including that derived for $R_e$) are substituted in Eq 2, one can obtain a mean value for $R_L$.

It is not too surprising to us that the results for the “constants” used with the BIS calculation are population specific or that they can be dependent on the criterion or reference method chosen for calibration. We already summarized in the Discussion (1) the various values derived for $k_{ECF}$ and $k_p$ as reported in the literature by other investigators. In a previous study that included adults (2), we compared the BIS estimates with those based on the dilution techniques. Although the dilution techniques, in principle, are conceptually straightforward, the actual measurements and assays are difficult to perform. A series of constants are needed, for example, to convert the deuterium and bromine spaces into estimates for TBW and ECW, respectively. Each step in the assay can introduce errors that are cumulative and we reported that the CV for $k_{ECF}$, based on dilution, was > 19%, whereas that for $k_p$ was 25–28%. The mean value for $k_{ECF}$ by dilution was ≈11% higher than that obtained in the present study. We found that the major difficulties with the dilution reference model were mainly with the bromine technique, a concern that has been expressed by others (3, 4). The CVs for dual-energy X-ray absorptiometry (DXA) and total body potassium (TBK), on the other hand, are of the order of 1–2% (5, 6), which is much better than for the dilution methods. Use of the DXA + TBK model as the reference resulted in significant improvements in the CVs for the BIS constants. The CV for $k_{ECF}$, for example, was ≈ 8%. We believe that the estimates derived for the BIS constants in the present study are much more reliable than are those based on the dilution techniques. We also believe that the prediction precision when BIS is used can be improved further if age-adjusted constants are used.

As noted in the first National Institutes of Health review of the BIA technology (7), and recently updated by an experienced expert panel (8), there are many technical advantages associated with the bioelectrical impedance methods. We believe that continued investigation of such techniques for use in various clinical applications will better show their strengths and weaknesses.

Kenneth J Ellis

Body Composition Laboratory
USDA/ARS Children’s Nutrition Research Center
Baylor College of Medicine
Houston, TX
E-mail: kells@bcm.tmc.edu

REFERENCES


Erratum

Ellis KJ, Shypailo RJ, Wong WW. Measurement of body water by multifrequency bioelectrical impedance spectroscopy in a multiethnic pediatric population. Am J Clin Nutr 1999;70:847–53. In Table 2 on page 849, three total body water (TBW) values are incorrect. The correct values are 24.6 ± 6.0 for 9–13-y-old Mexican American males, 39.4 ± 4.7 for 14–18-y-old Mexican American males, and 22.7 ± 4.6 for 9–13-y-old African American females. The data for all males and all females are correct as printed.