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ABSTRACT

Energy availability (EA) is calculated by subtracting exercise energy expenditure from energy intake, adjusted for fat free mass (FFM) obtained using accurate methods, such as dual-energy X-ray absorptiometry (DXA). Unlike DXA, the bioelectrical impedance analysis (BIA) is low in cost, simple and easy to carry out. This study aimed to test the concordance between the calculation of EA using FFM values from four BIA predictive equations and FFM obtained using DXA in female adolescent athletes (n=94), recruited via social media. Paired Student's t-test, Wilcoxon test, Lin's concordance correlation coefficient (CCC), root means square error (RSME), limits of agreement (LOA) and mean absolute percentage error (MAPE) were used to evaluate agreement between the FFM values obtained by the four SF-BIA predictive equations and DXA. Regression linear analysis was used to determine the relation between FFM values obtained using DXA and the BIA predictive equations. Standardized residuals of the FFM and EA were calculated considering DXA values as reference. The most appropriate model for the FFM (LOA= 4.0/-2.6 kg, RMSE=1.9 kg, MAPE= 4.34%, CCC=0.926) and EA (LOA= 2.51/4.4 kcal/kg.FFM/d, RMSE=1.8 kcal/kg. FFM/d, MAPE 4.24%, CCC=0.992) was the equation with sexual maturity as a variable, while the equation with the greatest age variability was the one with the lowest agreement. FFM-BIA predictive equations can be used to calculate EA of female adolescent athletes. However, the equation should be chosen considering sex, age, and maturation status. In the case of athletes, researchers should use equations developed for this group.

INTRODUCTION

Athletes' energy requirements depend on the volume, intensity, periodized training, and competition cycle. Some factors, such as exposure to cold, heat, high altitude, stress, physical injuries, and increases in fat-free mass (FFM), increase energy requirements above normal baseline levels (Thomas et al, 2016). Puberty is a biological phase of great growth and development, causing changes in body composition (Malina et al., 2011). In female adolescents, the age of menarche is a marker of sexual maturity leading to changes in body composition, such as accumulation of fat mass (FM) and FFM, the former mostly in certain body regions, such as the gluteal-femoral area, and the latter in a lower proportion than in male adolescents (Malina et al., 2011).

Energy balance is a primary factor in body composition, since energy intake higher than energy expenditure can lead to body weight gain, and energy expenditure higher than intake can reduce FFM and bone mineral density, cause changes in reproductive function, and impact the growth of adolescents (Loucks, 2004). Differently from energy balance, the concept of energy availability (EA) is broader, as it considers the FFM as a variable for the calculation. EA is defined as the residual energy available to support an athlete's body functions. Low EA (L-EA) is a primary mechanism of the female athlete's triad that predisposes athletes to menstrual irregularities and low bone mineral density (Nattiv et al., 2007), and is considered a major factor in several health problems in athletes of both sexes, and it is described as a relative energy deficiency in sports (Mountjoy et al., 2018).

EA is obtained by subtracting exercise energy expenditure from energy intake, adjusted by FFM (Loucks et al, 2004, 2011). Each component of the equation relies on accurate measurement tools and a clear definition of what should be measured (Loucks et al., 2004). FFM can be obtained by gold standard methods, such as four compartments model, or high-accuracy, such as DXA (Shepherd et al., 2017). However, these methods are expensive and makes it difficult to study large groups of athletes (Nana et al., 2015). Besides that, 4C model is time-consuming and difficult to perform in children and adolescents (Sopher et al., 2004). Conversely, bioelectrical impedance analysis (BIA) is low in cost, simple and easy to carry out, and does not expose the subject to radiation (Kyle et al., 2004). Although the BIA method is widely disseminated, few studies have used FFM from BIA predictive equations to calculate EA (Koehler et al, 2013, Lagowska 2014, Lagowska et al, 2016, Brown et al., 2017, Braun et al, 2018). However, these studies did not test the concordance between the results of the predictive equation and those obtained by a more accurate method.

Considering the importance of predicting FFM in adolescent athletes by low-cost methods such as BIA, and of calculating EA in this vulnerable group, this study aimed to test the concordance between the calculation of EA using FFM values from four BIA predictive equations and values obtained using DXA in female adolescent athletes.

METHODS

Participants

The sample size was determined *a priori* using a statistical software (G*Power 3.1.9.7 Stuttgart, Germany) assuming: effect size= 0.2; α= 0.5; Power (1-β error probability) = 0.95. The estimated number of participants was 70 individuals per group.

The participants were recruited via social media (Instagram advertisement [https://www.instagram.com/saude_de_atleta/]). After scheduling consultations, data were collected at the Interdisciplinary Laboratory of Nutritional Assessment, of the Institute of Nutrition of the University of the State of Rio de Janeiro, during the second semester of 2017. All participants in the study were adolescents (10 - 19 years; WHO, 1995). Only adolescents that had been playing sports in a sports club for at least 6 months and agreed to participate after being informed of the research objectives were included in the study.

This study was approved by the Ethics Committee of the Hospital Universitário Pedro Ernesto (CEP/HUPE649.202) in accordance with the Declaration of Helsinki. All guardians and participants provided prior written informed consent.

Study design

This was a cross-sectional study with female adolescent athletes. Individual data were collected on the same day, including anthropometric measurements and determination of body composition, using both single frequency SF-BIA and DXA methods. The athletes were divided into two groups according to EA cutoffs: adequate (≥45 kcal/kg/FFM-1/d-1) and inadequate (<45 kcal/kg/FFM-1/d-1) energy availability (Nattiv et al., 2007).

The FFM values obtained by DXA were used as a reference for the tests of concordance of the results obtained by SF-BIA predictive equations. The FFM values obtained by the predictive equations were used to calculate EA. Besides that, the concordance between EA values obtained using DXA and SF-BIA was tested.

Sexual maturity

Sexual maturity was determined by the menarche occurrence, which was reported by the individuals. The participants whose menstrual cycle had already begun were classified as sexually mature, and those whose menstrual cycle had not begun were classified as sexually immature.

Anthropometric measurements and body composition

Body mass and height were obtained using a digital scale and a stadiometer (Filizola, Rio de Janeiro, Brazil). Fat-free mass and bone mineral density were estimated with the DXA method. The Lunar iDXA device with enCore 2008 software version 12.20 (GE Healthcare, Madison, Wisconsin, USA) was used in the automatic full-body scan mode. The participants were placed in a dorsal position and asked to remain immobile until the end of the procedure. The exams were performed by a single trained and qualified professional, following the quality control procedures recommended by the manufacturer, and the official recommendations of the International Society for Clinical Densitometry (Crabtree et al, 2014). BMD z-scores < - 1.0 SD were classified as "low bone mineral density" (Nattiv et al, 2004).

Body composition using the BIA method was measured using a single frequency bioimpedance analyser (Biodynamics-450 Corporation, Seattle, USA), applying foot-to-hand technology. To avoid clinical disturbances in fluid distribution, participants were instructed to abstain from food and liquids for 4 hours and to abstain from caffeine intake and intense physical activity for 24 hours before SF-BIA. The adolescents were instructed not to undergo the exam during their menstrual period. Before each test, the analyser was checked with the impedance calibration (resistance R= 500 ohms); and the components inside the bioimpedance analyzer, such as the signal generator, the sensing apparatus, the scales of weight and height, and the electrical interference were tested as suggested by Kyle et al.

(2004). The average of the two repeated measurements of R and Xc was used in the subsequent analyses.

The predictive equations were selected based on the following criteria: 1) validated by DXA; 2) pertained to healthy participants and regular sports players; 3) BIA analyser used to develop the single frequency equation (50 kHz); 4) sex as a variation of the predictive equation; and 5) age range according to puberty. Four proposed predictive equations met the inclusion criteria: Deurenberg et al. (1991), Koury et al. (2019), Morrison et al. (2001), and Sun et al. (2003). The variables included in the calculation of FFM using SF-BIA predictive equations were: age, sex, reactance, body mass (except Koury et al. 2019), height^2/resistance ratio, menarche occurrence (Koury et al. 2019, only). Table 1 shows the details of the selected equations.

Energy availability

Two nutritionists applied a questionnaire, and each participant was interviewed once time by only one nutritionist. Energy intake was obtained by a 24-hour recall reported by the participants individually, and the target period of the interview was the previous typical day. Both nutritionists were trained to use the US Department of Agriculture Automated Multiple-Pass Method (Conway et al., 2003), which consists of five steps: 1) the participants are invited to verbally provide a quick list of foods and drinks consumed, without interruption as they speak; 2) the participants are asked about foods they might have forgotten to mention; 3) the participants describe in detail the time at which each food was consumed; 4) the participants are encouraged to describe in detail the food and the respective quantities, reviewing the information about the time and occasion of consumption; and 5) the information is reviewed, and foods that were consumed and any food that has not been reported are identified. The participants received the Brazilian Photographic Manual of Food Portion Quantification (Monteiro, 2007) containing main household items and their conversion into grams and millilitres (Pinheiro et al., 2004) to facilitate their description of the portions consumed. The Brazilian Table of Food Composition (Universidade Estadual de Campinas - UNICAMP, 2011) was used for the calculation of nutrient intake.

Metabolic equivalent task (MET) values were used for each sport as scored for moderate effort, using the youth compendium of physical activities (Ridley et al., 2008). Exercise energy expenditure was calculated individually using MET values and the period of time stated for exercise sessions. Energy availability was calculated as: energy intake minus energy expenditure divided by FFM (kg) values, obtained using DXA and the four SF-BIA predictive equations (Table 1).

To the best of our knowledge, there are no studies with specific cutoff points for energy availability in adolescents. Thus, the values for adult females have been used in studies on adolescents (Logue et al, 2020).

For young females who were physically active (Nattiv et al., 2007), energy availability was considered inadequate when the values were lower than 45 kcal/kg.FFM/d when assessing bone health, and when the values were lower than 30 kcal/kg.FFM/d when assessing reproductive function.

Statistical analyses

Statistical analyses were performed using SPSS software version 19 (IBM Corporation, Armonk, NY, USA) and MedCalc Statistical Software version 14.8.1 (MedCalc Software, Ostend, Belgium; http://www.medcalc.org; 2014). The Shapiro Wilk test was performed to determine whether data was normally distributed.

Anthropometric measurements and body composition compartments were expressed as mean±standard deviation. The independent Student's t-test was used to determine differences between groups, according to the EA classification (inadequate <45 kcal/kg.FFM/day, or <30 kcal/kg.FFM/day). Energy and nutrient intake were expressed as medians, and interquartile ranges and were compared using the Mann-Whitney-U test.

The paired t-test was used to determine the difference between the FFM values obtained by the four SF-BIA predictive equations and values obtained using DXA, and Wilcoxon test was used to compare EA values using FFM obtained using SF-BIA predictive equations. The mean absolute percent error (MAPE) and the root means square error (RSME) between FFM and EA observed (DXA) and predicted (SF-BIA) values were calculated.

Bland-Altman plots were also used to test individual-level agreement between each SF-BIA predictive equations and DXA values. Lin's concordance correlation coefficient (Lin, 1989) was used considering the strength-of-agreement criteria described by McBride (2005) (almost perfect: > 0.99; substantial: 0.95 - 0.99; moderate: 0.90-0.95; and poor: <0.90).

RESULTS

One hundred female athletes aged between 11 and 16 years agreed to participate in the study. Body composition data was obtained from 94 (40 [42%], sexually immature) of the participants, and all the necessary data for the calculation of EA (n= 16 [23%], sexually immature) was obtained from 70 (74%) of the participants. All participants trained regularly (6 times a week for at least 90 minutes/day).

The sports mentioned by the participants were soccer (n= 22), volleyball (n= 23), swimming (n= 14), table tennis (n= 15), and handball (n= 20). Regardless of the sport practiced, energy expenditure was similar between groups according to sexual maturity (immature - median = 352.3 kcal/d [IQR = 283.1 - 413.6]; mature - median = 398.7 kcal/d [IQR 289.1 - 523.5]; p = 0.155). The sport did not influence the other results.

Female adolescent athletes' energy and nutrient intake according to the availability of energy classification is shown in Table 2. L-EA (<30 kcal/kg.FFM/day (n=41,6%) or

<45kcal/kg.FFM/day (n=46,7%) female adolescent athletes presented lower carbohydrates, lipids, and proteins intake ($p < 0.01$) than adolescents with adequate EA.

The raw SF-BIA parameters (R and Xc) and phase angle values were: reactance (n=94), mean±SD= 70.4±9.4 Ω (95%CI 68.4 – 72.1); resistance (n=94) mean±SD= 666.4±73.5 Ω (95%CI 651.4 – 681.5), and phase angle (n=94), mean±SD= 6.1º±0.8 (95% CI6.0 – 6.3).

The paired t-test showed that the four equations tested provide different values than those obtained by DXA for FFM and for EA (Table 3). FFM data obtained by the SF-BIA predictive equations showed good symmetry (values between -0.5 and 0.5), and kurtosis showed flat curves (platykurtic). P-values for the Shapiro Wilk normality test indicated normal distribution results for all FFM predictive equations ($P > 0.05$). The results of the EA calculated applying the FFM values using SF-BIA predictive equations showed symmetry in the maximum limit (0.5), kurtosis showed an elongated curve (leptokurtic). The P-values for the Shapiro Wilk test showed no normal distribution ($P < 0.05$) for all predictive equations (Table 3).

The FFM values obtained by Deurenberg et al. (1991), Morison et al. (2001), and Sun et al. (2003) showed the lowest values of the concordance correlation coefficients (CCCs) classified as poor concordance by McBride (2005). The CCC values were corroborated by the different RMSE values obtained. The predictive equation proposed by Koury et al. (2019) showed a better result, less difference between the means, CCC classified as moderate (McBride, 2007), and lower RMSE. The Koury et al. (2019) (R^2= 0.927) and Sun et al. (R^2= 0.913) predictive equations showed higher R^2 values of the linear regression models for the sexually immature group. However, the RMSE and MAPE values showed a better performance for the Koury et al. (2019) equation (RMSE= 2.31 kg, MAPE= 4.34%) than Sun et al. (RMSE= 5.64 kg, MAPE= 12.58%) predictive equation (Figure 1).

All SF-BIA-predictive equations tested to calculate EA showed a high CCC value, being classified as excellent for the prediction of EA (McBride, 2005). Although the equation proposed by Sun et al. (2003) had a limit value to be considered as concordant (CCC= 0.95), the other equations had similar values (CCC= 0.99). Despite the high CCC values, the RMSE and MAPE values indicated that the predictive equation proposed by Sun et al. (2003) was the one with the greatest error (RMSE= 5.6 kcal/kg.FFM/day, MAPE= 12.05%), followed by those proposed by Morrison et al. (2001) (RMSE= 2.8 kcal/kg.FFM/day, MAPE= 5.31%), Deurenberg et al. (1991) (RMSE= 2.4 kcal/kg.FFM/day, MAPE= 4.34%), and Koury et al. (2019) (RMSE= 1.8 kcal/kg.FFM/day, MAPE= 4.23%) when compared with the EA values generated by DXA (Figure 2).

Considering all predictive equations, the standardized residuals for FFM showed that only one (1.8%) sexually mature participant was below the first quartile, and one was above the third quartile (1.8%), while 10 (25%) immature participants were below the first quartile. For EA, considering all predictive equations, standardized residuals showed that only one (2.5%) sexually immature participant was below the first quartile, and four (10%) were above the third quartile, while 8 (16%) sexually mature participants were below the first quartile and four (10%) above third quartile (Figure 3).

DISCUSSION

The present study is the first to assess the concordance between EA calculated with the FFM values, obtained from four SF-BIA predictive equations, and the FFM values obtained by DXA, in female adolescent athletes.

Although it is generally accepted that predictive equations of FFM using SF-BIA should be sex-specific for individuals over 13 years of age (Malina et al., 2011), only one study has proposed to estimate FFM-BIA considering maturity indicators in adolescent athletes, such as skeletal maturity for boys and sexual maturity for girls (Koury et al., 2019).

Among the four equations tested in the present study, two showed great variation in the age range: 82 years for Sun et al. (2003); 76 years for Deurenberg et al. (1991); one included an age range corresponding to childhood and adolescence (a variation of 11 years, Morrison et al., 2001); and the other one included an age range corresponding exclusively to adolescence, with a variation of 4 years, and a variable related to sexual maturity (Koury et al., 2019). The growth of adolescent athletes leads to specific adaptations in body composition (Toselli et al., 2020) that can be accurately detected by BIA method, in within- and between-athlete comparisons (Campa et al, 2022), when using adequate predictive equations.

The Koury et al. (2019) predictive equation presented the highest CCC, lowest bias, and lowest RMSE and MAPE values, all of which indicate a better fit, when compared to Deurenberg et al (1991) and Morrison et al (2003) predictive equations. These results are in line with the concept of Chumlea and Sun (2005), who stated that the equation with a high value of R^2 and a low value of RMSE is likely to have lower bias. Considering the FFM obtained using predictive equations developed by Koury et al. (2019) and Sun et al. (2003), both presented similar values of R^2 for the sexually immature participants. Despite the similarity, Koury et al. (2019) equation showed better performance in terms of RMSE and MAPE values for all participants and for the sexually immature group, confirming the importance of including the variable 'sexual maturity' in the equation. The results of the analysis of standardized residuals support the idea that the absence of sexual maturity as a variable in the predictive equation could overestimate the values of FFM of sexually immature participants.

Predicting FFM and calculating EA can protect athletes from serious health problems. EA was initially proposed for adult females who consumed less energy than needed to support physiological functions, daily activities, and physical exercise. An EA frequently below the value considered adequate leads to endocrine adaptations that can cause amenorrhea (<30 kcal/kg. FFM/day), excessive weight loss, damage to bone mineral density, and eating disorders (Nattiv et al., 2007). The consequences of inadequate EA for adolescent athletes are more severe because it can occur concurrently with the period of growth and development, and may lead to irreparable impairment (Loucks et al., 2004; 2011).

In the present study, the FFM-BIA tested for EA calculation showed excellent CCC (95% to 99%), despite having different degrees of concordance for FFM-DXA. The equation proposed by Sun et al. (2003) had the lowest CCC value. The smallest mean difference in the RMSE and the lowest percentage of the MAPE were obtained using the FFM predictive equation proposed by Koury et al. (2019). The observed CCC indicated that the insertion of FFM in the denominator of the EA equation reduces the margin of error when these equations are used to calculate EA, suggesting that the variables with the greatest impact are those found in the numerator (energy intake and exercise energy expenditure).

In the present study, it was observed that 58% and 66% of the participants presented EA values below the reference values for adult females of 30 or 45 kcal/kgFFM/day, respectively, considering the calculation based on FFM-DXA. Other authors have found a similar percentage in studies with female adolescent athletes, using different methods to predict FFM. Cherian et al. (2018) and Silva et al. (2018) used skinfolds and EA values higher than 30 kcal/kgFFM/day, and 45 kcal/kgFFM/day, respectively, as cutoff points for adequacy. Both studies found that 40% of the participants were below the cutoff points defined by the authors. Brown et al. (2018) used the BIA method to predict FFM, and observed that 53% of the participants were below the cutoff point of 30 kcal/kgFFM/day. The main limitation of the present study is the absence of robust methods for predicting ingested and expended energy. However, to our knowledge, this is the first study to test FFM obtained using SF-BIA for EA calculation in female adolescent athletes. Furthermore, the present study included DXA analyses, which is considered an accurate method for FFM measurement (Burke et al, 2018); and only athletes participated, thus reducing the margin of error.

In conclusion, our results suggest that FFM-BIA predictive equations can be used to calculate EA of female adolescent athletes. The model proposed by Koury et al. (2019) presented the best performance in the statistical tests used. Furthermore, the lack of statistical concordance and high MAPE percentage suggest that Sun et al. predictive equation should be interpreted with caution when estimating FFM in female adolescent athletes. In general, this suggests that the equation must be chosen considering sex, age group, and maturation. In the case of athletes, researchers should use equations developed for this group. The calculation of EA using more economical and less complex methods is of great use in the field of sports nutrition. Calculating the EA is of great importance because it makes it possible to treat eating disorders, and to avoid problems related to reproductive function and later to bone health.

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Table 1 – Characteristics of the selected equations for prediction of fat-free mass using BIA

Authors	**Age (years)**	**Sex**	**Fat-free mass predictive equation**	**SEE (kg)**	**R^2**
Deurenberg et al, 1991	≤15	F – M (n=166)	$= 0.406 \times H^2/R + 0.36 \times W + 0.0558 \times H + 0.56 \times Sex - 6.48$	1.7	0.97
Koury et al, 2019	11-15	F (n=151)	$= -2.65+0.603 \times Age+0.954 \times (\text{menarche occurrence})+ 0.713 \times H^2/R$	2.2	0.84
Morrison et al, 2001	6-17	F (n=126)	$= - 6.41 + 0.56 \times H^2/R + 0.34 \times W+0.06 \times Xc$	3.3	0.99
(Sun et al, 2003	12-94	F (n=944)	$= - 9.53 + 0.69 \times H^2/R + 0.17 \times W+ 0.02 \times R$	2.9	0.83

F = Female, M = Male; H= height (cm); W= weight (kg); R= resistance(Ω), Xc = reactance (Ω); H^2/R = Height ^{2}/Resistance; Sex: male = 1, female = 0; menarche occurrence: no = 0, yes = 1. SEE = standard error of estimate. R^2 = Coefficient of determination.

Table 2- Intake of energy and nutrients by female adolescent athletes according to energy availability.

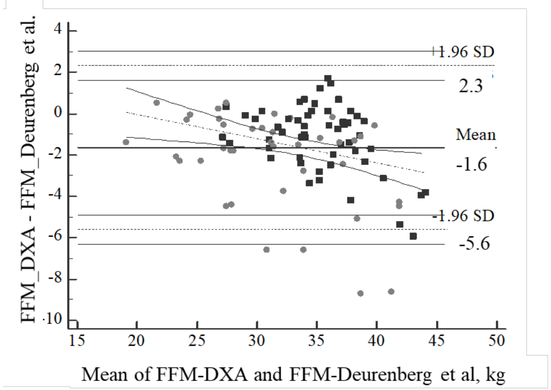
	All (n=70)	≥ 30kcal/kg.FFM/d (n=29)	< 30kcal/kg.FFM/d (n=41)	*p*	≥ 45kcal/kg.FFM/d (n=24)	< 45kcal/kg.FFM/d (n=46)	*p*
Energy, kcal	1,654.8 (1,246.4 – 1,987,3)	1,941.1 (1,682.9-2,505.1)	1,231.6 (1,003.4-1,431.4)	0.007	2,251.1 (1,787.7 - 2,679.9)	1,395.9 (1,101.1 - 1,654.8)	0.005
Carbohydrates, g	230.3 (174.5 – 287.5)	275.9 (230.8-370.2)	171.6 (142.9-200.3)	0.004	308.6 (242.5 - 408.1)	198.8 (159.9 - 236.8)	0.003
Lipids, g	45.1 (29.0 – 62.8)	55.3 (40.4-82.3)	34.3 (24.7-45.1)	0.003	75.6 (50.1 – 92.4)	34.7 (26.8 – 49.4)	0.005
Proteins, g	71.8 (53.2 – 84.7)	77.5 (70.0-95.4)	53.9 (41.8-69.6)	0.009	82.2 (71.9 – 101.7)	65.5 (46.5 – 76.8)	0.008

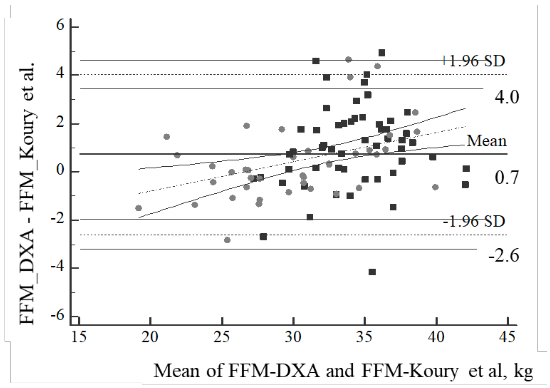
Median (interquartile range). FFM = fat-free mass. Mann-Whitney-U test.

Table 3 - Comparison between DXA and predictive equations from BIA for fat-free mass and energy availability of female adolescent athletes (n=94)

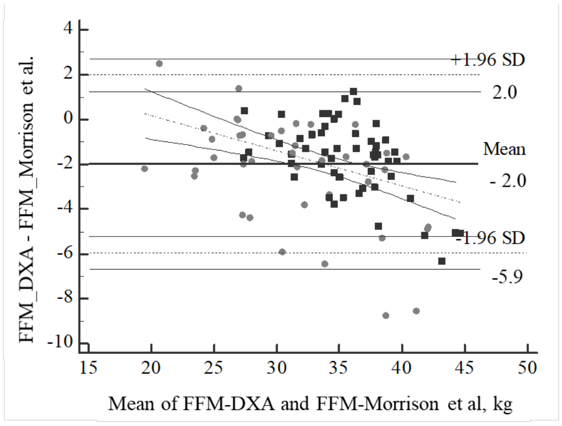
	Fat-free mass (n=94)				
	DXA	Deurenberg et al,1991	Koury et al, 2019	Morison et al, 2001	Sun et al, 2003
Mean (kg)	32.8±4.9	34.3±5.6	32.1±4.4	34.8±5.8	37.4±4.1
IC 95%	33.0 - 33.8	32.3 – 35.6	31.5 – 33.4	33.6 – 36.0	36.5 – 38.2
	(P-value¹)	0.01	0.01	<0.01	<0.01
	Skewness	-0.1	-0.4	-0.2	-0.09
	Kurtosis	-0.04	0.3	-0.09	0.04
	(P-value²)	0.54	0.12	0.69	0.95
	Energy availability (n=70)				
Median (kcal/kg.FFM /d)	36.8	34.5	37.6	34.2	32.5
IQR	25.3 – 50.6	23.3 – 52.5	25.8 – 53.7	22.9 – 52.2	22.2 – 44.8
	(P-value³)	< 0.01	<0.01	< 0.01	< 0.01
	Skewness	0.5	0.5	0.5	0.5
	Kurtosis	1.7	0.9	1.2	1.9
	(P-value²)	0.03	0.04	0.03	0.05

DXA = dual-emission X-ray absorptiometry. BIA = bioelectrical impedance. FFM = fat-free mass. CI = confidence interval. SD= standard deviation. (P-value¹) obtained using Paired t-test, comparison between DXA values and each SF-BIA predictive equation (<0.05 significant difference); (P²-vlaue) obtained using Shapiro Wilk test to test normal distribution (>0.05 normal distribution), (P³-vlaue) obtained using Wilcoxon test, comparison between DXA values and each SF-BIA predictive equation for EA calculation (<0.05 significant difference)





(A) **(B)**



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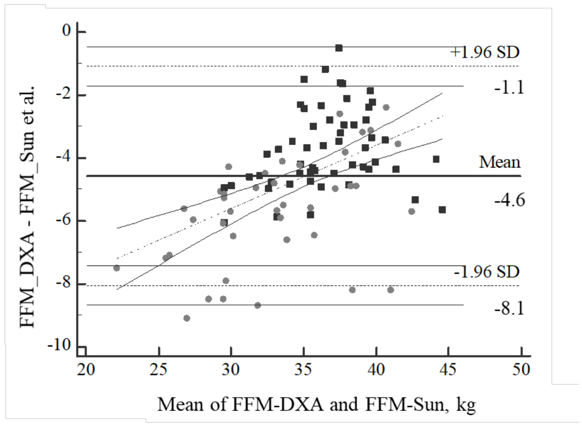
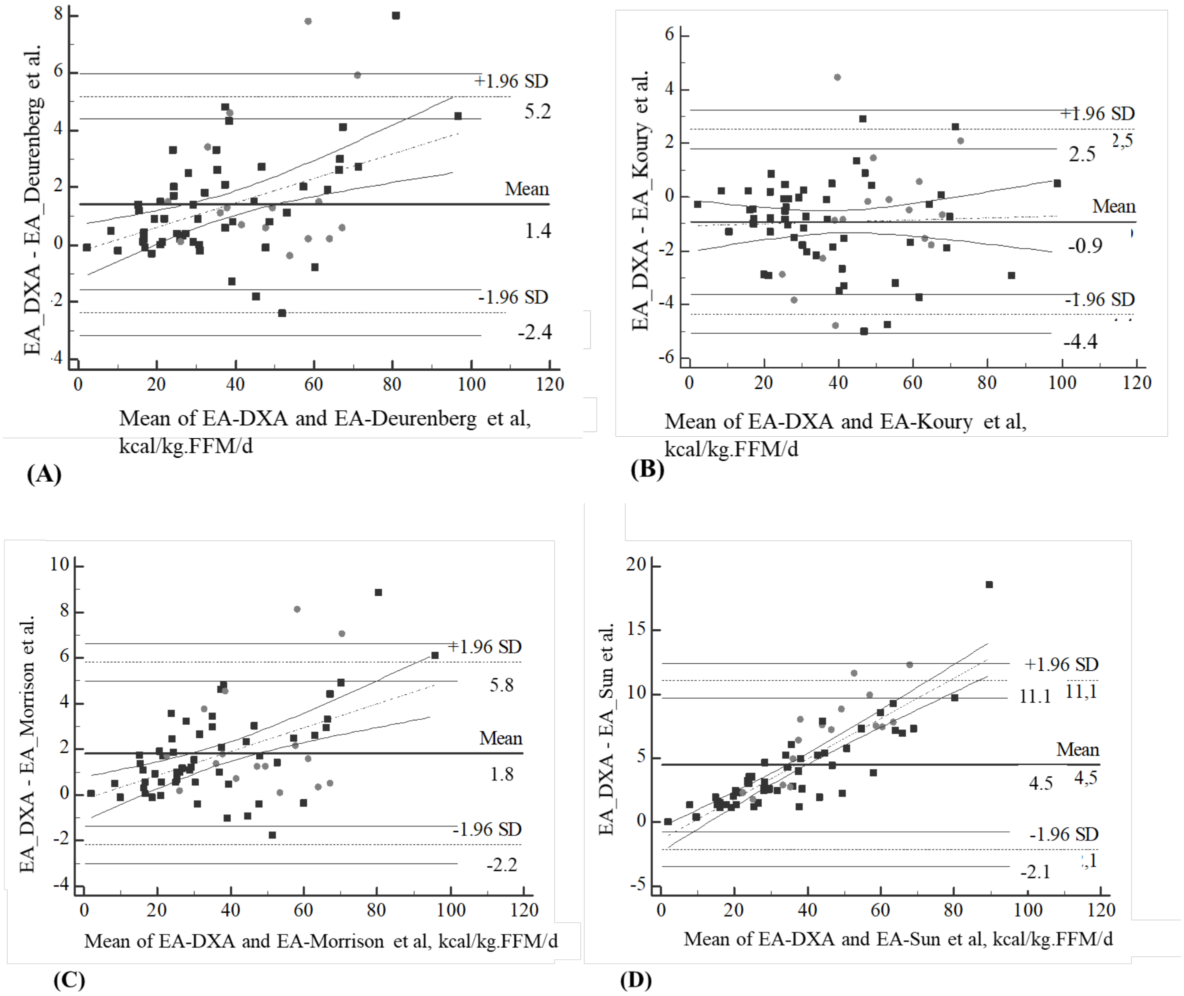


(D)

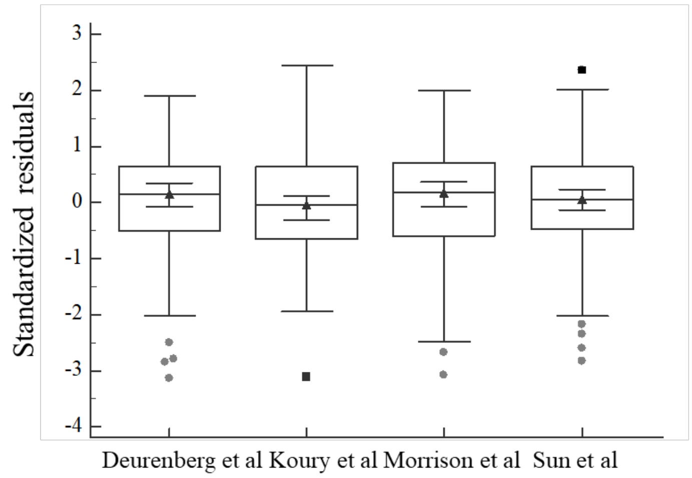
Predictive equations	R^2	RMSE, kg	MAPE%	CCC
A	0.871	2.6	5.0	0.885
B	0.888	1.9	4.3	0.926
C	0.886	2.8	6.0	0.871
D	0.887	4.8	12.6	0.613

Figure 1-Bland-Altman analysis and regression line between the FFM obtained using BIA predictive equations (A) Deuremberg et l; (B) Koury et al; (C) Morrison et al and (D) Sun et al and DXA measured for female adolescent athletes considering sexual maturity. R^2 considered all participants, RMSE=Root mean square error; MAPE= mean absolute percentage error; CCC=concordance correlation coefficient. Gray circle= sexual immature; dark square= sexual mature.

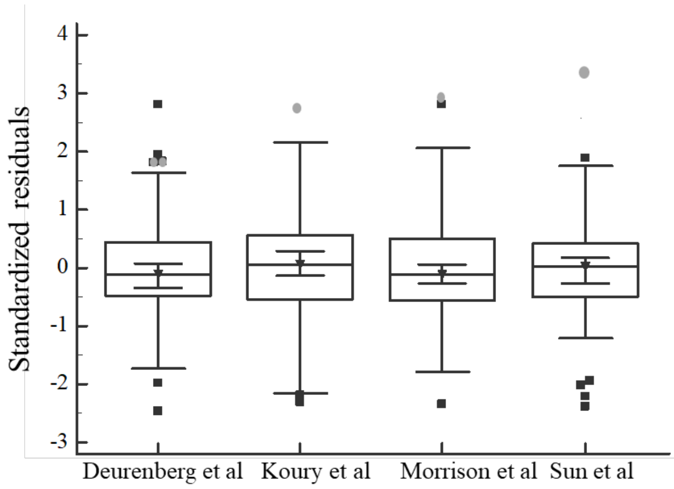


Predictive equations	R^2	RMSE, kcal/kg.FFM/d	MAPE%	CCC
A	0.992	2.4	4.3	0.992
B	0.997	1.8	4.2	0.992
C	0.991	2.8	5.3	0.989
D	0.991	5.6	12.1	0.954

Figure 2- Bland-Altman analysis and regression line between the EA obtained using BIA predictive equations (A) Deuremberg et l; (B) Koury et al; (C) Morrison et al and (D) Sun et al and DXA measured for female adolescent athletes considering sexual maturity. R^2 considered all participants, RMSE=Root mean square error; MAPE= mean absolute percentage error; CCC=concordance correlation coefficient. Gray circle= sexual immature; dark square= sexual mature.



(A)



(B)

Figure 3- Box plot of the standardized residuals of FFM (a) and EA (b) obtained using four BIA predictive equations. Standardized by FFM and EA obtained using DXA. Gray circle = sexually immature, black square = sexually mature. 95%CI for median