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RELATIONSHIP BETWEEN BODY MASS INDEX AND FAT MASS PERCENTAGE AMONG ADOLESCENTS FROM CONSTANTINE (ALGERIA)

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ABSTRACT

Several references based on body mass index (BMI) have been used in Algeria to define adolescent obesity. No studies have been published to assess the diagnostic accuracy of these references. This study aimed to evaluate the sensitivity and specificity of the International Obesity Task Force (IOTF) and Algerian national data based on BMI to detect excess fat in adolescents. A cross sectional study of 257 adolescents aged 16-19 was conducted in Constantine, Algeria. The BMI was calculated from weight and height measurements. The body fat percentage (BF%) was estimated by impedancemetry (BIA). The IOTF and Algerian national data were evaluated for their sensitivity and specificity to detect excess body fat. The BF% thresholds used to define true positives were 25% for boys and 30% for girls. Body mass index was significantly associated with BF% in the whole population (r=0.759). Obesity is more common in girls (p<0.01), regardless of the reference used. The percentage of obesity among adolescents according to the IOTF, Algerian data and BF% was 5.84%, 5.45% and 20.62%, respectively. The obesity rate estimated by BF% was significantly higher (p<0.00001). Sensitivity of the evaluated criteria, IOTF and Algerian data, was high for males (83.3% and 100%, respectively) and low for females (19.2% for both IOTF and Algerian data). Specificity of the two criteria was high for both sexes (100%). Specificity was higher than sensitivity; therefore, the ability of BMI to detect non-obese adolescents was higher than its ability to identify obese adolescents. As BMI is an index of body weight rather than body fat, it can be a source of error. Local data and international references gave the same percentages of obesity. Body mass index is a very specific but less sensitive method to assess increased body adiposity in adolescents. It fails to identify excessive adiposity in a significant percentage of female teenagers. It seems necessary to measure body fat in addition to BMI in adolescent girls. Therefore, it is important to consider body fat mass when determining obesity in order to predict the consequences of obesity, which are mainly due to an increase in fat mass in the body.

Key words: Adolescent, Obesity, BMI, Fat mass rate, IOTF, Impedancemetry, Algeria

INTRODUCTION

Obesity is defined as the excessive accumulation of adipose tissue or fat mass [1]. It is a major public health problem in both developed and developing countries. Screening of obese children and adolescents is widely recommended because of its rapidly increasing prevalence and health consequences. It is possible that obese adolescents will become obese adults [2]. Between 1975 and 2016, the number of obese young people in the world has increased by a factor of ten. There are now approximately 124 million obese children and adolescents worldwide [3]. In Algeria, obesity reached 4.6% in adolescents (12 to 18 years) according to the International Obesity Task Force (IOTF) [4]. In 2019, the obesity rate for adolescents aged 10-19 was 3.75%, according to the World Health Organization references [5].

The body mass index (BMI) has been recommended by the WHO to assess the nutritional status of adolescents. It is an index based on easily obtained measurements (weight and height) that do not require sophisticated equipment or specialised personnel. Body mass index is used to classify a person as underweight, normal weight, overweight or obese [1]. Body mass index has traditionally been used as a proxy for adiposity in epidemiological studies due to its low cost and simplicity. Although in obese adolescents, BMI is a good indicator of excess body fat, it shows good ability to discriminate it [6], there are limitations to its use as it is not a direct measure of body fat. Body mass index is unable to distinguish between lean and fat mass. It does not identify fat distribution and may not be equally valid across sex, races and ethnicities, and age groups [7]. The high prevalence of obesity and the ease of obtaining measurements have led several countries to propose their own BMI references. In Algeria, several BMI-based references have been used to define obesity, the most used is the cut-offs proposed by the International Obesity Task Force (IOTF) [8]. These references are based on data collected in six countries: Brazil, Hong Kong, the Netherlands, Singapore, the United Kingdom and the United States [9]. There is limited information on the validity of the BMI references, especially in populations other than those for which they were developed [10]. In Algeria, local data based on BMI have been proposed [11]. However, they have never been used to assess the nutritional status of children and teenagers. They require validation against a standard before use.

Measuring total body fat is considered a better measure of obesity because it provides estimates of lean mass or fat mass. The percentage of body fat (BF%) measured can therefore be a criterion for measuring obesity in adolescents [12]. There are several ways to measure body fat. Dual-energy x-ray absorptiometry (DEXA), isotope dilution, underwater weighing (densitometry), air displacement

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plethysmography, computed tomography and magnetic resonance imaging can provide accurate measurements of body fat. Some of these techniques have disadvantages: they are expensive, impractical in terms of equipment or exposure to low doses of radiation. These measurements are often not available for large-scale population surveys and are not interchangeable for assessing adipose tissue [13]. Bioelectric impedance analysis (BIA), on the other hand, is relatively easy, fast and non-invasive, providing reliable measurements of body composition with low intra- and inter-observer variability. Results are immediate and repeatable to < 1% error [14]. Bioelectric impedance analysis is suitable for assessing BF% in large numbers of children and adolescents [13].

The aim of this study was to estimate the prevalence of obesity using the body mass index (BMI) classification criteria of the IOTF and local Algerian data, and to compare its sensitivity and specificity with that of BF% in the screening of obesity in Algerian adolescents aged 16-19 years.

MATERIALS AND METHODS

Population

The study was carried out in the city of Constantine. In 2019, the Algerian population aged 5 to 19 years was 11 075 089 [15] and the school enrollment rate was 96.3% [16]. In 2007, the number of teenagers in Constantine was 176 902 [15]. This study was carried out from 17 February to 7 March 2007. It included 257 students (136 girls and 121 boys) aged 16-19 years from a high school chosen for its accessibility, located in a neighborhood known for its high socioeconomic status. Exclusion criteria were age above 19 years, female adolescents menstruated, adolescents with disease affecting body composition and contraindications to electrical bioimpedance.

Anthropometric measurements

Height was measured to the nearest 0.1 cm using a stadiometer (Seca, Hamburg, Germany). Weight, lean mass and fat mass were measured using the BC-418 MA 8-electrode body composition analyzer (Tanita Corporation, Tokyo, Japan). The electrodes are positioned to introduce current from the toes of both feet and the fingertips of each hand. The signal is conducted through the water in the body. Fat mass and lean mass have different conductivities. Lean tissue allows the current to pass easily, while fat mass resists its passage. The device registers the impedance and calculates the percentage of body fat to the nearest 0.1% based on age, sex, height and weight. The body fat percentage (BF%) is expressed as a percentage of body weight.

Anthropometric measurements (weight, height) were performed according to WHO recommendations [1] in lightly clothed adolescents by two investigators. These measurements were taken during the morning school-based health visits.

DATA ANALYSIS

The BMI values of Algerian adolescents are compared to international IOTF references [9] and Algerian data [11].

For estimating the prevalence of obesity using the BF% parameter, the thresholds proposed by Williams *et al.* [17] were used. These thresholds were significantly associated with cardiovascular risk factors in children and adolescents [17]. A girl is obese if the BF% is equal to or greater than 30%. For boys, this threshold is 25%.

The performance of BMI criteria in distinguishing adolescents with excess body fat from those with normal body fat (adolescent obesity) was evaluated. Sensitivity and specificity of BMI were calculated according to the BF% thresholds used to define obesity. The BF% references proposed by Williams *et al.* [17] were selected as true positives. Sensitivity is the proportion of true positives among all recorded positive values, while specificity is the proportion of true negatives among all recorded negative values.

The statistical analyses were performed using XLSTAT version 2009.1.01 (Addinsoft 1995-2009, USA). The Shapiro Wilk test was applied to check the normality of the data, which did not show a normal distribution except for height. Therefore, non-parametric tests were used. Spearman correlation was applied to investigate the possible association between BMI values and body fat. The significance level adopted was 5%.

Ethical statement

The study received ethical approval from the multidisciplinary scientific advisory board of the faculty. Approval was also obtained from the National Education Department of the state of Constantine. In the city of Constantine, the Ministry has approved BF% measurements to be included in school-based health screening. The study was based on a dataset obtained through scheduled school health visits. School health visits are required by the Ministry of Public Health. This visit is obligatory for all students. It includes anthropometric measurements and a medical consultation. The data collected in this study does not include any personal information that might identify the respondents. The data were collected anonymously. To calculate age, only the month and year of birth were collected and children were considered to be born on the 15th of the month of the birthday. Omitting the day of birth allowed for complete anonymity of the data.

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RESULTS AND DISCUSSION

The mean age of the 136 girls and 121 boys was 17.5 years. There was no significant age difference between the sexes (p > 0.05%). Boys were taller and had more lean mass (p<0.0001) while girls had significantly higher BF% (26.7% vs 15.4%, p<0.0001) (Table 1). Data from this study clearly indicate that although boys and girls had similar BMI (p > 0.05%) values, girls had significantly higher BF% values (p<0.0001).

Figure 1 shows the correlation between BMI and BF%, for Algerian adolescents. Body mass index was significantly related to BF%. Body mass index predicted BF% with reasonable precision in girls (r=0.859), boys (r=0.880) and the whole population (r=0.757). This result indicates that the correlation was high, as the value was between 0.80 and 1.00. The positive correlation between BMI and percentage of body fat means that the higher the BMI, the higher the percentage of body fat.

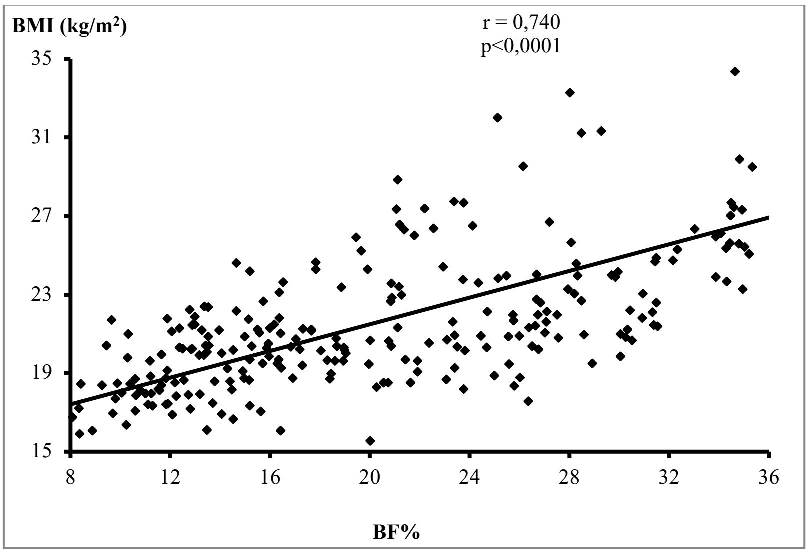

Figure 1: Correlation between BMI (Kg/m2) and body fat percentage (BF%) among the Algerian adolescent population

The results observed in this study are similar to those obtained by Jelena *et al.* [18] in the Republic of Serbia. The authors found a very strong correlation between BMI and BF% in both girls (r = 0.975) and boys (0.752).

The percentages of obesity, within the sample, calculated according to IOTF, the Algerian data (ALG) and the BF% are presented in Figure 2.

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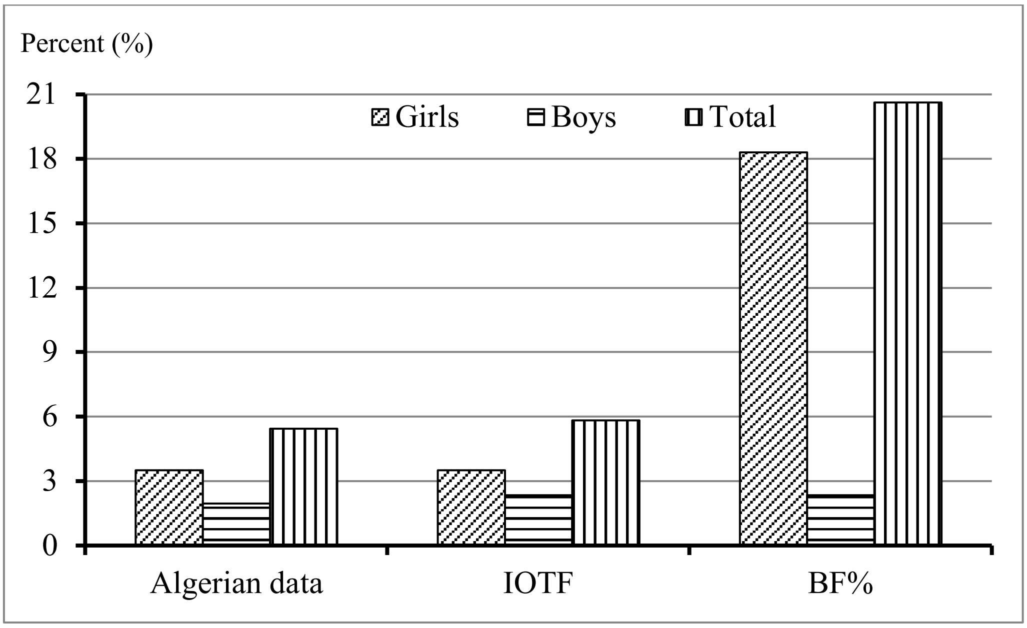

Figure 2: Obesity rate by sex and according to the three references (Algerian data, IOTF and BF%) in Algerian adolescents

In this sample, regardless of the reference used, more girls were significantly ($p<0.01$) more obese than boys (Figure 1). There was no significant difference between the percentages of obesity based on IOTF, Algerian data and BF% in boys ($p> 0.05$). In girls, the percentage of obesity was higher ($p< 0.0001$) when estimated by BIA than by BMI. The percentage of obesity was 5.8% according to IOTF and 5.5% according to Algerian data, with no significant difference between the two values ($p>0.05$). This result can be explained by the fact that the determination of the thresholds for assessing obesity in the Algerian data [11] was based on the method proposed by the IOTF references [9]. On the other hand, the obesity threshold for 18 years and older is the same as for adults, as recommended by the WHO. Students aged 19 and over represented 20% of the female population and 22% of the male population.

Specificity and sensitivity were calculated according to age and sex (Table 2). There was excellent agreement between the IOTF and Algerian data for both girls and boys. The sensitivity and specificity between these two references were very high. Taking the determination of BF% as the gold method, the sensitivity was high in boys with IOTF and Algerian data. However, the sensitivity was lower in girls (Table 2).

Calculating the percentage of obesity based on BF% showed a high value for girls. Boys had a low percentage, identical to that calculated on the basis of BMI. Girls are known to have more fat mass than boys. Up to the age of 18 years, girls tend to accumulate more fat [19, 20, 21], while boys have more lean body mass [22].

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Although the average BMI of Algerian boys and girls was similar, the BF% was higher in girls and the sex difference increased with age. These observations were consistent with previously reported results using different measures of adiposity [23, 24]. Puberty and growth spurt at an earlier age in girls could explain this finding. It has been reported that the number of adipose tissue cells increases during these periods, followed by a decrease after puberty [25]. In children and adolescents, the assessment of body composition seems to be even more difficult because of the large variation in the different body components (water, proteins, minerals, et cetera) depending on growth and biological maturation. This variation can significantly affect the estimation of fat mass and fat-free mass [26, 27]. Also, in children the height is not corrected for when measuring BMI and is done in adults.

Currently, most paediatric publications rely on BMI to identify obese children. According to WHO [1], experts and researchers have not yet reached the same level of agreement on the classification of obesity in children and adolescents as in adults. There are several reference populations and thresholds at which a child is considered obese. The BMI is not a substitute for the percentage of body fat in children due to differences in age, sex, race or stage of sexual maturation [28]. Body mass index is closely associated with adiposity, especially in obese teenagers [6], measured by different methods, although the strength of the association varies [23, 24, 29]. The strength of the association is influenced by factors such as race, sex, age and lifestyle factors such as physical activity. Other factors, such as BMI thresholds for obesity, BMI reference data, and the choice of standard method for assessing adiposity [30], may also be important. Mean BMI values may contribute to different correlation coefficients. It appears that the association is weaker in the BMI range 20-25 kg/m2 and stronger at higher BMI values [31].

Although BMI is an important epidemiological and clinical tool, one limitation is that it does not distinguish between fat and fat-free mass [7]. Individuals with the same BMI may have different levels of fat mass [32]. Body mass index refers to excess body weight in relation to height. It does not distinguish between those whose high body mass is due to excess fat and those whose high body mass is due to excess muscle. In this study, all boys with a high BMI also had a high percentage of body fat, with a false negative rate of zero. Thus, it is clear that BMI was more indicative of excess body fat in boys than in girls. For the identification of Algerian adolescents with excess body fat, the IOTF references and Algerian data showed a very high specificity in both sexes, but the sensitivity was very low in girls and therefore in the whole sample. In girls, BMI was less satisfactory for classifying individuals with excess fat as obese. In this study, the low to moderate sensitivity and high specificity reported in females are generally consistent with those reported in the literature [10, 33]. Specificity was higher than sensitivity; therefore, the ability to detect non-obese adolescents was higher than the ability of BMI to identify obese adolescents.

In this study, the proportion of obese boys was identical for BF% and BMI. However, the percentage of girls classified as obese by BF% was higher than by BMI. Of the girls classified as obese by BF%, 43.6% (n = 37) were not classified as obese by BMI. Of the 37 girls, 17 were classified as normal weight and 20 were classified as overweight by BMI. All girls classified as obese according to the IOTF or Algerian data were truly obese according to BF%, but more than 80% of the truly obese girls (according to BF%) were misclassified as overweight or normal weight according to BMI. As a result, many obese girls would be rejected from intervention programmes using BMI as a screening criterion. A meta-analysis showed that BMI was very specific but not sensitive in detecting excess fat and did not identify more than a quarter of children with excess body fat [30]. In a study of adolescents aged 16-17 years, BMI showed weak or no correlation with other methods of determining BF%, showing that BMI identified fewer obese individuals [34].

The BF% thresholds used in the present study were derived from a white American sample. This may explain the difference found between obesity prevalence using BMI and BF%. Other cut-off values have also been proposed. In 17-year-olds, cut-offs of 23.9% and 37.3% have been suggested for males and females, respectively [24]. For Australian boys and girls aged 9-15 years, the corresponding cut-offs were 20% and 30% [35]. The use of different cut-off points for the assessment of BF% leads to differences in the estimation of the prevalence of obesity. The use of a single body fat cut-off point (25% in boys and 30% in girls) to define obesity may not be appropriate, as body fat varies with age in subjects under 18 years of age. Therefore, the use of gender- and age-specific cut-offs may be more appropriate to define obesity in children and adolescents, although there is no general agreement on the values of these cut-offs. As with adult BMI, body fat thresholds should be based on health risk. There is currently little information on the health effects of increased body fat in children [20]. Defining excess body fat is somewhat arbitrary, even when BF% is known. There is currently no consensus on BF% cut-offs for obesity in adolescents. As there are no clear cutoffs, the most consistent BF% values for defining excess body fat are between 30 and 35 % in female adolescents and 20 to 25 % in male adolescents [36]. Body composition measurement methods give more accurate information, but they are generally based on adult hypotheses [37].

The method used to estimate BF% may also be a source of variation In results between studies [38, 39]. The use of machine-integrated equations to assess BF%

in children and adolescents should be validated [29, 31]. Bioelectric impedance analysis is a practical method for estimating BF% in children and adolescents, but its validity and measurement error are unsatisfactory [40]. However, in children and adolescents, waist circumference appears to be the best simple anthropometric predictor for screening for metabolic syndrome [36].

CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

In Algerian adolescents, several BMI-based obesity estimates have been used. However, no studies have evaluated the diagnostic accuracy of these references and local Algerian data. This study highlighted the differences in classifying obesity using BMI and BF% in adolescents aged 16-19. In this study, the obesity rate was similar between the IOTF references and the local Algerian data for both sexes, but this was not the case for BF% in girls. The IOTF and the local Algerian data underestimate the body fat, especially in the girls. These results suggest that the low sensitivity of BMI may be equivalent to an important underestimate of the true prevalence of obesity (according to the BF% definition) in teenage girls. The study is subject to a design bias. The results cannot be generalised to the entire Algerian population because the sample of adolescents studied came from a high socio-economic background, which introduces a selection bias.

As a recommendation, in view of the increasing prevalence of obesity in children and adolescents, there is a need for an accurate method to measure obesity. Age- and sex-specific body fat thresholds should be used to define obesity in the Algerian population. It seems necessary to measure body fat in addition to BMI, especially in adolescent girls.

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Table 1: Distribution of anthropometric characteristics of Algerian adolescents by sex

Anthropometric indices	Whole population, n = 257 Median (Min – Max)	Girls, n = 136 Median (Min – Max)	Boys, n = 121 Median (Min – Max)	p
Age (years)	17.5 (16 - 19)	17.5 (16 - 19)	17.5 (16 - 19)	>0.05
Weight (kg)	62.7 (4.2 – 116.4)	60.1 (40.2 – 98.7)	65.6 (44.8 – 116.4)	=0.001
Height (cm)	168.9 (150.6 – 189.1)	163.4 (150.6 – 175.4)	175.1 (160.4 – 189.1)	<0.0001
BMI (kg/m²)	22.0 (15.5 – 35.8)	22.5 (15.5 – 35.8)	21.3 (16.1 – 34.4)	>0.05
Lean mass (kg)	48.8 (34.6 – 83.8)	43.3 (34.6 – 59.3)	54.9 (39.5 – 83.8)	<0.0001
BF (%)	21.4 (8.1 – 48.9)	26.7 (8.3 – 48.9)	15.4 (8.1 – 34.6)	<0.0001

n: effective Min: minimum Max: maximum

Table 2: Sensitivity and specificity of obesity classification according to the three references

Sex	ALG vs IOTF		ALG vs BF%		IOTF vs BF%	
	Sensitivity	Specificity	Sensitivity	Specificity	Sensitivity	Specificity
Girls	100	100	19.2	100	19.2	100
Boys	83.3	100	83.3	100	100	100
Total	93.3	100	26.4	100	28.0	100

ALG: Algerian data BF%: determined according to Williams *et al.* [17]

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