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Original Article

COMPARISON OF METABOLIC PARAMETERS IN CHILDREN AND ADOLESCENTS WITH AND WITHOUT INSULIN RESISTANCE

COMPARAÇÃO DE PARÂMETROS METABÓLICOS EM CRIANÇAS E ADOLESCENTES COM E SEM RESISTÊNCIA À INSULINA

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ABSTRACT
The aim of the study was to compare the behavior of metabolic parameters, blood pressure, and obesity indicators in children and adolescents with and without insulin resistance. Sixty-one overweight children (6 to 18 years) underwent anthropometric measurements of body mass (BM), height and waist circumference (WC), blood pressure (BP), bioimpedance (relative (%F) and absolute fat (BF)), and blood collection for determination of glucose, insulin, and lipid profile (TG, CT, HDL-C, LDL-C). The BMI z-score was used to classify nutritional status and the HOMA-IR index (> 2.5) for insulin resistance. Participants were divided into two groups, insulin resistant (IR, n= 27) and non-insulin resistant (NIR, n= 33). Regardless of age, children and adolescents with excess weight and IR presented higher BM, WC, BMI, %F and BF (kg), TG, and plasma insulin than their NIR counterparts, who in turn presented higher LDL-C. The groups did not differ in nutritional status (BMI z-score); however, in the comparison between the undesired proportions of the metabolic components, only three presented alterations with significant differences between the groups (TC, LDL-C, and TG). It is concluded that IR influences the development of dyslipidemias in this age group, especially TG.
Keywords: Obesity, Adolescents, Metabolism.

RESUMO
O objetivo do estudo foi comparar o comportamento de parâmetros metabólicos, pressão arterial e indicadores de obesidade em crianças e adolescentes com e sem resistência à insulina. Participaram do estudo 60 crianças e adolescentes com excesso de peso (6 a 18 anos)que foram submetidos amedidas antropométricas de massa corporal (MC), estatura ecircunferência da cintura (CC), pressão arterial (PA), bioimpedância[gordura relativa (%G) e absoluta (GC)] e coleta sanguínea para determinação das concentrações de glicose, insulina e perfil lipídico (TG, CT, HDL-C, LDL-C). O IMC z-scorefoi empregado para classificação do estado nutricional e o índice HOMA-RI (>2,5) para resistência à insulina.Os participantes foram divididos em dois grupos, resistentes (RI, n=27) e não resistentes à insulina (NRI, n=33).Independente da idade, crianças e adolescentescom excesso de peso e RI, apresentaram maior MC, CC, IMC, %G e GC (kg), TG e insulina plasmática do que contraparesNRI, que por sua vez, apresentaram valores mais elevados de LDL-C. Os grupos não diferiram para oestado nutricional(IMC z-score)porém, na comparação entre as proporções indesejadas dos componentes metabólicos, apenas três apresentaram alterações com diferenças significativas entre os grupos (CT, LDL-C e TG). Conclui-se que a RI apresenta-se com influência para o desenvolvimento de dislipidemias nessa faixa etária em especial o TG.
Palavras-chave: Obesidade, Adolescentes, Metabolismo.

Introduction

The onset of metabolic diseases in young people in recent decades has been increasingly evident[1-4]. Insulin resistance impairs the proper functioning of various organs such as the liver, vessels, muscles, and adipose tissue, and predates glucose intolerance and type-2 diabetes mellitus[5]. Thus, insulin resistance becomes an important variable since it is presented as one of the first disorders that can lead to more serious complications related to the increase in adipose tissue, arterial hypertension, and elevated cholesterol[6].

A sedentary lifestyle and excessive fat gain are determinants for insulin resistance, emphasizing the existence of a genetic component that can be aggravated by environmental

factors[7]. However, even though insulin resistance and obesity are closely associated, not all obese individuals are resistant to insulin, nor are all resistant individuals obese[8]. Thus, the influence of insulin resistance on different metabolic aspects needs to be better explored, especially in childhood and adolescence[9].

Considering overweight and obesity in children and adolescents as an important public health problem in both developed and developing countries[10], despite evidence of the association between excess fat and metabolic abnormalities in adults[11,12], the results of studies in young people are still conflicting[13-15]. Additionally, in adolescents with excess weight, the presence of insulin resistance may be associated with other metabolic disorders, regardless of the level of adiposity. In view of these facts, the objective of this study was to compare the behavior of metabolic parameters (blood glucose, insulinemia, and lipid profile), blood pressure, and obesity indicators (quantity and fat distribution) in children and adolescents with and without insulin resistance.

Methods

Participants

The current study was part of an extension project entitled "Program for the Control and Treatment of Obesity in Children and Adolescents in the Municipality of Guarapuava-PR", financed by the Notice 02/2011 of the Extension Program University without Borders, Health Support Subprogram, of the State Department of Science, Technology and Higher Education (USF / SETI) of Parana. According to the objectives and schedule, all study participants were overweight, obese, or extremely obese according to the Z-score (3 for severe obesity, 2 for obesity, and 1 for overweight). The project was publicized in newspapers, radio, and television and the state and private schools of the municipality were visited with consent of the Regional Nucleus of Education. After disclosure, 120 children and adolescents, through their parents / guardians, enrolled in the project. Of these, 31 girls and 29 boys (60 children and adolescents), aged 6 to 18 years completed all the evaluation phases, consisting of anthropometric measures, body composition (bioimpedence), and fasting blood collection for glucose determination and lipid profile (HDL-C, LDL-C, TG and CT). None of the subjects reported taking any medication that could interfere with the data collected. The project was approved by the research ethics committee (opinion no. 297.649) of the State University of Midwestern Parana (UNICENTRO) and all participants signed a Free and Informed Consent Term.

Anthropometry

The anthropometric measures were collected using the standard procedures of Lohman, Roche and Martorel[16]. Body mass measurement (BM) was performed on a Welmy® brand scale, with an accuracy of 0.1 kg and the height measurement was obtained on a wooden stadiometer with a precision of 0.1 cm. For both measurements, the subjects wore light clothing and were barefoot. The Body Mass Index (BMI = weight kg / height m^2) was used to classify nutritional status. For the cut-off points of the BMI, the WHO z-score1 standards were used.

Waist circumference (WC) was obtained at the midpoint between the last ribs and the iliac crest, using a flexible but non-elastic metric tape with a precision of 1mm, with the individual in an anatomical position. Three measures were taken and the recommendations of Mccarthy, Jarrett and Crawley were used to classify WC measurements as normal or increased values[17].

The percentage of fat (%F) and body fat (BF) were estimated by means of electrical Bioimpedance (MALTRON Body Fat Analyzer BF-906® England). Participants were

evaluated in the morning, in a fasting state for foods and liquids for at least 4 hours. In addition, participants were instructed not to consume alcohol or foods with caffeine in the 24 hours prior to the test, as well as any diuretic medication in the previous 7 days. The patient lay in a supine position on a stretcher with a non-conductive surface during the entire assessment procedure[18]. To classify the %F of the participants as normal or increased values, the cut-off points of Lohman[19] were adopted.

Hemodynamic and metabolic parameters

Blood pressure (BP) was measured using the auscultatory technique, with a mercury column sphygmomanometer[20] duly calibrated and fitted with a cuff compatible with the sample. During the procedure the participants remained seated, with uncrossed legs and feet on the floor[21]. From the values of systolic BP (SBP) and diastolic BP (DBP) the mean BP was estimated according to the following formula: MBP = [SBP + (2DBP)] / 3.

Participants attended a clinical laboratory of the municipality for blood collection after night fasting (10 to 12 hours). The collection was performed by puncture of the antecubital vein through the vacuum collection system (Vacutainer™ Becton Dickinson Company, Plymouth, UK), using 4.0 mL tubes with anticoagulant (fluoride associated with EDTA 1 mg/mL blood) and 3.5 mL tubes with heparin. Plasma was used to determine the concentration of Total Cholesterol (CT), Triglycerides (TG), High Density Lipoproteins-Cholesterol (HDL-c), glucose, and insulin.

Plasma determinations of TG, CT, HDL-C, and glucose were performed using the enzymatic colorimetric method. Plasma insulin was determined by the ELISA method, using ultra-sensitive kits and intra-assay and inter-assay coefficients of 5.96 ± 1.17 µU/mL and 10.3 ± 0.9 µUU/mL, respectively. The Low Density Lipoprotein-Cholesterol (LDL-C) fraction was estimated by the Friedewald formula: LDL-C = CT-HDL - (TG / 5)[22].

The parameters of glucose and lipid metabolism were classified according to the following cut-off points: Glucose: ≥ 100.0 mg/dL; CT: ≥ 150.0 mg/dL; HDL-C: ≥ 45.0 mg/dL; LDL-C: <100.0 mg/dL; TG: <100.0 mg/dL[23]. The method used for the evaluation of insulin resistance was HOMA-IR (Homeostasis Model Assessment-Insulin Resistance), calculated from the formula[24]: HOMA-IR = fasting insulinemia (mU/L) x fasting glycemia (mmol/L) / 22.5. IR was defined as HOMA values above 2.5 units[25]. Based on this criterion, the 60 participants were divided into two groups, insulin resistant (IR; n = 27) with HOMA-RI index values equal to or greater than 2.5 units, and non-resistant to insulin with values lower than 2.5 units (NIR; n = 33).

Statistical analysis

The characterization of the sample was performed from the median for age, anthropometry, and body composition. The comparative analysis between the resistant and non-resistant groups was performed using the Mann-Whitney and ANCOVA tests. The ANOVA covariance analysis was applied respecting the non-violation of the assumption of homogeneity of the variances verified by the Levene test. For this comparison, age was used as a correction co-variable. In the comparison of the percentages of altered values, the chi-square test was applied. The data were stored and processed in Microsoft Excel 2010 Software. The analytical process, performed with SPSS software version 20.0, started with the application of normality assumption tests. The Shapiro-Wilk test was applied. Some of the variables that did not meet the normality assumption were passed through logarithmic transformations prior to the inferential tests.

Results

The results of the comparisons between the IR and NIR groups are shown in Table 1. The NIR children and adolescents demonstrated significantly lower values for age, BM, height, BMI, BF (kg), and WC.

Table 1. Characterization of the sample

Variables	NIR (n=33)			IR (n=27)			
	Median	p25	p75	Median	p25	p75	*p*
Age (years)	9.7	8.9	11.4	12.8	11.3	13.2	0.001
BM (kg)	48.7	40.4	55.8	69.7	61.7	83.1	0.001
Height (m)	141.3	133.2	147.6	158.2	147.5	164.2	0.001
BMI (kg/m^2)	23.4	21.5	26.2	28.1	26.8	32.1	0.001
%F (Bio)	32.3	29.4	35.3	32.1	28.6	36.7	0.766
BF (kg)	14.5	12.6	19.8	20.9	17.1	29.6	0.001
WC (cm)	79.4	75.0	86.3	90.0	84.0	98.5	0.020

Note: NIR: not insulin resistant; IR: insulin resistant; BM: body mass; BMI: body mass index; %F: percentage of fat (Bioimpedance); BF: body fat; WC: waist circumference; p25- Percentile 25; p75- Percentile 75; Mann-Whitney U; $p<0.05$.
Source: Authors

In Table 2, the anthropometric and metabolic variables were adjusted by the age of the participants. The IR group demonstrated significantly higher values than the NIR group for BM, BMI, BF, WC, TG, insulin, and HOMA-IR. In turn, the NIR group presented significantly higher LDL-C content than the IR group.

Table 2. Comparison of age-corrected anthropometric and metabolic variables between the NIR and IR

Variables	NIR (n=33)	IR (n=27)	p
BM (kg)	54.3±2.3	68.6±2.6	0.001
Height (m)	146.8±1.3	149.9±1.5	0.160
BMI (kg/m^2)	24.6±0.8	29.9±1.0	0.001
%F (Bio)	31.4±1.1	32.8±1.2	0.430
BF (kg)	17.4±1.3	21.7±1.5	0.040
WC (cm)	82.2±1.8	90.6±2.0	0.005
SBP (mmHg)	111.0±2.0	114.8±2.2	0.220
DBP (mmHg)	73.1±1.5	76.2±1.7	0.190
MBP (mmHg)	85.7±1.5	89.1±1.7	0.160
CT (mg/dL)	156.6±4.8	144.2±5.3	0.100
HDL-C (mg/dL)	44.5±1.1	43.0±1.2	0.400
LDL-C (mg/dL)	96.4±4.3	77.2±4.8	0.007
TG (mg/dL)	86.9±7.5	120.7±8.4	0.006
Glycemia (mg/dL)	81.7±1.5	85.1±1.7	0.170
Insulin (mcU/mL)	8.3±1.7	20.3±1.9	0.001
HOMA-IR	1.6±0.4	4.3±0.5	0.001

Note: NIR: not insulin resistant; IR: insulin resistant; BM: body mass; BMI: body mass index; %F: percentage of fat; (Bioimpedance) BF: body fat; WC: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; MBP: mean blood pressure; Values presented as mean and (±) standard deviation; Estimated values for age = 11.0731; Ancova adjusted for Age; *$p<0.05$
Source: Authors

Table 3 presents the absolute (n) and relative (%) frequency according to cut-off points and the comparisons between sex, BMI (Z-score), %F, WC, CT, HDL- C, TG, and glycemia. There were no differences between NIR and IR according to sex, suggesting homogeneity of the groups. However, significant differences were observed in the proportion

of children and adolescents with altered (increased) values for TC (p = 0.030), LDL-C (p = 0.010), and TG (p = 0.002). In this sense, NIR children and adolescents showed a higher frequency of participants with increased values for TC (57.6% vs 29.6%) and LDL-C (33.3% vs 7.4%) when compared to the IR, respectively. In contrast, the IR included a higher frequency of participants with increased values for TG (63.0% vs 24.2%) than the NIR, respectively.

Figure 1 shows the estimate of the probability of not finding an insulin resistance frame from the TG content. The finding of the decreasing survival curve of insulin resistance from the TG suggests a tendency to influence TG changes in insulin resistance, i.e., the higher the TG rate, the greater the probability of the child and/or adolescent presenting insulin resistance.

Table 3. Percentages and incidences according to gender, and anthropometric and metabolic variables between the NIR and IR

Variables	Classification	NIR (n=33)		IR (n=27)		p
		n	%	n	%	
Sex	Girls	17	51.5	14	51.9	0.970
	Boys	16	48.5	13	48.1	
BMI/age (z-score)	Overweight	08	24.2	03	11.1	0.320
	Obesity	19	57.6	16	59.3	
	Severe Obesity	06	18.2	08	29.6	
%F	Normal	03	9.1	03	11.1	0.790
	Increased	30	90.9	24	88.9	
WC (cm)	Normal	12	36.4	07	25.9	0.380
	Normal	21	63.6	20	74.1	
CT (mg/dL)	Normal	14	42.4	19	70.4	**0.030**
	Increased	19	57.6	08	29.6	
HDL-C (mg/dL)	Normal	13	39.4	09	33.3	0.620
	Increased	20	60.6	18	66.7	
LDL-C (mg/dL)	Normal	22	66.7	25	92.6	**0.010**
	Increased	11	33.3	02	7.4	
TG (mg/dL)	Normal	25	75.8	10	37.0	**0.002**
	Increased	08	24.2	17	63.0	
Glycemia (mg/dL)	Normal	33	100.0	25	92.6	0.110
	Increased	00	0.0	02	7.4	

Note: NIR: not insulin resistant; IR: insulin resistant; BM: body mass; BMI/age Z-score: body mass index according to age[1]; %F: percentage of fat[18]; WC: waist circumference[17]; Risk for CT; HDL-C; LDL-C; TG; Glycemia[23]; Absolute (n) and relative (%) frequency of individuals per group*p<0.05.
Source: Authors

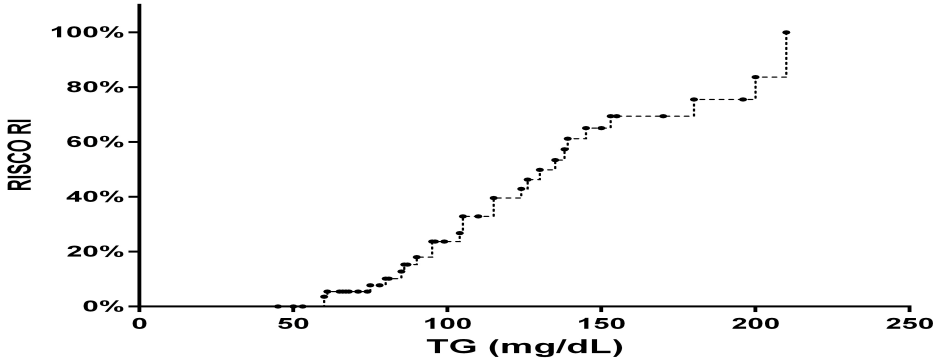

Figure 1. Estimation of survival of absence of IR from TG
Source: Authors

Discussion

The results of the present study revealed that, irrespective of age, children and adolescents with IR presented significantly higher values for BM, BMI, BF, WC, TG, insulin, and HOMA-IR compared to the NIR group. These results are in accordance with other studies with similar samples[26,27]. In turn, the NIR group demonstrated significantly higher LDL-C content than the IR group.

The differences between the IR and NIR groups for BM, BMI, and BF corroborate with the literature, indicating an association between insulin resistance and body composition. Understanding obesity as an inflammatory process is essential to recognize the possibility of developing insulin resistance early[28]. Insulin resistance added to excess weight may be an important trigger for increases in the inflammatory process and alterations in carbohydrate and lipid metabolism[29]. In addition, there is an effect exerted on the synthesis of hepatic proteins that may result in an anti-inflammatory response[30]. The results of the present study are equivalent to the study by Gobato et al.[27], who investigated the relationship between obesity (% F, BMI, abdominal circumference, and subcutaneous fat) and insulin resistance in 79 adolescents (10 to 18 years). The results showed a significant positive correlation between indicators of obesity and insulin resistance ($r = 0.346$, $r = 0469$, $r = 0.428$, and $r = 0.388$, respectively). Among the groups in the present study, no significant differences were observed for height. The pubertal spurt occurs non-linearly and is susceptible to several external or external influences, such as diet, psychosocial or environmental actions, and hormones involved in puberty[31]. The absence of significant differences in this variable strengthens the findings of this study.

Even with evidence of an association between BP and insulin resistance[32], the present study did not find significant differences between the IR and NIR groups. Among the possible causes, we can point out the period and exposure of the participants to the risk condition (age group), since a study by Ulbrich et al.[33] suggests that alterations in BP levels (hypertension) are commonly observed from 40 years of age in both overweight and/or obese individuals of both sexes.

In a study carried out by Mascarenhas et al.[34], oscillation in the behavior of lipid metabolism during adolescence was identified. In the current study, it was observed that both CT and HDL-C decreased in the final phase of puberty in relation to the other phases. Our findings did not present significant differences between the IR and NIR groups in either variable. Even so, the literature suggests a reduction in HDL-C levels as a function of the insulin resistance condition, which is due to the lower availability of apolipoproteins and phospholipids from the chylomicrons and VLDLs used for the formation of HDL-C[35]. In this regard, altered levels of HDL-C between the IR and NIR groups were not observed in this study. In turn, participants in the NIR group exhibited significantly higher levels of LDL-C than those in the IR group. In addition, when applying LDL-C, normal and altered, a higher frequency of participants in the NIR group with elevated LDL-C was confirmed. However, it is interesting to note that 91% of NIR children and adolescents presented excess fat, a condition that is favorable to diseases in biomarkers of cardiometabolic disorders.

In the present study, there were no differences between the sexes for IR and NIR in the variables BMI (Z-score),%F, WC, HDL-C, and glycemia. However, there is evidence pointing to differences in the prevalence of insulin resistance according to gender, favoring girls[36,37], with possible mechanisms present in the hormonal changes that occur during puberty[38,39]. On the other hand, no differences were demonstrated between boys and girls in a meta-analysis performed with 18 articles from 13 different countries, after adjustment for pubertal development[39]. In another study conducted with 205 children and adolescents from Muzambinho-MG (Brazil), no significant differences were found between boys and girls in

any of the studied variables, which included obesity, BP, blood glucose, and cholesterolemia[40].

The high frequency of children and adolescents with altered CT and LDL-C in the NIR group in relation to the IR, can be explained as a function of the variations in the pubertal stage. In turn, the significant differences in TG, as well as the behavior of the decreasing curve of survival from IR to TG, are justified by the inability of insulin to successfully activate lipoprotein lipase. In this sense, its function would be to hydrolyze the TG transported by the very low density lipoprotein (VLDL-C), which may not be occurring adequately in the IR group. In addition, accumulation of fat in the liver leads to increased secretion of VLDL-C[33]. It is also worth noting that TG is not influenced by the puberty factor of the participants, since there were no significant differences in TG between the different pubertal stages in a study conducted with 662 adolescents aged between 10 and 17 years[32].

Despite the methodological rigor adopted, it is necessary to highlight limitations that could affect the analysis of the results. One of these concerns the absence of data on parents. A study carried out by Psyrogiannis et al.[41] points out that children of diabetic parents (type 2 diabetes mellitus) present higher IR and higher amounts of TG. In addition, the fact that both groups were overweight, made it impossible to compare the variables investigated with a control group (non-obese). Another possible limitation is the lack of consensus about the cut-off point of HOMA-IR for children and adolescents, which can range from 2.1 to 5.56[42]. The variation in cut-off points used for insulin resistance restricted, in part, comparison of the data with other studies. Better understanding of the phenomenon of insulin resistance in childhood and adolescence is paramount for the treatment of the abnormalities that this metabolic disorder can cause. The results found may serve as a basis for new research and interventions aimed at seeking treatments for insulin resistance and its aggravations.

Conclusion

Regardless of age, overweight children and adolescents with a HOMA-IR index above 2.5 units presented higher body mass, BMI, relative (%) and absolute (kg) fat, adipose tissue in the abdominal region (waist circumference), triglyceride levels, and plasma insulin than their non-insulin resistant counterparts. Insulin resistance in overweight children and adolescents has been shown to be associated with dyslipidemias, with emphasis on TG.

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