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AGREEMENT BETWEEN BODY MASS INDEX AND THE SUM OF SKINFOLDS IN ADOLESCENTS WITH DIFFERENT LEVELS OF PHYSICAL ACTIVITY

original paper
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ABSTRACT
Purpose. The purpose of this study was to examine the agreement between body mass index and body fat estimate among adolescents with different physical activity (PA) levels, using the sum of skinfolds as our criterion.
Methods. This was a cross-sectional study with 732 adolescent participants (63.4% of which were female), with an average age of 16.1 (±1.1) years old. The reference method used to estimate the body fat was the sum of triceps and subscapular skinfolds. BMI was calculated using body mass and height values. The PA was estimated using the International Physical Activity Questionnaire – IPAQ (short version). Bland-Altman diagrams were used to evaluate the agreement between BMI and the sum of skinfolds and were transformed into a Z score.
Results. For males, BMI overestimated body fat among those who did (mean error = -0.67; $p < 0.001$) and those who did not (mean error = -0.45; $p < 0.001$) meet the recommended PA values with a greater error observed for those who met PA recommendations. For females, BMI underestimated body fat among those who met (mean error = 0.29; $p < 0.001$) and did not meet (mean error = 0.41; $p < 0.001$) the recommended PA values with a greater error observed for those who did not meet recommendations.
Conclusions. Compared to sum of skinfolds, there was weak agreement between BMI and body fat among adolescents, especially among those with higher or lower PA levels. The use of other methods to estimate body fat in such cases is strongly recommended.
Key words: overweight, body composition, exercises, youths

Introduction

Overweight and obesity are characterized by the excessive accumulation of body fat and represent a health risk [1]. The worldwide prevalence of overweight and obesity is usually estimated using the Body Mass Index (BMI) classification system, and is elevated in countries with different economic situations [1-3]. BMI is an accessible and cheap anthropometric indicator that uses body mass and height values to calculate body fat composition. However, despite the fact that it presents a high correlation with body fat [2], it miscategorises 50% of people with body fat excess [3].

Despite its frequent use, BMI cannot distinguish between fat mass and lean mass and therefore does not properly reflect body fat distribution [4, 5], resulting inaccurate overweight and obesity epidemiological data. These inaccuracies may be greater in data collected from adolescents due to changes linked to the growth process, biological maturation [6], and behaviors which change body composition (e.g. physical activity [PA] levels) [7]. Due to these factors higher BMI values among adolescents may reflect gains in lean mass in addition to fat mass [8].

Several studies have found evidence to support physical activity (PA) as a non-pharmacological treatment to reduce overweight and/or obesity during adolescence [7, 9-12]. PA helps us to achieve energy balance resulting in changes to body composition (increase of lean mass and reduction of fat mass) [7, 10]. Such changes

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are not well discriminated by BMI which has a tendency to remaining stable even after the inclusion of regular PA [7, 12]. A more sophisticated instrument is therefore required for body composition analyses.

Although instruments such as air displacement plethysmography, dual-energy x-ray absorptiometry (DEXA), and bioelectrical impedance provide a more accurate picture of body fat composition, their use is unfeasible in many cases due to their elevated costs and difficult operationalization [13]. The sum of skinfolds represents an anthropometric indicator which is as cheap as but may be more accurate than BMI, and which may be used to monitor body fat composition among adolescents [14].

Previous research investigating BMI agreement with more precise methods to estimate body fat are controversial and do not specifically investigate adolescent participants groups with varying PA levels [15-18]. Therefore, the purpose of this study was to examine the agreement between BMI and body fat as measured by sum of skin folds among adolescents with different PA levels.

Material and methods

Population and sample

This school-based transversal epidemiological study used the data of the project "Níveis de atividade física e comportamento social relacionado à saúde em escolares de Florianópolis," which was approved by the Committee of Ethics and Research with Human Subjects of the Federal University of Santa Catarina (protocol 372/2006). The target population was composed of adolescents of 14 to 19 years old (mean = 16.1 ± 1.1 years) who were enrolled for secondary education in public state schools of the city of Florianópolis-SC. The mean body mass for all adolescents was 58.0 ± 1.1 kg and height 166.0 ± 0.1 cm.

The sample selection conducted in two stages: 1) stratified by geographic regions (Center, Continent, East, North, and South), considering the larger secondary school of each region, and 2) by conglomerates of randomly selected classes in which all students present in the classroom at the data collection day were invited to participate in the research.

According to the State Management of Education, the total number of enrolled students in the collection year was 12,741. The sample was estimated adopting a confidence level of 95%, a tolerable margin of error of five percentage points, an estimated prevalence of 50% (unknown outcome), and a design effect of 1.5 [19]. To such parameters 20% was added for eventual losses and/or refusals, estimating a representative sample of 671 adolescents. Due to the sampling process of class conglomerates established *a priori*, the final collected sample comprised 1,056 adolescents distributed proportionally among the five geographic regions.

All students present in class during the data collection day aged from 14 to 19 years old who voluntarily accepted to participate in the research were considered eligible. Those under 14 and over 19 years old, and those who claimed to have a disease that would hinder the measurement of the anthropometric measures were excluded from the study. Those adolescents who did not want to participate in the research and those that did not present their signed Term of Free and Clarified Consent (TCLE) were considered refusals. Data collection was performed on school-premises on days and times previously arranged with the principals and Physical Education teachers. Participants delivered their TCLEs signed by their parents (for those under 18 years old) and signed the Term of Assent. They were informed that their personal data would be confidentially stored and that they could withdraw from the study at any time.

Procedures

Participants' demographic (sex and age) and PA information were collected through the use of a questionnaire filled by the students. PA levels were estimated using the International Physical Activity Questionnaire (IPAQ) proposed by the World Health Organization short version. The IPAQ short version in Portuguese was validated for the monitoring of adolescent PA levels using a sample of 161 Brazilian adolescents of both sexes, aged from 12 to 18 [20]. The world recommendation for PA levels (420 minutes or more of moderate/vigorous PA per week) was used to classify participants as someone who "meets" or "does not meet" recommended PA levels [21].

Body fatwas estimated through the sum of triceps and subscapular skinfolds (ΣSF), which were measured by a trained evaluator, in duplicate, using a scientific-model adipometer (Cescorf® Mitutoyo, Porto Alegre, Brazil) with a resolution of 0.1 mm. During the measurements participants were instructed to remain in an orthostatic position with their arms stretched besides their bodies. All folds were pinched at the right side of the body following a pre-established standardization [22]. The means of the first and second skinfold measurements were calculated and then summed (ΣSF = triceps + subscapular).

Body mass (kg) and height (meters) values were measured according to pre-established procedures [22]. Body mass was measured using a digital scale (Filizola, São Paulo, SP, Brazil) which had a maximum capacity of 150 kg and a resolution of 100 grams. Height (m) was measured with the assistance of a portable stadiometer (Seca Corporation, Hamburg, Germany) fixed vertically on the wall with a maximum height of 200 cm and a resolution of 0.1 cm. BMI was determined by the division of body mass (kg) by the square of height (m).

Statistical analysis

Statistical analyses were conducted using IBM SPSS Statistics for Windows, version 20.0 (SPSS, Chicago, IL, USA) with a significance level of 5%. Data were presented in means and standard deviations. Normality was assumed due to the large sample sizes (based on the central limit theorem) and independent samples *t*-tests were conducted to verify differences between boys and girls. The Chi-square test was used to determine differences in PA levels between boys and girls. The agreement between the ΣSF (mm) and BMI (kg/m^2) values was evaluated with the assistance of the Bland-Altman plot [23] with both variables standardized (Z score) to the same measurement scale. A dispersion graph was plotted comprising the mean error (mean of the difference between ΣSF – BMI) and the mean of both measures [(ΣSF + BMI)/2]. The difference between these two measures was verified through the use of a paired *t*-test (systematic bias) and *Spearman*'s correlation coefficient was used to verify whether the mean error correlated with the measurements' magnitude (heteroscedasticity). All *p* values presented were two tailed.

Ethical approval

The research related to human use has been complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the authors' institutional review board or an equivalent committee.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

We collected information from 1,056 adolescents, 324 of which did not have all their anthropometric measures collected to allow the execution of the analysis. Therefore, the total sample was comprised of 732 adolescents (268 boys and 464 girls) with an average age of 16.1 ± 1.1 years. The male sex presented higher mean PA value than the female sex, with female participants presenting with significantly higher mean skinfold values in comparison with male participants. The proportion of subjects who meet the PA recommendations was higher among male adolescents than among females (Table 1).

The dispersion diagrams for the agreement analysis were created separately for each sex (Figure 1). For male participants BMI did not present a good agreement with body fat with a systematic mean error ($p <$ 0.001) between the measurements. A greater mean error was observed among adolescents who meet PA recommendations (overestimating the body fat) which increased proportionally to the measurements' means ($p < 0.001$).

Table 1. Descriptive participant data

Variables	Total $\bar{x}$ (sd)	Sex		*p* value
		Male $\bar{x}$ (sd)	Female $\bar{x}$ (sd)	
BMI, kg/m^2	21.11(3.6)	21.27 (3.6)	21.00 (3.6)	0.336*
Triceps SF, mm	14.3 (6.5)	10.0 (5.0)	16.8 (5.9)	< 0.001*
Subscapular SF, mm	13.1 (6.7)	10.5 (6.5)	14.6 (6.7)	< 0.001*
ΣSF (triceps + subscapular)	27.4 (12.6)	20.5 (11.0)	31.4 (11.7)	< 0.001*
Physical Activity, min/week	402.9 (517.8)	419.0 (653.6)	181.4 (304.3)	< 0.001*
Physical activity (%)				0.002†
Meet recommendations	443 (60.5)	182 (67.9)	261 (56.,2)	
Does not meet recommendations	289 (39.5)	86 (32.1)	203 (43.8)	

BMI – Body Mass Index; SF – skinfolds; ΣSF – skinfold sum
* Independent *t*-test; † Chi-square test

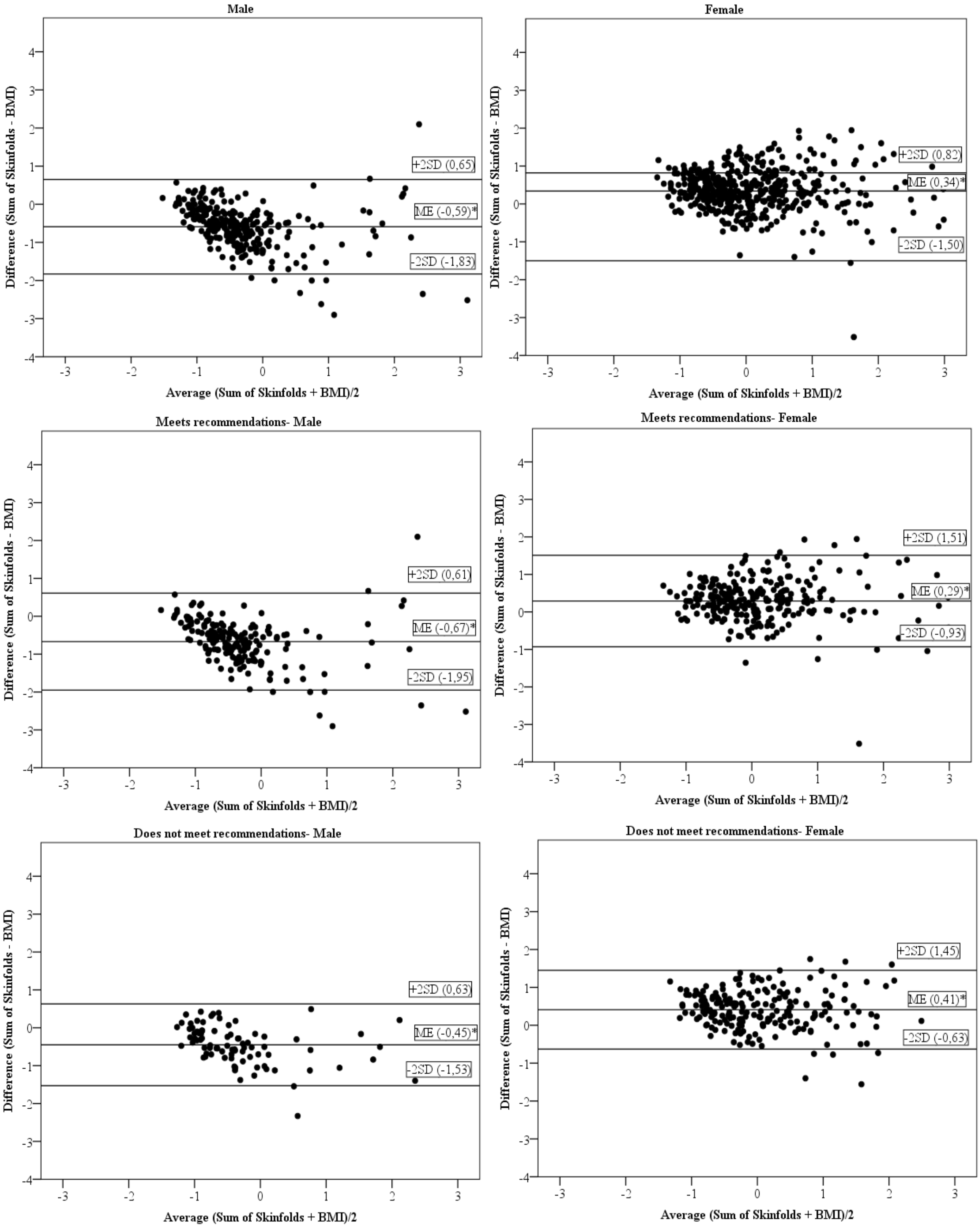

Figure 1. Adolescent's distribution within the agreement limits between the standardized skinfold and BMI measurements (Z score) according to sex and physical activity level.
*Paired *t*-test: statistically significant at $p < 0.05$

For female participants BMI did not present a good agreement with the body fat, also presenting a systemic bias ($p < 0.001$) between the measurements (underestimating the fat), with a more prominent difference between those that did not meet the PA recommendation values despite its constant bias ($p > 0.001$).

Discussion

The main findings of the current study indicate that BMI overestimates body fat for male adolescents in general, especially among those that meet PA recommendations. For female adolescents BMI underestimates the amount of body fat with a greater difference between the measurements among those that do not meet PA recommendations.

For male participants BMI overestimated the body fat, especially among those who were more active. This finding is consistent with previous systematic reviews which found that, regardless of the method used to estimate adolescents' body fat, BMI measurements' sensitivity to detect fat mass is low [4] and that PA is inversely related to fat mass but not to BMI [12]. Additionally, researchers controlling for physical growth and biological maturation found that PA explains 21% of the increase in lean muscle mass [10] and that physically active adolescents who maintain such condition present with higher amounts of lean mass in comparison with their insufficiently active peers [24]. Conversely, in a population study performed with adults with the same BMI, it was found that those that were physically active presented a greater percentage of body fat [2].

Based on these results we suggest that for male adolescents, especially the more active ones, BMI may produce imprecise body fat estimates, incorrectly classifying participants as overweight and/or obese when they might instead present with greater lean mass levels due to the PA they perform and to other factors inherent to adolescence. This hypothesis is supported by the results of a prior study in which adolescents who completed scheduled PA for one year presented with BMI stability, lean mass increase, and fat mass reduction in the triceps region [7].

Therefore, the findings of the present study, and of other studies mentioned above [2, 7, 10, 24] reinforce the hypothesis that BMI measurements must be carefully interpreted especially among physically active adolescents. Due to the risk of misclassifying male adolescents who meet PA requirements as being overweight, the use of a more accurate assessment of body composition is strongly recommended.

For female participants BMI measurements underestimated body fat, especially among those that did not meet recommended PA levels. We must underscore that the direction of the differences seen in the results between the sexes may simply be a result of the bodily characteristics of adolescence [6] or even of the amount of PA performed during that stage of life. For example: male adolescents, usually more active, present higher levels of lean mass than females while females generally present with higher levels of fat mass[7].

In addition to the greater of body fat mass required to maintain the metabolic levels that lead to menarche and to the maintenance of female reproductive ability [6, 25], if engaged in lower amounts of PA female adolescents will naturally present greater body fat levels that will not be properly classified by the BMI. Consequently, BMI may be even more inaccurate when estimating body fat excess among female adolescents who do not meet recommended PA levels. This hypothesis may be confirmed in future studies conducted to verify the agreement between BMI and lean mass indicators in adolescents with different PA levels.

The use of a subjective PA measurement may be considered as the main limitation this study and may have resulted in imprecise PA level estimates. The use of skin fold measurements as a reference method instead of others of greater accuracy to estimate body fat (e.g.: air displacement plethysmography, bioelectrical impedance, and dual emission X-ray absorptiometry) may also have affected the final results. However, due to the size of the included sample such methods were not feasible.

Among the virtues hereof, the authors underscore the use of a representative sample of public school adolescents and the collection in duplicate of the skin fold measurements by a single trained evaluator. Finally, these results may be used for comparison purposes with future studies, considering that no other studies have analyzed the agreement between the BMI and skin folds or other body mass composition reference methods in adolescents with different PA levels.

Conclusions

Weak agreement was observed between BMI and body fat in adolescents of both genders. For higher PA levels BMI overestimates body fat in male adolescents, whereas for lower PA levels BMI underestimates body fat in females. Future studies directed to evaluation of body fat composition among a large number of adolescents should consider the possibility of using other anthropometric indicators because for adolescents with higher or lower PA levels the use of BMI does not seem appropriate.

Disclosure statement

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Conflict of interest

The authors state no conflict of interest.

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Authors' contributions

AP and ELP were the main researchers. AAP analyzed the data and drafted the paper, including writing. AP and ELP assisted in analyses, writing and contributed to the conception and protocol of the study. All authors aided in preparing the manuscript.

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