Fat-free mass of healthy North African children aged 8-16 years

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ABSTRACT

Introduction: To test the applicability, to North African Children, of previously published reference equations for fat-free mass (FFM), and if need be to establish a more reliable reference equation for FFM. Materials and Methods: Anthropometric data (gender, age, weight and height) were used as variables for 1000 healthy Tunisian children aged 8-16 years via a bioelectrical impedance analysis (Maltron analyzer BF-906). Results: The published reference equations did not reliably predict measured FFM. The reference equation was expressed as follow as: FFM (kg) = 0.4706 × body weight (kg) + 0.2161 × height (cm) - 2.4659 × gender (boys: 0; girls: 1) + 0.2167 × age (years) - 19.4452. A measured FFM is considered abnormal when it is beyond the limit of normal range (reference value ± 5.5 kg). The anthropometric data explained 86.9% of the FFM variance. Discussion: This FFM reliable reference equation enriches the World Bank of reference equations, and provides useful references for the care of paediatric patients.

KEYWORDS

Body Fat Distribution, Child, Body Composition, Anthropometry.

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INTRODUCTION

In children, there is a growing recognition of the need to measure the body composition, especially fat mass and fat-free mass (FFM), since it is an important index for an accurate evaluation of the nutrition status\(^1\), and a powerful prediction of mortality and morbidity\(^2\). This measure provides more useful information than the whole measurements of the weight, height and the derived parameter, body-mass index (BMI)\(^3\). The FFM, considered as a basis for the evaluation of an obese patient\(^4\), is often measured by the bioelectrical impedance analysis (BIA). The BIA, a non-invasive, inexpensive, portable and practical method for assessing the human body composition, widely used, is recognized for estimating the body composition\(^5,6,7\) and is known for its validity and utility for various sample groups including young and obese\(^8\).

The basis of the FFM interpretation relies on the comparison of the measured FFM with the predicted one from reference equations\(^9,10,11,12,13,14\). We should been in mind that Specific reference equations are most suitable for subjects who would closely match the reference population used originally when deriving the equation\(^15\). In North Africa, where paediatricians are faced with a growing choice of prediction equations for the estimation of FFM, the need for children’s specific local reference equations has been evidenced, at least for spirometric and exercise data\(^16,17\). As the use of non-local equations may lead to an erroneous clinical interpretation and possibly have a profound effect on the estimate obtained, the applicability of the published FFM reference equations in children\(^9,10,11,12,13,14\) should be assessed in this population this was demonstrated in the Sri Lankan Australian\(^3,14\) and Caucasian pubertal\(^15\) children.

As for other physiological parameters\(^16,17,18\), the use of the lower and upper limits of normal range (LLN, ULN, respectively) could be more appropriate to the body composition where the clinical question may involve a value that may be either too high or too low.
Thus, the aims of the present study are to test the applicability of previously published reference equations in relation to North African, and if need be, to establish a more reliable reference equation for FFM using anthropometric data.

**MATERIAL AND METHODS**

**Participants**
This prospective study was performed during a 15-month period (October 2007-December 2008) among a representative sample of healthy Tunisian White School children aged 8 to 16 years (12 ± 2 years). Children were chosen randomly from twelve different schools situated in the centre of Tunisia.

Os indivíduos selecionados eram voluntários saudáveis não sofrendo de doenças cardíacas ou pulmonares, síndrome metabólica e diabetes. Nenhuma criança esportista ou atlética foi selecionada.

Antes de iniciar o processo de tomada de medidas, foi dado aconselhamento integral sobre a natureza do protocolo aos sujeitos e aos seus pais, que deram um consentimento informado por escrito para o protocolo experimental. A aprovação do estudo foi obtida a partir da Comissão de Ética regional (Farhat Hached Hospital de Sousse, Tunísia), com número de aprovação e de registro fiscal 3405095/A/M/000.

**Procedures**
Data from each volunteer child included: gender, age (years), height (cm), weight (kg), and medical history. The predictive equation of the sample size was initially calculated, achieving a quantitative of 500 girls and 500 boys.

The height was measured with a standing stadiometer with a precision of 0.1 cm. The weight was measured with approximation of 0.1 kg with a digital scale (OHAUS, Florham Park, NJ, USA). The body mass index (BMI) was calculated as weight divided by height squared (kg·m⁻²). All the tests were performed in the morning between 8h and 13h.

**Bioelectrical impedance analysis:** The FFM was measured using a BIA (Maltron analyzer BF-906) according to the manufacturer’s specified instructions. The BIA applies a 50 Khz oscillating current of 800 µA. It has been previously reported that BIA shows a high reliability in the assessment of FFM.

Before beginning measurements, each child had a 10-minute rest. Children were instructed not to undertake any physical activity and to fast for 12 hours prior to the test. During the experiment, each child was first invited to empty his/her bladder and then was positioned calmly lied in dorsal decubitus, with arms slightly removed from the body; the legs were separated so that the thighs were apart. Tetra polar electrodes were used, being placed on the dorsal surface of the right hand and foot, in the metacarpal and metatarsal distal parts, respectively, and between the distal prominences of the radius and the ulna at the wrist, and medical and lateral malleoli at the ankle.

New electrodes were placed between each reading, and care was taken to ensure that the distance between them was at least 3 cm to avoid any possible interaction between electrodes, which may cause elevated resistance readings. Just before the test, we had to enter in the Maltron analyzer BF-906, the following parameters in appearing order: gender (boys/girls), height, weight and age. The average of three resistance readings was recorded for each subject. BIA measurements include the following parameters: body fat (kg), total body water (TBW, kg), FFM (kg), body impedance (Z, Ω) and resistance (R, Ω).

**Statistical treatment**
Data are presented as means ± standard deviation. The variables distribution and normality were assessed by Kolmogoroff-Smirnoff test. Data were analyzed using Statistica Software (Statistica Kernel version 6, StatSoft, France).

Comparison with published reference equations: The measured FFM was compared, for the same age range, with the predicted FFM calculated by each one using multiple published reference equations using paired t-tests and scatter plots. The limits of agreement (LOA) for FFM were calculated using the Bland-Altman method (measured FFM minus predicted FFM) by evaluating the mean differences against the average (mean ± 1.96 x standard deviation). The reference equation that provides the LOA closest to zero will be the most appropriate for our population.

Univariate correlation: The dependent variable (FFM) was normally distributed. t-tests were used to evaluate the association between FFM and the categorical variable (gender). Pearson product-moment correlation coefficients evaluated the associations between FFM and the continuous measures: age, height, weight, BMI.

FFM reference equation: The linearity of association between FFM and the continuous measures was checked graphically by plotting each regressor against the FFM. Only significantly and linearly associated variables were entered into the model. A linear regression model was used to evaluate the independent variables explaining the variance in FFM. Candidate variables were stepped into the model with a stepwise selection method. To determine
Table 1 - Morpho-anthropometric data in different age groups (n=1000)

<table>
<thead>
<tr>
<th>Age</th>
<th>Girls (n=80)</th>
<th>Boys (n=86)</th>
<th>Girls (n=80)</th>
<th>Boys (n=86)</th>
<th>Girls (n=138)</th>
<th>Boys (n=166)</th>
<th>Girls (n=196)</th>
<th>Boys (n=172)</th>
<th>Total sample (n=500)</th>
<th>Boys (n=500)</th>
<th>BMI = Body mass index. FFM = Fat-free mass. TBW = Total body water</th>
</tr>
</thead>
<tbody>
<tr>
<td>weight (kg)</td>
<td>29.0 ± 4.3</td>
<td>29.9 ± 5.3</td>
<td>33.9 ± 7.0</td>
<td>35.0 ± 7.1</td>
<td>45.9 ± 9.5</td>
<td>43.3 ± 7.9*</td>
<td>52.9 ± 11.0</td>
<td>52.0 ± 10.9*</td>
<td>43.6 ± 12.8</td>
<td>43.2 ± 12.1</td>
<td>16 ± 2</td>
</tr>
<tr>
<td>height (cm)</td>
<td>134 ± 6</td>
<td>138 ± 7*</td>
<td>144 ± 7</td>
<td>144 ± 6</td>
<td>156 ± 7</td>
<td>155 ± 9</td>
<td>160 ± 5</td>
<td>162 ± 9*</td>
<td>152 ± 11</td>
<td>153 ± 12*</td>
<td>5.3 ± 2.3</td>
</tr>
<tr>
<td>BMI (kg·m⁻²)</td>
<td>16 ± 2</td>
<td>16 ± 3</td>
<td>16 ± 2</td>
<td>17 ± 3</td>
<td>19 ± 3</td>
<td>18 ± 2*</td>
<td>21 ± 4</td>
<td>20 ± 3*</td>
<td>19 ± 4</td>
<td>18 ± 3*</td>
<td>5.5 ± 3.5</td>
</tr>
<tr>
<td>ffm (kg)</td>
<td>24.0 ± 3.7</td>
<td>24.8 ± 4.0</td>
<td>28.7 ± 5.4</td>
<td>30.1 ± 4.9</td>
<td>36.5 ± 5.8</td>
<td>36.7 ± 6.4</td>
<td>38.9 ± 6.1</td>
<td>44.5 ± 8.9*</td>
<td>34.0 ± 7.9</td>
<td>36.7 ± 10.1*</td>
<td>4.8 ± 1.6</td>
</tr>
<tr>
<td>body fat (kg)</td>
<td>4.8 ± 1.6</td>
<td>4.9 ± 2.0</td>
<td>5.3 ± 2.3</td>
<td>4.8 ± 3.2</td>
<td>9.3 ± 4.7</td>
<td>6.8 ± 3.9*</td>
<td>13.7 ± 7.3</td>
<td>7.3 ± 5.0*</td>
<td>9.5 ± 6.3</td>
<td>6.4 ± 4.2*</td>
<td>14.8 ± 2.4</td>
</tr>
<tr>
<td>tbw (kg)</td>
<td>14.8 ± 2.4</td>
<td>15.4 ± 2.6</td>
<td>18.0 ± 3.2</td>
<td>18.9 ± 2.8</td>
<td>21.4 ± 3.3</td>
<td>22.7 ± 4.7*</td>
<td>21.8 ± 3.2</td>
<td>28.0 ± 6.6*</td>
<td>19.9 ± 4.1</td>
<td>23.0 ± 6.9*</td>
<td>688 ± 59</td>
</tr>
<tr>
<td>resistance (Ω)</td>
<td>688 ± 59</td>
<td>672 ± 43</td>
<td>689 ± 66</td>
<td>695 ± 73</td>
<td>690 ± 81</td>
<td>651 ± 70*</td>
<td>693 ± 86</td>
<td>591 ± 76*</td>
<td>690 ± 77</td>
<td>638 ± 80*</td>
<td>672 ± 43</td>
</tr>
</tbody>
</table>

Data is expressed as mean±SD. ∗p < 0.05 (boys vs. girls).

Table 2 - Univariate Spearman’s correlation coefficients between the fat-free mass and children data

<table>
<thead>
<tr>
<th>Variables</th>
<th>Girls (n=500)</th>
<th>Boys (n=500)</th>
<th>Total sample (n=1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>age, yr</td>
<td>0.72*</td>
<td>0.76*</td>
<td>0.73*</td>
</tr>
<tr>
<td>height, cm</td>
<td>0.78*</td>
<td>0.88*</td>
<td>0.84*</td>
</tr>
<tr>
<td>weight, kg</td>
<td>0.89</td>
<td>0.94*</td>
<td>0.90</td>
</tr>
<tr>
<td>body mass index, kg·m⁻²</td>
<td>0.78*</td>
<td>0.70*</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Table 3 - Independent variables included in the forward linear stepwise multiple regression equation for the fat-free mass (FFM)

<table>
<thead>
<tr>
<th>independent variables</th>
<th>B</th>
<th>cumulative r²</th>
<th>se</th>
<th>1.64 × RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>girls (n=500)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>constant</td>
<td>-6.1965</td>
<td></td>
<td></td>
<td>6.6</td>
</tr>
<tr>
<td>BMI, kg·m⁻²</td>
<td>1.1803</td>
<td>0.607</td>
<td>1.08</td>
<td>6.6</td>
</tr>
<tr>
<td>age, years</td>
<td>1.4827</td>
<td>0.743</td>
<td></td>
<td></td>
</tr>
<tr>
<td>boys (n=500)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>constant</td>
<td>8.6649</td>
<td></td>
<td></td>
<td>4.5</td>
</tr>
<tr>
<td>weight, kg</td>
<td>0.9450</td>
<td>0.887</td>
<td>1.06</td>
<td>4.5</td>
</tr>
<tr>
<td>BMI, kg·m⁻²</td>
<td>-1.0272</td>
<td>0.923</td>
<td></td>
<td></td>
</tr>
<tr>
<td>age, years</td>
<td>0.4627</td>
<td>0.928</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total sample (n=1000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>constant</td>
<td>-19.4452</td>
<td></td>
<td></td>
<td>5.5</td>
</tr>
<tr>
<td>weight, kg</td>
<td>-2.4659</td>
<td>0.868</td>
<td></td>
<td>5.5</td>
</tr>
<tr>
<td>height, cm</td>
<td>0.4706</td>
<td>0.805</td>
<td>1.88</td>
<td>5.5</td>
</tr>
<tr>
<td>gender (Boys: 0; Girls: 1)</td>
<td>0.2167</td>
<td>0.869</td>
<td></td>
<td></td>
</tr>
<tr>
<td>age, years</td>
<td>0.2167</td>
<td>0.869</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B = Non standardized regression coefficient. r² = Determination coefficient. SE = Standard error. RSD = Residual standard deviation.
Retained FFM reference equation: FFM (kg) = -19.4452 + 0.4706 × Weight (kg) + 0.2161 × Height (cm) - 2.4659 × Gender (Boys: 0; Girls: 1) + 0.2167 × Age (Yr).
Interpretation: After the predicted FFM value from this retained equation for an individual child is computed, the lower limit of normal (LLN = - 1.64 × RSD) or the upper limit of normal (ULN = + 1.64 × RSD) for that patient may be obtained by, respectively, subtracting or adding 5.5 kg to the calculated value.
entry and removal from the model, significance levels of 0.15 and 0.05 were used, respectively. No colinearity between predictors was detected with variance inflation factors.

The appreciation of the model from this study was evaluated by the correlation and determination coefficients ($r$, $r^2$, respectively) and the standard error (SE). The 95% confidence interval (95% CI) was calculated: 95% IC = $1.64 \times$ residual standard deviation$^{19}$. A measured FFM superior to the ULN (reference value + 95% IC) or inferior to the LLN (reference value - 95% IC) was considered as abnormal$^{18,19}$.

P < 0.05 was considered statistically significant.

RESULTS

Anthropometric data

The number of children in each age group, the gender distribution and the morpho-anthropometric data are given in Table 1. In the total sample, there were no significant differences between boys ($n = 500$) and girls ($n = 500$) or weight (Table 1). Boys have significantly higher height, FFM and TBW. Girls have significantly higher BMI, resistance and body fat (Table 1). The difference in FFM between boys and girls is significant only in age group of 14-16 years. This difference could be related to the height and BMI differences within the same group (Table 1).

Figure 1 shows the FFM data of the 1000 children, according to age (Figure 1.A), height (Figure 1.B) and weight (Figure 1.C) ranges. Wide FFM ranges were noted for the entire group, from 15.1 kg to 62.2 kg in girls, and 15.1 kg to 77.7 kg in boys.

Comparison with published reference equations

Figure 2 shows the Bland and Altman$^{25}$ comparisons between the measured and predicted FFM from the published reference equations$^{9,10,11,12,13,14}$. There was a systematic bias between the measured and predicted values for all these equations. For the same age ranges, our mean $\pm$ SD measured FFM was significantly underestimated by $1.5 \pm 3.1$ kg ($p < 0.05$) (Figure 2.A), $2.0 \pm 2.8$ kg ($p < 0.05$) (Figure 2.B), $1.2 \pm 2.6$ kg ($p < 0.05$) (Figure 2.C), $1.2 \pm 3.0$ ($p < 0.05$) (Figure 2.D), $3.4 \pm 4.1$ kg ($p < 0.05$) (Figure 2.E) and $4.9 \pm 3.4$ kg ($p < 0.05$) (Figure 2.F), respectively, with the reference equations from Rush et al.$^{13}$, De Lorenzo et al.$^{12}$, Deurenberg et al.$^{9}$, Houtkooper et al.$^{10}$, Schaefer et al.$^{11}$, Wickramasinghe et al.$^{14}$

Univariate analysis

Gender affects significantly the FFM (Table 1). On average, the FFM value was 2.7 kg greater in boys when compared to girls ($p < 0.05$). Table 2 exposes the coefficient correlation between the FFM and children

Figure 1 - The fat-free mass (FFM) of different subgroups of children, according to age (Figure 1.A), height (Figure 1.B) and body weight (Figure 1.C) ranges.

n = number of children.

* $p < 0.05$: Comparison (Man Witney U test) from one range to the next. NS: not significant.
data. All the anthropometric data were significantly correlated to the FFM.

**FFM reference equation**

For practical, daily interpretation of FFM, a reference equation should include only easily measured anthropometric data. Consequently we established reference equation with the common parameters: gender, age, weight and height. Table 3 presents, for girls, boys and the total sample, the cumulative $r^2$ of the independent variables included in the FFM linear multiple regression equation.

The single model for the total sample, taking into consideration gender \[FFM (kg) = -19.4452 + 0.4706 \times \text{weight (kg)} + 0.2161 \times \text{height (cm)} - 2.4659 \times \text{gender (boys: 0; girls: 1)} + 0.2167 \times \text{age (years)}\], which explain at 86.9% ($r^2$) the FFM variability (Table 3). We thus used this model as the reference equation for our North African population (Table 3).

Relying on this reference equation calculated for the 1000 healthy children, the measured FFM by BIA corresponds to 100 ± 8% of the predicted FFM. The mean ± standard deviation measured FFM was not significantly different from the predicted value of our retained reference equation (-0.0 ± 3.3 kg) ($p = 0.99$). When compared with the published reference equation9,10,11,12,13,14 (Figure 2), our retained equation provides the closest LOA to zero (Figure 2.G).

**DISCUSSION**

In the present study, the FFM of a large group of healthy North African children aged 8-16 years was prospectively measured. Aware of the fact that available published reference equations did not reliably predict FFM in the referred North African population, it was looked for specific values in these children. Using anthropometric data as independent predictors, it was established a new single reference equation that explained 86.9% of the FFM variability.
The procedural factors that affect the FFM variability were controlled, such as the respect of the exclusion criteria, clear information and preparation of the children, the schedule of test\textsuperscript{15}. The adoption of exclusion criteria in the present research is motivated by the fact that their presence influences negatively the accuracy of the results obtained\textsuperscript{15}. These methodological precautions, thus, allowed us to obtain reliable results. Therefore, the present study, which is the first in a North African population, provides useful results for the interpretation of FFM in this population.

Each of the reference equations evaluated for this study has focused on a relatively small number of healthy children (number varied between 35 and 282) and on a limited age range often in prepubertal children (Table 4). Collected Data on a large age range between 8 and 16 years explain up to 86.9% of the FFM variability (Table 3), which appeared to be satisfactory.

In addition to the BIA, FFM can be effectively assessed using different methods, particularly, hydro-densitometry, K spectrometry, skin fold method and dual X-ray absorptiometry\textsuperscript{23,26}. Although BIA is less sensitive and less precise than the above-mentioned methods, it is useful as a highly reproducible, relatively accurate, clinically non-invasive, inexpensive, and portable technique\textsuperscript{3,22,23}. In addition, it is easy to perform because it requires minimal subject cooperation and an operator training\textsuperscript{23,27}. Also, BIA is a simple and rapid technique which can be provided by the push of a few buttons and by the exhibition of total body water (ACT) and FFM. To minimize the influence of fat-caused distortions in determining FFM, the operator applied to the children two pairs of topically placed electrodes using an alternating current, and this significantly reduces the influence of skin resistance\textsuperscript{15}.

In actual use, however, the BIA calculation of a subject’s body fat may vary by as much as 10% of weight because of the difference in machine and methodology used\textsuperscript{15}. Equations and their variables differ, as does the choice of a reference method\textsuperscript{10}. There is need for a consensus among experts in the appropriate conditions.

Figure 2 - Bland and Altman representation between measured and predicted fat-free mass (FFM), determined from Rush et al. (Figure 2.A), De Lorenzo et al. (Figure 2.B), Deurenberg et al. (Figure 2.C), Houtkooper et al. (Figure 2.D) Schaefer et al. (Figure 2.E), Wickramasinghe et al. (Figure 2.F) and from the local reference equations (Figure 2.G).

Continue line: Mean difference. Dotted line: Mean ± 1.96 standard deviation.
of use and appropriate applications of BIA. In addition, results vary from one person to another because of a different body size, shape, electrolytes, fluid distribution, or other aspects of the body composition and will vary in the same person from time to time as these characteristics change. Thus, the smallest change in the body size, shape, or composition will at least have a small effect on impedance\textsuperscript{3,14}.

The drawback of the BIA method is that it estimates FFM by using mathematically derived prediction equations, the majority of which were derived from North American and west European populations. The validity of their usage on other populations has been questioned\textsuperscript{3}. It is always prudent to develop an appropriate equation to convert the measured impedance to a body composition parameter.

As recommended for such a study aiming to establish a reference equation, the instruments and procedures used to generate the reference equations met current standards. The reference population was well-defined, had a reasonable size and the limits of the reference range were well-defined. The reference equation was biologically appropriate to the subjects we serve, with a focus on anthropometric data and ethnic characteristics\textsuperscript{18}.

Discussions of the BIA reports often include a discussion of “equations”. These equations are those describing the statistical relationships found for a particular population and are not derived from biophysical reasoning, although plausible arguments in their support are often provided. In this study, were focused only the anthropometric data. Weight is commonly included in formulas used to estimate FFM (Table 4) from BIA measurements, and thus it is important that weight be measured accurately. Over- or underestimation of weight by 1 kg can cause an error of 0.2 liters of TBW. Thus, subjects should have weight determined to the nearest 0.1 kg\textsuperscript{14}.

In the current prediction equation, the height showed a high degree of association with the dependent variable of the total sample (Table 2) and present best correlation to the published reference equations\textsuperscript{9-14}. Gender, in line with other studies\textsuperscript{9-14}, appears to be an independent influencing factor of FFM. The use of age- and gender-specific reference equations for the density of FFM for children provides more accurate criteria estimates of FFM and therefore of percentage of body fat\textsuperscript{14}. In our population sample, the difference between girls and boys could be attributed to the height, the BMI, the resistance and the TBW differences (Table 1). In this study, age\textsuperscript{11} was found to be a very good predictor of FFM (Table 3). It provides reference values and prediction equations for FFM based on a large (n = 1000) sample of a healthy

### Table 4 - Fat-free mass (FFM) reference equations

<table>
<thead>
<tr>
<th>gender (n)</th>
<th>age</th>
<th>FFM influencing factors</th>
<th>FFM reference equations</th>
<th>r²</th>
<th>se</th>
<th>1.64 x RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>not mentioned (n=35)</td>
<td>7.7-13.0</td>
<td>h²/r, weight</td>
<td>= 0.588 × h²/r + 0.211 × weight + 2.330</td>
<td>0.92</td>
<td>1.0</td>
<td>?</td>
</tr>
<tr>
<td>Netherlands: Deurenberg et al. 1989 (14)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>boys (33)</td>
<td>girls (31)</td>
<td>gender, h²/r, weight</td>
<td>= 0.430 × h²/r + 0.354 × weight + 0.9 × gender (1: boys; 2: girls)</td>
<td>1.65</td>
<td></td>
<td>?</td>
</tr>
<tr>
<td>USA: Houtkooper et al. 1992 (15)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>boys (53)</td>
<td>girls (41)</td>
<td>h²/r, weight</td>
<td>= 0.61 × h²/r + 0.25 × weight + 1.31</td>
<td>0.95</td>
<td>3.9</td>
<td>?</td>
</tr>
<tr>
<td>New Zealand: Rush et al. 2003 (18)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>boys (83)</td>
<td>girls (89)</td>
<td>h²/r, weight</td>
<td>= 0.622 × h²/r + 0.234 × weight + 1.166</td>
<td>0.96</td>
<td>2.44</td>
<td>?</td>
</tr>
<tr>
<td>Germany: Schaefer F et al. 1994 (16)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>not mentioned (n=112)</td>
<td>4-19</td>
<td>h²/r, age</td>
<td>= 0.65 × h²/r + 0.68 × age + 0.15</td>
<td>0.97</td>
<td>1.98</td>
<td>?</td>
</tr>
<tr>
<td>Sri Lanka: Wickramasinghe et al. 2007 (19)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>boys (158)</td>
<td>girls (124)</td>
<td>h²/r, weight, gender</td>
<td>= 0.56 × h²/r + 0.22 × weight + 1.6 × gender (1: boys; 0: girls) -0.22</td>
<td>0.87</td>
<td>2.7</td>
<td>2.8</td>
</tr>
<tr>
<td>North Africa: Present study</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>boys (500)</td>
<td>girls (500)</td>
<td>weight, age, gender, h</td>
<td>= 0.4706 × weight + 0.2161x height - 2.4659 × (boys: 0; girls: 1) + 0.2167 × age -19.4452</td>
<td>0.87</td>
<td>1.88</td>
<td>5.5</td>
</tr>
</tbody>
</table>

n = number of children. h = height (cm). r = resistance. bmi = body mass index (kg.m²). r² = determination coefficient. se = standard error. rsd = residual standard deviation.
Tunisian children (8-16 years). Accurate reference values for this age group are important for clinical purposes. As occur with all predictive equations, they are only valid for this specific group, i.e. children aged 8-16 years and with a height of 134-160 cm for the boys and 138-162 cm for the girls. Significant differences were found between the measured and predicted FFM from the published reference equations (Figures 2). This is in agreement with the study of Reilly et al. investigating the ability of some published pediatric FFM equations to predict FFM in 98 Caucasian prepubertal children. They found that the equations of Deurenberg et al. and Schaefer et al. systematically underestimated reference FFM. The equation of Houtkooper et al. predicted FFM with negligible bias and had narrower LOA agreement relative to the reference method than the other equations tested. They conclude that the ability of the whole body impedance to predict the body composition in children depends on the chosen equation and that the general applicability of the whole body impedance equations cannot be safely assumed.

The implications of this on children with chronic diseases, such as obesity or diabetes, may be considerable and include potential errors regarding the level of the patient’s disability and unrealistic expectations of therapeutically interventions. This argues for the use of a specific reference equation. For purely practical reasons, we established a single FFM reference equation that included easier measured parameters (weight, height, gender and age), as independent variables. This equation still explains 86.9% of the FFM variability, which is at least as good as the published reference equation (Table 4).

The way of interpreting the measured FFM is a subject of controversy. The present investigation in all medical decisions making depends as much on selecting and properly using reference equations and their limits - the boundaries that lead to changes in action - as it does on getting the measurements correct. In interpreting the reference values for FFM, we compared typically a patient’s measured values with reference values drawn from the population studies and labelled ‘normal’ values. The LLN or the ULN are most commonly defined, respectively, as the lower and the higher 95% IC (Table 3). Patient values between those 2 demarcations are often arbitrarily labelled ‘normal’ while those below or above are labelled ‘abnormal’. The terms ‘normal’ and ‘abnormal’ are problematic because they may inaccurately imply health or disease.

Using only a LLN or ULN is adequate for FFM since the clinical question being asked is to know whether the measured value is too low or too high. One should also be more cautious in the interpretation when the measured value is close to a threshold, the situation where errors are more likely to occur. When possible, clinical information should be used to make these ‘close calls’.

As recommended, our reference equations should not be extrapolated beyond the reported ranges of the age (8-16 years) and stature (121-192 cm) of the reference population.

The BIA is useful for a rapid assessment of the body composition in a series of circumstances. It is important that the body composition assessment techniques to be valid for the population in which they are used. This way, it was established an equation of reliable reference equation to interpret the results of FFM in healthy North African children. The present FFM reference equation, which helps to overcome the interpretation obstacle, can be easily predicted from simple measured anthropometric parameters. The current FFM equation enriches the World Bank of reference equations, from which the physician should choose according to the patient’s local and ethnic background.

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REFERENCES


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