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Body morphology and bone age in girls with obesity and without obesity aged 8 to 15 years: a cross-sectional study

Morfologia corporal e idade óssea em meninas com obesidade e sem obesidade de 8 a 15 anos: um estudo transversal

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Abstract
Introduction: *childhood obesity is one of the main public health problems worldwide, leading to health status repercussions and growth and maturation process implications in both children and adolescents.* ***Objective:*** *the aim of this study was to verify body morphology and bone age variations in girls with obesity and without obesity.* ***Methodology:*** *this comprises a cross-sectional study conducted with 140 girls aged 8 to 15 years old, 70 with obesity and 70 without obesity. Hip and waist circumferences, body mass, height and and Body Mass Index (BMI) were determined. For maturation status determinations, bone ages were determined by a left wrist and hand radiography employing the Fels method.* ***Results:*** *the findigs indicate significant correlations between nutritional and maturation statuses (r=0.80; p<0.01). Girls with obesity presented higher weight and BMI values, larger waist and hip circumferences and more advanced bone age compared to girls without obesity (p<0.01). The same significant differences (p<0.01) were noted in the contrasting maturational group analysis, where girls presenting advanced maturation always exhibited the highest parameter values.* ***Conclusion:*** *nutritional status is associated to maturation status, and girls with obesity exhibit more advanced bone age than girls without obesity.*
Keywords: *Growth; maturation; skeletal maturation; obesity. BMI.*

Resumo
Introdução: a obesidade infantil é um dos principais problemas de saúde pública mundial, com repercussões no estado de saúde e implicações no processo de crescimento e maturação de crianças e adolescentes. **Objetivo:** verificar a variação da morfologia corporal e da idade óssea em meninas com e sem obesidade. **Metodologia:** estudo transversal conduzido com 140 meninas de 8 a 15 anos de idade, sendo 70 meninas com obesidade e 70 sem obesidade. Foram mensuradas as circunferências do quadril e da cintura, massa corporal, altura e o Índice de Massa Corporal (IMC). Para o status maturacional foi determinada a idade óssea por meio de radiografia de punho e mão esquerdos pelo Método Fels. **Resultados:** os resultados apontaram a existência de correlação entre o status nutricional e o status maturacional (r=0,80; p<0,01). As meninas com obesidade apresentaram maior peso, IMC mais elevado, circunferências maiores e idade óssea mais avançada quando comparadas às meninas sem obesidade (p<0,01). Na análise dos grupos maturacionais contrastantes as mesmas diferenças se apresentaram com valores significativos (p<0,01), sendo as meninas avançadas maturacionalmente sempre com valores superiores. **Conclusão:** o status nutricional apresentou correlação com o status maturacional, e as meninas com obesidade apresentam idade óssea mais avançada que aquelas sem obesidade.
Palavras-chave: Crescimento; maturação; maturação esquelética; obesidade; IMC.

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INTRODUCTION

The childhood obesity is increasing worldwide, reaching alarming proportions in many countries and representing a serious and urgent challenge to public health[1]. In 2014, about 41 million children under the age of 5 were overweight or obese, and over 340 million children and adolescents between 5 and 19 years of age were overweight in 2016[1,2].

This is extremely worrying, since childhood and adolescence obesities are strong predictors for adult obesity, as these stages comprise critical developmental periods for future adult health[1,3]. In this regard, a systematic review has recently demonstrated that about 55% of obese children will remain with obesity when adolescents, and 80% adolescents with obesity will remain obese during the development of their future adult health into adulthood[4]. This condition can affect immediate child health, educational levels, and quality of life, is of particular concern among the risk factors for noncommunicable diseases and displays the potential to nullify many of the health benefits that would contribute to increased life expectancy[1].

Childhood and adolescence with obesity are directly associated with several comorbidities such as type 2 diabetes, hypertension, dyslipidemia, sleep apnea, fatty liver disease and an increased risk of premature death in early adulthood, among others[5,6]. In addition to a relationship with several well-known cardiovascular and metabolic complications, children and adolescents with obesity undergo growth and maturation pattern alterations, and obesity is also associated with early signs of puberty in girls and early or late puberty in boys[7].

Children and adolescents with obesity can present accelerated skeletal maturation and, consequently, more advanced bone age compared to chronological age, and are usually taller and heavier, although the growth rate speed decreases during puberty and may even stop earlier than children belonging to the same age group and presenting normal weights[8,9]. Bone age is a commonly employed child and adolescent biological maturation indicator for the assessment of growth hormone-related diseases or changes in sex steroids that may cause early or late puberty[10,11].

The skeletal maturation process involves the transformation of the cartilaginous epiphyseal growth plate into bone, which occurs during child growth and maturation. Individuals reach their adult height as soon as the epiphyseal plate ossifies[12]. An increasing gender gap is noted from birth to early adolescence, with girls reaching bone maturity up to two years earlier than boys[10,13]. Bone age assessments can be performed by analyzing hand and wrist radiographs, widely applied by pediatricians and professionals interested in the study of human growth[14].

A bidirectional relationship between obesity and growth can take place. On the one hand, accelerated growth during childhood can become a risk factor for the onset of obesity, and on the other, excess adiposity in childhood can affect growth patterns, leading to the acceleration in this process and anticipating the onset of puberty[9]. In this context, the aim of the present study was to assess body morphology and bone age variations and analyze differences between contrasting skeletal maturation stages in girls with obesity and without obesity aged 8 to 15 years old.

METHODOLOGY

Study sample

This study was carried out in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology *(STROBE) standards[15], in a cross-sectional one segment epidemiological assessment (one arm).*

The study sample was defined at two different timeframes. Initially, girls from eight to 15.9 years old, by stratifying all students from elementary to high school, totaling 81,088 students, categorized as public (155) and private schools (93) schools, totaling 248 schools.

The sample size was established with an error of three percentage points and a confidence interval of 95%, and a design effect (Deff) of 1.5, plus 10% accounting for possible losses and/or refusals. This led to a total selection of 2,560 girls, of which 520 were excluded due to the non-delivery of a signed informed consent and/or due to participant absence at the data collection moment. The final sample thus comprised 2,040 participants.

In a second step, 105 girls classified with obesity in accordance with the World Health Organization[16] (WHO), International Obesity Task Force[17] (IOTF), Centers for Disease Control and Prevention[18] (CDC), and Conde & Monteiro[19] cutoff criteria were selected according to a BMI classification to undergo X-ray examinations of the left wrist/hand to determine bone age. Unfortunately, 35 girls did not present the TALE signed by their tutors or guardians or did not attend the examination. Thus, participants with obesity totaled 70. For the subsequent analyses and comparisons, 70 girls without obesity classified according to the same BMI cut-off criteria were then randomly selected by means of a simple draw within the first sample group. The final sample then considered 140 school girls from Montes Claros - MG, aged eight to 15.9 years old.

Procedures

The study was approved by the Research Ethics Committee by the State University of Montes Claros – Unimontes (protocol number 1,866,852, date of ap-

proval: December 14, 2016). Written informed consent was obtained from all participants and their parents, were informed about the procedures and objectives of the study, in accordance with resolution 466/12 of the National Health Council.

Prior to project approval by the Unimontes Research Ethics Committee, a letter of clarification was sent along with an authorization request to the Montes Claros Municipal Education Department, to obtain permission to recruit city school participants for the research. A letter with the same content was then delivered to the directors of each school for research authorization. Schools were then visited and the data collection took place during Physical Education classes.

Variables

Anthropometric variable measurements were taken according to the anthropometric parameters, methodologies and techniques proposed by Lohman, Roche and Martorell[20]. Participant height, body mass and waist and hip circumference were determined, followed by BMI calculations. A Plena® digital scale (0.1 kg precision), a stadiometer (0.1 cm precision), and a Sanny® metallic tape measure (2 meters in length, 0.1 cm precision) were employed to obtain the anthropometric data.

Concerning skeletal maturation, bone age was determined by the Fels Method, developed from the use of a sample composed of children of medium socioeconomic level from south-central Ohio (USA) participating in the Fels Longitudinal Study[21]*. The Fels method is based on the objective assessment of up to 98 individual bone maturity indicators from 29 wrist bones, depending on child age[22]. Criteria for the specific classifications of each maturity indicator are based on the shape of each carpal bone, epiphysis and corresponding diaphyses of the radius and ulna, metacarpals, and phalanges of the first, third and fifth fingers. The presence or absence of the pisiform or sesamoid adductor of the first metacarpal is also applied. Scores are assigned to each bone indicator by comparing the assessed radiographs to the described criteria. Linear measurement ratios of the widths of the epiphysis and metaphysis of each of the long bones are also employed[23].*

Although other methods. such as Greulich & Pile and Tanner & Withehouse are more applied in pediatrics, the Fels method is the only one that provides a standard error, allowing the calculation of confidence limits for the determined skeletal age[24].

For maturational status classification, individuals with bone age 1 year or more below the group mean were considered delayed, those with a bone age 1 year or more above the group mean were considered as displaying advanced bone age, and those displaying bone age maturity within the range of 1 year above or below the group mean were considered as presenting normal bone age. An IRS-3 Neodignomax® table X-ray machine (100 to 500 mas) from the radiology sector of the Clemente de Faria Unimontes University Hospital was employed.

Data analysis

Data were entered and analyzed using SPSS® 24.0 for Windows software. Data normality was first verified by the Kolmogorov-Smirnov test and by histograms, evaluating asymmetry (≥3) and kurtosis (≥7) coefficients. The data did not present considerable variations in these parameters. Descriptive statistics procedures (minimum, maximum, means and standard deviations) were then applied for sample characterization.

Absolute and relative frequencies were first presented to classify the total sample according to nutritional and maturational status, followed by the chi-square test to verify obese and non-obese individual associations regarding maturational status. The Student's "t" test for independent samples was used to compare average chronological and bone ages and average body morphology variables between girls with obesity and girls without obesity. A one-way ANOVA test at a 95% confidence interval and an effect size (η^2) assessments were used to verify th variations of these same variables according to the maturational status. A significance level of $p \leq 0.05$ was adopted for all tests.

RESULTS

Table 1 presents the descriptive values of the investigated variables, in a general sample characterization. Table 2 displays the differences between girls with obesity and girls without obesity. No significant differences were noted only for chronological age and height (p=0.141 and p=0.612, respectively), while all other assessed variables exhibited significant differences, with the highest values always noted for the obese group.

Table 1 – *Sample characterization according to chronological age, bone age and body morphology of the total sample investigated herein of 140 girls.*

	Minimum	Maximum	Means	Standard deviation
Chronological age (years)	8.0	15.9	12.01	2.18
Bone age (years)	7.66	18.00	12.97	2.60
Body mass (kg)	21.6	91.4	52.46	16.15
Height (cm)	121.5	172.4	152.27	11.39
Waist circumference (cm)	50.0	98.6	69.52	11.33
Hip circumference (cm)	60.5	112.2	88.59	12.77
BMI	12.77	39.40	22.31	5,58

Table 2 – *Bivariate analysis between girls with obesity and girls without obesity of chronological age, bone age and body morphology, of the total sample investigated herein of 140 girls.*

	BMI classification	Minimum	Maximum	Means ± SD	Sig.(p)
Chronological age (years)	Without Obesity	8.00	15.80	11.74±2.25	0.141
	With Obese	8.10	15.70	12.28±2.09	
Bone age (years)	Without Obesity	7.66	16.23	11.84±2.34	0.01**
	With Obese	9.12	18.00	14.09±2.35	
Body mass (kg)	Without Obesity	21.60	60.70	40.94±10.33	0.01**
	With Obese	36.10	91.40	63.98±12.22	
Height (cm)	Without Obesity	121.50	172.40	151.78±13.21	0.612
	With Obese	129.60	170.50	152.76±9.15	
Waist circumference (cm)	Without Obesity	50.0	85.4	60.95±6.07	0.01**
	With Obese	59.5	98.6	78.09±8.53	
Hip circumference (cm)	Without Obesity	60.5	95.3	80.39±9.54	0.01**
	With Obese	78.2	112.2	96.79±10.06	
BMI	Without Obesity	12.77	22.33	17.46±2.27	0.01**
	With Obese	21.49	39.40	27.15±3.15	

Table 3 displays the sample distributions according to nutritional and maturation statuses. In the case of nutritional status, an equal with obesity to without obesity ratio was noted, as 70 participants were distributed in each of these classifications. Regarding maturational status, 10 girls were classified as displaying delayed maturation, 72 as exhibiting normal maturation and 58 as displaying advanced maturation.

Table 3 - *Sample distribution according to BMI and Maturational Status classifications.*

	Frequency	Percentage	Valid percentage	Accumulated percentage
		BMI		
Without Obesity	70	50.0	50.0	50.0
With Obesity	70	50.0	50.0	100.0
Total	140	100	100.0	
		Maturational Status		
Delayed	10	7.1	7.1	7.1
Normomature	72	51.4	51.4	58.6
Advanced	58	41.4	41.4	100.0
Total	140			

Table 4 indicates a significant association between nutritional status and maturation status (r=0.800, p<0.01), indicating that the with obesity group did not contain any girls classified as displaying delayed maturation, while the without obesity group did not contain any girls classified as displaying advanced maturation.

Table 4 - *Association of Maturational Status with BMI classification.*

Maturational status	Without obesity	With Obesity	Total	R (Pearson)	Sig. (p)
BMI					
Delayed	10	0	10		0.001
Normomature	60	12	72	0.781	
Advanced	0	58	58		
Total	70	70	140		

Table 5 indicates the variation of the investigated measures according to maturational status. Girls classified as displaying advanced maturation presented higher values for almost all variables (p<0.01), except for chronological age and height. Regarding the size of the maturational status effect on the investigated variables the effect was smaller in terms of chronological age and height, verified as 0.034 and 0.035 respectively.

Table 5 - *Chronological and bone age variations and body morphology according to maturational status.*

	Maturational status						Effect size (η^2)
	Delayed (n=10)		Normomature (n=72)		Advanced (n=58)		
	Means±SD	CI [95%]	Means±SD	CI [95%]	Means±SD	CI [95%]	
Chronological age (years)	12.48±2.45	10.73 – 14.24	11.62±2.23	11.10 – 12.15	12.41±2.03	11.87 – 12.94	0.034
Bone age (years)	11.46±2.53	9.64 – 13.26	11.94±2.30	11.40 – 12.48	14.52±2.16**	13.95 – 15.08	0.255
Body mass (kg)	43.72±7.95	38.03 – 49.41	43.86±14.07	40.55 – 47.16	64.64±11.02**	61.74 – 67.54	0.405
Height (cm)	156.80±10.31	149.42 – 164.18	150.34±13.23	147.23 – 153.45	153.88±8.40	151.67 – 156.09	0.035
Waist circumference (cm)	61.00±4.84	57.54 – 64.46	63.52±9.03	61.40 – 65.64	78.44±8.28**	76.27 – 80.62	0.445
Hip circumference (cm)	82.84±8.21	76.97 – 88.71	82.00±10.95	79.43 – 84.58	97.76±9.58**	95.24 – 100.28	0.367
BMI	17.66±1.91	16.30 – 19.03	19.11±4.74	17.99 – 20.22	27.08±2.72**	26.37 – 27.80	0.526

***p<0.01*

DISCUSSION

An association between nutritional status and maturation was observed according to bone age, with a significant difference between groups. In the case of nutritional status, girls with obesity were always heavier and displayed a considerably higher BMI, as well as larger waist and hip circumferences and a significantly older bone age (p<0.01). These variables exhibited a similar trend regarding maturation status, with girls classified as displaying advanced maturation exhibiting the same trend.

Bone ages of girls without obesity and girls with obesity were 11.84±2.34 years and 14.09±2.35 years, respectively, and significantly different (p<0.01), in accordance to other assessments, which have reported that obesity is directly associated with early bone age advancement[9,11,12,25,26], which can lead to precocious puberty, compromising final height and leading to excess weight in adulthood[12].

A positive and strong correlation was observed between maturation and nutritional status based on BMI (r=0.8, p<0.01), similar, albeit stronger, than that reported in a study carried out in Netherlands, where the authors indicated a correlation between BMI and advanced bone age of r=0.55 (p<0.01)[27]. This difference may be explained by different study designs, as the present study comprises a cross-sectional model, while the Dutch study is a cohort. Furthermore, differences in the sample characteristics and the method employed to determine bone age may also play a role, as the Dutch study used the Greulich & Pyle method, while the present study applied the Fels method.

According to Duren et al.[22] the Fels method displays an advantage over the Greulich & Pile method, as the latter consists of a rather subjective procedure of photographic atlases containing standard radiographs for each age, where the evaluator obtains a sense of whether a child displays accelerated or delayed maturation. The Fels method, on the other hand, is based on an objective assessment of up to 98 individual skeletal maturation indicators of 29 wrist bones according to child age.

Other studies have also compared bone ages between different nutritional status classifications, regardless of the applied method. One study carried out in Korea, for example, evaluated 93 prepubertal children with a chronological age of 7.4±1.5 years, reporting significant differences between the investigated variables when comparing children with obesity and without obesity. In this case, body mass, height, BMI and bone age were always higher in children with obesity, but only height and bone age were significantly different (p<0.01)[28], noting that the authors applied the Greulich & Pyle method to determine bone age.

In another study carried out in India, 60 children aged 8 to 11 years old were divided into two groups containing 30 children each, one comprising only children with obesity and the other, children with overweight. The BMI classification was performed according to CDC parameters and bone age was determined according to the Tanner & Whitehouse (TW2) method. Children with obesity were always heavier, exhibited a higher BMI (p< 0.01), and more advanced bone age (p=0.016)[29].

In the USA, one study evaluated 167 children and adolescents from 3 to 18 years old, and among other procedures, compared bone age between participants displaying normal BMI, overweight and obesity. The 85% and 95% percentiles were used for overweight and obesity BMI classifications, respectively, and bone age was determined according to Greulich & Pyle. In this case, overweight and obese participants exhibited significantly more advanced bone age compared to their normal weight peers (p<0.01)[30].

Also in this sense, one assessment carried out in Shanghai evaluated 1,330 children aged between 3 and 7, also comparing bone age between children presenting normal weights, overweight and obesity. The WHO parameters were used for BMI classification, and bone age was determined according to Tanner & Whitehouse (TW3). In this case, it was evident that the participants with obesity exhibited the most advanced bone age, while those with normal weight presented lower bone age compared to the other group (p<0.01)[11].

In Brazil, a study carried out in the state of Sergipe evaluated 175 children and adolescents aged 10 to 15 years old, employing WHO criteria for BMI determinations and the TW3 method for bone age assessments. The authors reported advanced bone age in group with obesity, significantly different in relation to the low and normal weight groups (p<0.01)[31].

In addition to differences in bone age in relation to nutritional status, the present study also evaluated maturational status according to bone age. In this case, the group presenting advanced maturation also exhibited higher values (p<0.01) for almost all variables, except for height, as well as a larger BMI effect size (η^2=0.526), corroborating previous assessments.

Similarly, one study in Korea compared participants presenting normal and advanced bone age, comprising 232 overweight and obese children and adolescents aged 6 to 15 years old. The 85% and 95% percentiles were used for BMI overweight and obesity categorizations, respectively, and bone age was determined by the TW3 method. In a direct comparison between advanced and normomature individuals, the BMI was always higher in participants with advanced bone age (p<0.01)[8].

According to our findings and other literature assessments, obesity is an important predictor of advanced bone age in children and adolescents displaying advanced biological maturation, especially girls[12,31]. This may seriously affect the maximum height expected for children or adolescents[32]. Although children with obesity exhibit higher growth speed and accelerated bone age, these prepubertal advantages tend to gradually decrease during adolescence, when individuals with obesity display a reduced growth spurt[9].

In addition, some studies point to an association between advanced bone age and idiopathic short stature, comprising a height 2 or more standard deviations below the mean for age and sex[33,34]. Although a combination of short stature and advanced bone age is not so frequent, when it does occur, the result is a poor height prediction and marked short stature in adults[33].

Likewise, obesity seems to be related to musculoskeletal problems such as pain, injuries, and fractures since childhood, which can cause damage to the osteoarticular system during the adolescence[35,36]. Children with overweight and obesity are more likely to report musculoskeletal problems in daily life than normal weight children[37].

This study presents important methodological strategies that can aid in understanding the relationship between obesity and the maturation process in children and adolescents. A direct comparison between a group of girls with obesity and without obesity allowed us to clearly visualize morphological and maturational differences between nutritional status, as well as a sample categorization into contrasting maturational groups, also contributing to the understanding of these discrepancies.

This study, however, displays certain limitations, only one sex and two nutritional statuses, which should be considered in order to delve a little deeper into these issues, and the use of a sample composed of subjects of both genders and more varied nutritional statuses, such as overweight and underweight children, in addition to children with obesity and normal weight, is recommended.

CONCLUSION

Contrasting nutritional statuses result in important body morphology and maturation status variations in children and adolescents. Girls classified with obesity always exhibited higher anthropometric data values compared to girls without obesity. Furthermore, significant differences were noted for bone age, with girls with obesity always more advanced than the other investigated group. In terms of maturational status, girls exhibiting more advanced bone age were also heavier and exhibited a higher BMI than girls exhibiting normal and delayed bone age.

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