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Body composition indicators in the metabolic syndrome risk prediction in 6-10-year-old children

Indicadores de composição corporal na predição de risco de síndrome metabólica em crianças de 6 a 10 anos de idade

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Abstract – The aim of this study was to develop percentiles of body composition indicators and determine cutoff points to predict metabolic syndrome (MS) risk in 6-10-year-old children. This is a cross-sectional, population-based epidemiological study with the participation of 1480 schoolchildren aged 6-10-year. Anthropometric assessment (body mass, height, and skinfolds) and blood pressure measurement were performed in schools. The body mass index (BMI), as well as the body fat percentage (%BF), lean body mass (LBM), fat body mass (FBM), were calculated according to standardized formulas for children. Blood collection to assess the lipid and glycemic profile was also performed at school, on pre-established days and times. The MS diagnosis was determined based on changes in triglycerides, HDL-c, blood glucose, waist circumference, and blood pressure. The LMS method was used to develop the percentiles, the area under the ROC curve (AUC) to identify the accuracy of the indicators, and the sensitivity and specificity to determine the cutoff points. FBM and %BF had significantly higher values in girls, who also had lower values for %LM compared to boys ($p<0.05$). The indicators of body composition, BMI, FBM, and %BF were accurate in predicting the MS risk for both sex at all ages. The main indicators of body composition to predict the MS risk, in both sex, were BMI, FBM, and %BF. These findings suggest that simple anthropometric measurements, which can be performed in clinical practice, have the potential to direct non-pharmacological actions.

Key words: Body composition; Metabolic syndrome; Child.

Resumo – *Objetivou-se desenvolver percentis de indicadores de composição corporal e determinar pontos de corte para predizer o risco de síndrome metabólica (SM) em crianças de seis a 10 anos de idade. Estudo epidemiológico de corte transversal, de base populacional, com participação de 1480 escolares de seis a 10 anos de idade. A avaliação antropométrica (massa corporal, estatura e dobras cutâneas) e a aferição da pressão arterial foram realizadas nas escolas. O índice de massa corporal (IMC) bem como o percentual de gordura (%GC), percentual de massa magra (%MM), massa corporal gorda (MCG) foram calculados de acordo com fórmulas padronizadas para crianças. A coleta de sangue para avaliar o perfil lipídico e glicêmico também foi realizada na escola, em dias e horários pré-estabelecidos. O diagnóstico da SM foi determinado com base em alterações nos triglicerídeos, HDL-c, glicemia, perímetro de cintura e pressão arterial. O método LMS foi utilizado para desenvolver os percentis, a área sob a curva ROC (AUC) para identificar a acurácia dos indicadores e a sensibilidade e especificidade para determinar os pontos de corte. MCG e %GC apresentaram valores significativamente superior nas meninas e também valores inferiores para a MCM em relação aos meninos ($p<0,05$). Os indicadores de composição corporal, IMC, MCG e %GC apresentaram acurácia na predição do risco de SM para ambos os sexos em todas as idades. Os principais indicadores de composição corporal para predição do risco de SM, em ambos os sexos, foram o IMC, %GC e MCG. Esses achados sugerem que medidas antropométricas simples, que podem ser realizadas na prática clínica, tem potencial para direcionar ações não medicamentosas.*

Palavras-chave: *Composição corporal; Síndrome metabólica; Criança.*

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INTRODUCTION

Chronic non-communicable diseases are among the main passive harms of prevention that burden the health system and are responsible for a high burden of morbidity and mortality[1]. Among these diseases, we highlight metabolic syndrome (MS), which can be characterized by the simultaneity of risk factors such as central obesity, arterial hypertension, low levels of HDL-c, hypertriglyceridemia, and hyperglycemia[2]. The presence of MS increases the risk for diabetes by five times and doubles the chances of developing cardiovascular diseases.[3] Furthermore, longitudinal data demonstrate that children diagnosed with MS are more likely to have MS in adulthood.[4] Therefore, two points seem to be crucial to reduce the prevalence of MS, I) to establish environments that control risk factors from childhood; and II) to validate simple, non-invasive, and low-cost methods for early detection of MS risk[5,6].

The worldwide MS prevalence among children and adolescents varies between 1.2% and 26%, reaching up to 60% among overweight/obese young people[7]. In Brazil, a systematic review of the literature showed a prevalence of MS in the pediatric population ranging from 0% to 40%[8]. The marked differences in the prevalence of MS between studies may be associated, especially, with differences in the sample profile and the criteria used for the MS diagnosis. According to Haffner[9], the difficulty in defining accurate cutoff points that are adjusted to the growth curves also represents a challenge for epidemiologists in the MS diagnosis in children and adolescents. Nevertheless, assessments for the MS diagnosis involve laboratory collections to obtain indicators of lipid, glycemic, and insulinemic profiles. These techniques are invasive, expensive, and difficult to access, highlighting the need to identify practical and low-cost methods to enable the assessment of this syndrome at a population level.

Anthropometric measurements have received special attention due to their consistent association with this outcome and their possibility of use in many sectors of public health, such as schools, family health units, and hospitals. Considering the consensus in the literature that obese and overweight young people are more likely to have MS[7,8]; anthropometric indicators of body composition could be used as important tools for MS screening in pediatric population. Thus, this study aimed: I) to verify the accuracy of anthropometric indicators of body composition to predict MS risk in children, and II) to develop percentiles and determine cutoff points for body composition indicators to predict the MS risk in children.

METHODS

Study design and population

This is a cross-sectional, population-based epidemiological study with a probabilistic sample of 6-10-year-old children, enrolled in public and private schools in urban and rural areas of the city of Uberaba/MG, Brazil.

For the sample calculation, we considered the number of children enrolled in elementary school (1st to 9th grade), the MS prevalence of 50% (prevalence unknown in the municipality), tolerable error of 3.5%, and confidence level of 95%. The minimum sample number was 768 children and after adding 10% to

compensate for losses and refusals and 20% to minimize confounding factors, the sample was estimated at 1014 children. To select the sample, schools were stratified according to educational segment (municipal, state, and private). We randomly selected 15 schools in the city. The number of children in each stratum was determined in proportion to the number of enrollments, according to data provided by the State Department of Education.

After approval by the Ethics Committee for Research with Human Beings (Protocol CEP/UFTM: 1710), the directors of the selected schools were contacted to obtain authorization and schedule for data collection. The selected students who met the study's inclusion criteria and were interested in participating in the research received the Informed Consent Form for their parents to know and sign. Data collection was carried out at the school from August 2011 to August 2012.

Evaluations

Body mass (BM) was obtained using a digital electronic scale (Plenna, Ice, São Paulo, Brazil). Height was measured using a portable anthropometer (Welmmy, Santa Bárbara d'Oeste/SP, Brazil). Body mass index (BMI) was calculated with measurements of body mass and height. The classification of overweight and obese children was performed based on the criteria proposed by Cole et al.[10] Waist circumference (WC) was obtained at the end of normal expiration using a flexible and inelastic measuring tape with a length of 2m (TBW, São Paulo). All measurements were taken in triplicate and the mean value of the three measurements was considered. Measurements were taken at the midpoint between the iliac crest and the last floating rib, as recommended by the World Health Organization.

Triceps (Tri-SK) and subscapular (Sub-SK) skinfolds were obtained using an adipometer (Lange Skinfold Caliper, Cambridge, MA, USA) which exerts a constant pressure of 10g/mm2, on the right side of the body and with three non-consecutive repetitions for each measurement. The final measure was obtained by the average of the three values. To calculate the body fat percentage (%BF) we used the equations proposed by Slaughter et al.[11] based on ethnicity and Tri-SK and Sub-SK thickness summation. The lean body mass (LBM) was obtained by subtracting the fat body mass (FBM) from the body mass total.

Blood pressure was measured with a mercury column sphygmomanometer (Unitec, São Paulo, Brazil), following standards protocols for children[12]. Two other measurement moments were set aside for children with high blood pressure levels. Children who had systolic or diastolic blood pressure above the 90th percentile were diagnosed with high blood pressure National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents[13] on three different occasions.

Blood samples (8mL) were collected in BD Vacutainer® vacuum tubes and centrifuged at 3400rpm for 8-minute. Serum samples were analyzed for the determination of HDL-c and triglycerides and plasma for blood glucose. We used the semi-automated Bio 200F analyzer (Bioplus, São Paulo, Brazil).

The MS diagnosis was determined by the presence of, at least, three of the following alterations triglycerides ≥ 100mg/dL; HDL-c < 50mg/dL; blood glucose ≥110mg/dL; waist circumference ≥ 75th percentile of the sample for

age and sex, blood pressure (diastolic or systolic) > 90th percentile adjusted for age, height and sex[13].

Statistical analysis

The SPSS statistical program was used to perform the Kolmogorov-Smirnov, Mann-Whitney, and Chi-square tests. Outliers were identified and removed using the quartile interval method. The ROC curve assessed the ability of anthropometric indicators of body composition to predict MS. The sensitivity (SE) and specificity (SP) values of the anthropometric indicators of body composition were calculated for each cutoff point present in the sample. The statistical significance of each analysis was verified by the area under the ROC curve (AUC) and by the lower limit of the 95% confidence interval > 0.5. For comparability with other studies, the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles were chosen as reference values. The percentiles, Box Cox (L), adjusted median (M), and coefficient of variation (S) values were performed using the LMS method proposed by Cole, using the LMS Chartmaker program[14].

RESULTS

The participants of this investigation were 1.480 children of both sex (52.2% girls), with a mean age of 8.55 (SD=1.53), students from the urban and rural areas in the municipality of Uberaba/MG. The BM, height, and BMI did not differ significantly between boys and girls ($p>0.05$). The FBM and %BF was significantly higher in girls, who also had lower values for the LBM compared to boys ($p<0.05$) (Table 1). The MS prevalence was 12.6% and 8.5% for girls and boys, respectively, with a statistically significant difference between sex ($p<0.05$).

The percentiles (5th, 10th, 25th, 50th, 75th, 90th, and 95th) of body composition indicators (BMI, BFM, LBM, and %BF), Box Cox (L), adjusted median (M), and coefficient of variation (S) values for age and sex for all variables analyzed were presented in Tables 2 and 3.

BMI, FBM, and %BF showed statistically significant accuracy for predicting the MS risk for both sex at all ages evaluated. On the other hand, the LBM showed significant accuracy values only for girls aged 7-10-year and boys aged 6, 9, and 10 years (Table 4).

Table 1. Anthropometric characteristics and body composition of 6-10-year-old children according to sex.

Variables	Girls (n=773)		Boys (n=707)		p-value
	Mean (SD)	Median (min-max)	Mean (SD)	Median (min-max)	
Body mass (kg)	30.05 (8.88)	28.70 (15.70 - 64.70)	30.58 (9.54)	28.25 (16.50 - 69.90)	0.500
Height (m)	1.31 (0.10)	1.31 (1.03 -1.70)	1.31 (0.10)	1.31 (1.07 - 1.66)	0.900
BMI (kg/m2)	17.49 (3.31)	16.52 (10.24 - 30.53)	17.49 (3.51)	16.40 (10.75 - 31.43)	0.600
LBM (kg)	23.09 (4.60)	22.63 (12.63 - 40.17)	23.72 (4.44)	23.22 (13.15 - 41.64)	0.010
FBM (kg)	7.49 (5.19)	5.84 (1.43 - 33.93)	6.80 (6.18)	4.60 (1.05 - 39.34)	0.001
%BF	22.42 (8.47)	20.96 (5.01 - 55.56)	19.66 (10.18)	16.55 (5.31 - 57.98)	0.001

Legend: n = sample; SD = standard deviation; min = minimum value; max = maximum value; BMI = body mass index; LBM = lean body mass; FBM = fat body mass; % BF = body fat percentage. Note: Significant difference between sex $p \leq 0.05$ from Mann Whitney test.

Table 2. Coefficient Box Cox (L), Median (M) and coefficient of variation (S), followed by percentile values for body mass index, lean body mass, fat body mass, and body fat percentage by age for girls.

Variable	Age (years)	L	M	S	5th	10th	25th	50th	75th	90th	95th
BMI	6	-1.16	15.69	0.15	12.60	13.16	14.24	15.69	17.50	19.56	21.07
	7	-1.23	15.91	0.16	12.65	13.24	14.37	15.91	17.88	20.19	21.93
	8	-1.29	16.23	0.17	12.80	13.41	14.59	16.23	18.36	20.92	22.90
	9	-1.36	16.87	0.18	13.20	13.85	15.10	16.87	19.21	22.12	24.43
	10	-1.43	17.03	0.18	13.25	13.90	15.19	17.03	19.51	22.66	25.25
LBM	6	-0.16	17.97	0.15	14.07	14.84	16.24	17.97	19.92	21.89	23.17
	7	-0.11	19.88	0.15	15.65	16.49	18.01	19.88	21.96	24.05	25.40
	8	-0.06	22.15	0.14	17.52	18.44	20.11	22.15	24.41	26.65	28.10
	9	-0.01	24.66	0.15	19.36	20.42	22.33	24.66	27.24	29.79	31.43
	10	0.03	26.13	0.15	20.33	21.49	23.58	26.13	28.95	31.74	33.53
FBM	6	-0.11	3.77	0.57	1.54	1.86	2.59	3.77	5.59	8.08	10.15
	7	-0.08	4.46	0.60	1.73	2.12	3.00	4.46	6.70	9.79	12.35
	8	-0.04	5.56	0.62	2.06	2.56	3.68	5.56	8.46	12.43	15.70
	9	-0.01	6.84	0.64	2.42	3.04	4.46	6.84	10.53	15.55	19.66
	10	0.02	7.83	0.66	2.61	3.34	5.01	7.83	12.19	18.12	22.93
%BF	6	-0.03	18.20	0.34	10.51	11.86	14.52	18.20	22.85	28.08	31.78
	7	0.02	19.08	0.36	10.44	11.94	14.91	19.08	24.38	30.38	34.63
	8	0.06	20.44	0.38	10.88	12.53	15.83	20.44	26.29	32.86	37.50
	9	0.11	22.16	0.39	11.50	13.34	17.02	22.16	28.64	35.86	40.92
	10	0.15	22.87	0.39	11.55	13.51	17.43	22.87	29.69	37.23	42.48

BMI = body mass index; LBM = lean body mass; FBM = fat body mass; % BF = body fat percentage

Table 3. Coefficient Box Cox (L), Median (M) and coefficient of variation (S), followed by percentile values for body mass index (BMI), lean body mass, fat body mass, and body fat percentage by age for boys.

Variable	Age (years)	L	M	S	5th	10th	25th	50th	75th	90th	95th
BMI	6	-2.68	15.54	0.12	13.29	13.68	14.45	15.54	17.00	18.87	20.45
	7	-2.30	15.68	0.14	13.11	13.56	14.44	15.68	17.37	19.56	21.42
	8	-1.93	16.06	0.16	13.03	13.55	14.59	16.06	18.07	20.69	22.91
	9	-1.55	16.84	0.18	13.24	13.86	15.09	16.84	19.21	22.27	24.80
	10	-1.17	17.50	0.20	13.27	14.00	15.45	17.50	20.25	23.69	26.44
LBM	6	0.44	19.06	0.13	15.33	16.11	17.47	19.06	20.72	22.28	23.24
	7	0.31	20.72	0.13	16.53	17.40	18.92	20.72	22.63	24.44	25.58
	8	0.18	22.89	0.13	18.30	19.24	20.91	22.89	25.02	27.07	28.37
	9	0.06	25.04	0.13	20.15	21.14	22.91	25.04	27.36	29.61	31.04
	10	-0.05	27.16	0.13	21.97	23.02	24.89	27.16	29.65	32.10	33.66
FBM	6	-0.20	3.03	0.59	1.24	1.49	2.06	3.03	4.61	6.94	9.01
	7	-0.20	3.35	0.68	1.22	1.50	2.16	3.35	5.40	8.68	11.80
	8	-0.17	4.34	0.72	1.47	1.84	2.72	4.34	7.20	11.84	16.28
	9	-0.23	5.27	0.76	1.77	2.20	3.26	5.27	9.07	15.77	22.78
	10	-0.03	6.76	0.80	1.86	2.46	3.96	6.76	11.62	19.06	25.70
%BF	6	-0.20	14.85	0.40	8.02	9.13	11.43	14.85	19.57	25.43	29.95
	7	-0.17	14.81	0.44	7.54	8.69	11.12	14.81	20.02	26.64	31.83
	8	-0.15	16.88	0.47	8.16	9.52	12.41	16.88	23.32	31.64	38.25
	9	-0.13	17.84	0.50	8.17	9.65	12.83	17.84	25.17	34.80	42.52
	10	-0.11	19.82	0.53	8.59	10.27	13.94	19.82	28.58	40.23	49.67

BMI = body mass index; LBM = lean body mass; FBM = fat body mass; % BF = body fat percentage

Table 4. Area under the curve, confidence interval (95%), cutoff points, sensitivity, and specificity of body composition indicators as predictors of metabolic syndrome in schoolchildren according to sex.

Girls									Boys							
Age (year)	Variable Predictive	AUC	p- value	Confidence Interval (95%)		Cut-off point	SE (%)	SP (%)	Variable Predictive	AUC	*p*- value	Confidence Interval (95%)		Cut-off point	SE (%)	SP (%)
				Lower limit	Upper limit							Lower limit	Upper limit			
6	BMI	0.900	0.003	0.820	0.980	17.9	100	84.06	BMI	0.908	0.006	0.803	1	18.2	100	83.1
	LBM	-	-	-	-	5	100	73.5	LBM	0.788	0.054	0.648	0.929	21	75	77.4
	FBM	0.842	0.011	0.727	0.957	20.4	100	72	FBM	0.927	0.004	0.846	1	6.6	100	87.3
	% BF	0.842	0.011	0.727	0.957	20.4	100	72	% BF	0.944	0.003	0.879	1	24.6	100	87.5
7	BMI	0.922	< 0.001	0.866	0.977	18.4	100	83.51	BMI	0.892	0.003	0.778	1	17.6	80	86.3
	LBM	0.923	< 0.001	0.869	0.978	8.3	100	87.5	LBM	-	-	-	-	-	-	-
	FBM	0.737	0.026	0.592	0.882	22.4	75	74.2	FBM	0.865	0.006	0.72	1	6	80	81.4
	% BF	0.933	< 0.001	0.883	0.983	27.3	100	87.6	% BF	0.861	0.007	0.72	1	18	80	71.2
8	BMI	0.838	< 0.001	0.711	0.965	19	80	84	BMI	0.919	0.014	0.848	0.989	20.4	100	88.3
	LBM	0.728	< 0.001	0.59	0.866	23	80	62	LBM	-	-	-	-	-	-	-
	FBM	0.876	< 0.001	0.794	0.958	8.6	80	83	FBM	0.874	0.028	0.756	0.992	6.9	100	75.5
	% BF	0.878	< 0.001	0.795	0.96	23.2	93.3	72	% BF	0.846	0.043	0.646	1	18.6	66.6	61.6
9	BMI	0.881	< 0.001	0.789	0.973	18.6	85.7	77.7	BMI	0.843	0.001	0.692	0.995	17.9	88.8	71.4
	LBM	0.82	< 0.001	0.696	0.944	27.7	71.4	83.3	LBM	0.759	0.016	0.531	0.987	26.9	66.6	74.4
	FBM	0.887	< 0.001	0.801	0.972	8.7	92.8	72.5	FBM	0.920	0	0.861	0.979	8.6	100	81.4
	% BF	0.877	< 0.001	0.792	0.962	27.5	85.7	82.4	% BF	0.904	0	0.839	0.969	24	100	78.8
10	BMI	0.806	< 0.001	0.688	0.924	18.1	78.9	62.6	BMI	0.800	<0.001	0.672	0.927	18.6	78.5	71.2
	LBM	0.681	0.021	0.538	0.824	27.5	63.1	61.3	LBM	0.801	<0.001	0.684	0.917	27.9	86.6	65.1
	FBM	0.809	< 0.001	0.685	0.933	12.4	75	84	FBM	0.797	0.001	0.68	0.915	9.4	85.7	72.7
	% BF	0.802	< 0.001	0.675	0.929	29.9	80	81.3	% BF	0.77	0.002	0.637	0.903	27.6	80	74.2

BMI = body mass index; LBM = lean body mass; FBM = fat body mass; % BF = body fat percentage; AUC = area under the curve; SE = sensitivity; SP = specificity; - = indicates that LBM did not present significant AUC to predict metabolic syndrome.

DISCUSSION

This study investigated different body composition indicators as predictors of MS risk in Brazilian children, including the proposition of percentiles and cutoff points. Among the investigated body composition indicators, those that estimate the amount of body fat were the most accurate for predicting MS in 6-10-year-old children. We believe that the percentiles and cutoff points developed in this study may be useful in screening for MS risk at an early age, aiming at the development of prevention strategies by health-promoting agents.

The prevalence of MS observed in this study, compared with Brazilian[8] and international studies[7], suggests that actions to deal with this health problem are necessary. BMI cutoff points have been used to determine overweight and obesity in population studies involving children[10,15]. On the other hand, BMI percentiles were also used as one of the diagnostic MS factors, for example, BMI 97th percentile for age and sex[16,17]; > 95th percentile[18,19]; ≥ 85th percentile of the sample[20].

The suggested BMI cutoff point to predict MS risk among girls in this study was 18.5 kg/m^2 (S=80.33%, E=76.33%). BMI had the highest AUC (0.867) among girls. For boys, BMI was the fourth most accurate predictor (AUC=0.872), behind FBM (AUC=0.880). The suggested BMI cutoff point to predict MS among boys was 18.6 kg/m^2 (S=80%, E=80%). A previous study with Spanish children[21] suggested the 65th percentile of BMI, regardless of sex and age, in predicting the set of cardiovascular risk factors that compose MS (AUC=0.868, S=80%, and E=75%).

The BMI cutoff points (≥ 75th percentile of the sample) suggested to predict MS, by age and sex, in the present study, approached the overweight diagnosis proposed by the International Obesity Task Force/IOTF (criterion internationally used with a representative sample of six countries, including Brazil)[10] and Conde and Monteiro[15], the national reference.

In another study, Ferreira et al.[22] reported that BMI was the most accurate predictor of MS risk in a study with 109 Brazilian children aged 7-11-year-old. Among the different anthropometric measures tested, the BMI > 24.5 kg/m^2, WC > 78cm, and %BF > 41% (measured by DEXA) were considered to be MS predictors. The lack of description of the anatomical point of PC measurement and generalization of data (without distinction of age and sex) limits the possibility of comparisons between studies.

The BMI values in this study, which are close to those reported for the diagnosis of obesity[10,15], are found in the reference curve ≥ 90th percentile, with high specificity values in predicting the risk of MS. Halley Castillo et al.[23] reported that high BMI values have an impact on the MS prevalence, as eutrophic and overweight boys had 3% and 66% of MS prevalence, respectively. However, the MS prevalence in 6-12-year-old Mexican children was 23.3%, while in the overweight group, the prevalence was 28.5%[24].

Sellers et al.[25] found unexpected results in a cohort of Australian Aboriginal children, as BMI had low values in the sample, with a prevalence of overweight of 6.4% and obesity of 4.9%, while the MS prevalence was 14%, a result contradictory to that found in an American study with the same parameters, prevalence of obesity of 15% and MS of 4%[26]. The use of BMI as a diagnostic criterion for overweight and obesity in children is consolidated in the scientific literature; however, its use, as a predictive criterion for the MS risk, should be

carried out with caution, as children with a classification of "normal weight" by BMI, they can be considered falsely thin, and, as a result of excess body fat, especially in the central region of the body, present metabolic changes in MS components.

The %BF was an accurate predictor of MS for girls (AUC = 0.867) and boys (AUC = 0.864) with cutoff points between the 50th and 75th percentile. The values suggested for predicting the MS risk in 6-8-year-old girls and 7-8-year-old boys approached the cutoff points they classify as adequate[27] or excellent[28] (SE≥93.3% and SP=72%) the amount of %BF. Cutoff points for 7, 9, and 10-year-old girls were included in the classification of moderately high and high body fat[27,28], which was repeated among 6,9, and 10-year-old boys. A previous study carried out with Brazilians suggested a cutoff point of 25.7% of %BF (SE=75% and SP=71.25%) in the MS prediction in girls with a mean age of 9.9 years, classification of the moderately high amount of %BF[28], and among boys, there was no significant accuracy for this predictor. The recommendations for the amount of %BF in children were proposed only by sex, without age stratification[27,28]. Thus, divergences between cutoff points for %BF presented in this study (by age and sex) and the recommendations may have occurred due to the lack of specificity attributed to different age groups in previous recommendations.

Sun et al.[29] warn of the secular trend of increasing %BF. The average %BF of North American children born in the 1990s was significantly higher than the average of children born three decades earlier. The estimate of the growth trajectories of the %BF differed between sex, with an increase in the %BF among boys up to 12 years old and a subsequent decrease, and a linear increase in the %BF with age among girls. Girls had significantly higher mean %BF than boys at all ages (8-18-year-old) and in all four decades of birth. In the present study, girls, in addition to having higher %BF, following the secular trend, had a higher prevalence of MS compared to boys ($p<0.05$), strengthening the consistent relationship between %BF and risk of MS in the pediatric population.

We should highlight the FBM, which presented AUC>0.737 for boys and girls. Suggested cutoff points were ≥ 75th percentile for girls and > 50th percentile for boys. The girls in this study had significantly higher FBM values compared to boys ($p<0.05$). It is difficult to compare our findings with other studies, as values are expressed, most of the time, in percentages and not in kilograms.

The LBM was not accurate in predicting the risk of MS in different age groups in both sex, and it had the worst performance when compared to the other indicators analyzed in this study for the MS prediction. These findings are in agreement with the body of evidence that suggests a strong relationship between body fat indicators and MS during childhood and adolescence.[7,8]

One of the limitations of the present investigation is the lack of comparability with other studies that have been conducted on this topic, as there is no standardization of the measurements and cutoff points used. Another important aspect is the standardization of data collection on anthropometric measurements, which must be considered when using this technique. In our study, all anthropometric measurements were performed by two trained evaluators, ensuring greater reliability of the results. Although we have a representative sample of the population with children of different ethnicities, the results were not stratified in this way in our study.

Respecting the limitations of the study and based on the observed results, we concluded that the main anthropometric indicators for MS, in both genders, were BMI, BFM, and %BF. These findings suggest that simple anthropometric measurements, which can be performed in clinical practice, have the potential to direct non-pharmacological actions, such as regular physical activity and healthier eating habits, aimed at promoting health and preventing MS at an early age.

COMPLIANCE WITH ETHICAL STANDARDS

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Ethical approval

Ethical approval was obtained from the local Human Research Ethics Committee – Ethics Committee for Research with Human Beings of the *Universidade Federal do Triângulo Mineiro* (Protocol CEP/UFTM: 1710) was written in accordance with the standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conceived and designed the experiments: TMBQ, APG, ELM, ACRA; Performed the experiments: TMBQ, APG, ELM, ACRA; Analyzed the data: TMBQ, APG, ELM, ACRA; Contributed reagents/materials/analysis tools: TMBQ, APG, ELM, ACRA; Wrote the paper: TMBQ, APG, ELM, ACRA.

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