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Are metabolic syndrome and its components in obese children influenced by the overweight status or the insulin resistance?

Czy u otyłych dzieci wystąpienie zespołu metabolicznego i jego składowych jest warunkowane stopniem otyłości czy insulinoopornością?

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Abstract

Introduction: The aim of this study was to determine which factors increase the risk of metabolic syndrome (MS) and its components in obese children and adolescents.

Material and methods: In 78 obese children (42 girls, 36 boys), mean age 14.6 ± 3.5 years, blood pressure, total cholesterol, triglycerides, HDL-cholesterol (HDL), insulin and glucose at fasting state as well as in OGTT were measured. Body mass index (BMI) Z-score, LDL-cholesterol, and insulin resistance indices (FIGR, R-HOMA) were calculated.

Results: Metabolic syndrome was diagnosed in ten (12.8%) children. Hyperinsulinaemia was present in 42 (53.8%) subjects, increased FIGR in eight (10.3%) and increased R-HOMA in 49 (62.3%). Significant correlations between BMI Z-score ≥ 2.5 and MS occurrence and its components (hypertriglyceridaemia, isolated systolic and diastolic hypertension) were found. Hypertriglyceridaemia, low HDL and hypertension, as well as MS occurrence, correlated significantly with stimulated hyperinsulinaemia and increased FIGR. Risk of hypertension was increased 5.6 times by fasting hyperinsulinaemia. Stimulated hyperinsulinaemia increased the risk of hypertriglyceridaemia 3.7 times, risk of low HDL 14.4 times and risk of MS 10.3 times. These risks did not change significantly when adjusted for BMI Z-score.

Conclusions: Our study results show that both BMI Z-score and OGTT stimulated hyperinsulinaemia are good predictors of MS occurrence in obese children and adolescents. The risk of dyslipidaemia and hypertension increase significantly with hyperinsulinaemia and insulin resistance, with low HDL cholesterol being the most affected. **(Pol J Endocrinol 2011; 62 (2): 102–108)**

Key words: *insulin resistance, hyperinsulinaemia, metabolic syndrome, children, adolescents*

Streszczenie

Wstęp: Celem pracy było określenie czynników ryzyka wystąpienia zespołu metabolicznego (MS, *metabolic syndrome*) i jego składowych u otyłych dzieci i młodzieży.

Materiał i metody: U 78 dzieci z otyłością prostą (42 dziewczynek, 36 chłopców) w średnim wieku 14,6±3,5 lat oznaczono stężenia cholesterolu całkowitego, triglicerydów, cholesterolu frakcji HDL (HDL), insuliny i glukozy na czczo i w OGTT, obliczono indeks masy ciała (BMI, *body mass index*) i jego Z-score oraz wskaźniki insulinooporności (FIGR, R-HOMA). Dokonano 3-krotnych pomiarów ciśnienia tętniczego.

Wyniki: Zespół metaboliczny rozpoznano u 10 (12,8%) dzieci, podwyższone stężenie insuliny na czczo odnotowano u 42 (53,8%), podwyższony FIGR u 8 (10,3%), a podwyższony R-HOMA u 49 (62,3%) badanych. Wskaźnik masy ciała Z-score ≥ 2,5 był istotnie związany z występowaniem MS oraz jego komponentów (hipertriglicerydemią, izolowanym nadciśnieniem skurczowym i rozkurczowym). Stwierdzono istotną korelację hipertriglicerydemii, niskiego stężenia HDL, nadciśnienia i występowania MS z hiperinsulinemią w OGTT i podwyższonym FIGR. Ponadto ryzyko nadciśnienia było 5,6-krotnie wyższe u dzieci z hiperinsulinemią na czczo. Hiperinsulinemia w OGTT zwiększała ryzyko wystąpienia hipertriglicerydemii 3,7-krotnie, ryzyko niskiego stężenia HDL — 14,4-krotnie, a ryzyko MS — 10,3-krotnie. Związki te nie zmieniły się istotnie po skorygowaniu dla BMI Z-score.

Wnioski: Stwierdzono, że zarówno BMI Z-score, jak i hiperinsulinemia w OGTT są dobrymi czynnikami prognostycznymi wystąpienia MS u otyłych dzieci i młodzieży. Ryzyko wystąpienia nadciśnienia i dyslipidemii, a szczególnie niskiego stężenia HDL, wzrasta istotnie u dzieci z hiperinsulinemią i insulinoopornością. **(Endokrynol Pol 2011; 62 (2): 102–108)**

Słowa kluczowe: *insulinooporność, hiperinsulinemia, zespół metaboliczny, dzieci, młodzież*

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Introduction

Obesity, the 21st century pandemic, affects more than a billion people worldwide. In recent decades, a constant and significant increase in overweight and obesity has been noted. Childhood obesity has reached epidemic proportions [1] and is associated with a wide range of serious complications including increased prevalence of cardiovascular risk factors. The clustering of these risk factors, known as metabolic syndrome (MS), if present in children, predicts adult cardiovascular disease [2]. MS has a common background: insulin resistance (IR). IR is an inappropriate metabolic response to insulin (INS) action resulting in dysfunction in glucose (GLU) metabolism. Together with compensatory hyperinsulinaemia, IR can be responsible for the development of several metabolic abnormalities: dyslipidaemia, type 2 diabetes, arterial hypertension and increased risk of cardiovascular disease [3]. However, heterogeneity exists among obese individuals with respect to INS sensitivity and risk of IR-associated metabolic abnormalities [4]. It is believed that obesity, especially with central fat distribution, is the state that promotes IR, particularly in genetically predisposed subjects [3]. An increased accumulation of intramyocellular lipid as well as visceral fat, that can be a source of increased release of free fatty acids into portal blood, may play a crucial role in obesity-related IR [3, 5].

The aim of our study was to evaluate whether MS risk, and the risk of its components, is associated with a degree of obesity, or rather with hyperinsulinaemia and IR.

Material and methods

As the centre specialising in paediatric obesity and endocrinology, we studied a group of obese children and adolescents who were consecutively referred by their family physicians for obesity evaluation and treatment. The inclusion criteria were age above 10 years and no endocrine or syndromal disorders. Seventy eight patients (and their parents or guardians) gave informed consent to participate in the study (42 girls and 36 boys, mean age 14.6 ± 3.5 years range 10–18 years). The study was approved by the Local Ethics Committee of the Medical University of Silesia.

For every participant, height, weight and waist circumference (WC) were recorded and pubertal development according to Tanner stage was assessed by the same person (M F-P). Eleven (14%) children were prepubertal (Tanner stage 1) and 67 (86%) had entered puberty (Tanner stage ≥ 2). Weight was measured to the nearest 0.1 kg on a medical balanced scale. Height was measured to the nearest 0.1 cm with a wall-mounted stadiometer. Body mass index (BMI) was calculated and obesity was defined according to BMI above the 97th percentile on Polish charts [6]. In every child, BMI standard deviation score (BMI Z-score) was also determined [7,8]. Severity of obesity was classified as mild (BMI Z-score ≤ 1.99), moderate (BMI Z-score 2.0–2.49), severe (BMI Z-score 2.5–2.99) or morbid (BMI Z-score ≥ 3.0) [9]. WC measurement was taken at the level of umbilicus with nonelastic flexible tape and plotted on a percentile chart [10]. Blood pressure (BP) was measured three times, on the right arm, in the seated position, using a sphygmomanometer, and the mean of the three measurements was calculated. In all subjects, serum fasting GLU and INS levels were measured and oral GLU tolerance test (OGTT) (1.75 g/kg of body weight of oral GLU, max 75 g) was performed. Fasting INS to GLU ratio (FIGR) and homeostatic model assessment of IR [R-HOMA, fasting GLU (mmol/L) × fasting INS (mIU/L)/22.5] were calculated as indices of IR [11]. Serum total cholesterol (TC), triglycerides (TG) and HDL-cholesterol (HDL) concentrations were determined and LDL-cholesterol (LDL) level was calculated using Friedewald's equation [12].

Biochemical parameters were measured using chemical procedures in a dimension analyser (Dade Behring). TG and TC levels were analysed enzymatically, and HDL concentration was measured by direct procedure using synthetic polymer and detergent (SPD procedure — Daichi). Insulin tests were performed using chemiluminescent immunoassay by Immulite 2000 analyser (DPC).

The levels of TG, HDL, GLU and BP were considered abnormal and MS was diagnosed according to International Diabetes Foundation (IDF) criteria [13]. TC level ≥ 200 mg/dL and LDL ≥ 130 mg/dL were considered as elevated [14]. Fasting and OGTT stimulated hyperinsulinaemia was diagnosed when fasting INS exceeded 15 mIU/mL and INS during OGTT was higher than 150 mIU/mL, respectively [15]. The child was considered to be insulin resistant if FIGR exceeded 0.3 or/and R-HOMA was above 2.5 [11, 16].

For statistical analysis, a Statistica 6.0 PL program was used. All values were expressed as mean/median and standard deviation/interquartile range. Correlation analysis was performed using Spearman's correlation coefficient for non-normally distributed samples and Gamma correlation for non-normal distributions with many tied ranks. The associations between hyperinsulinaemia and IR and metabolic disturbances, hypertension as well as MS were estimated by univariate analysis and multivariate logistic regression analysis after adjusting for BMI Z-score. The univariate logistic regression analysis was also performed for estimation of relationship between the degree of obesity and MS and its components. A p value < 0.05 was considered to be

Table I. *Correlation coefficients of BMI Z-score ≥ 2.0, ≥ 2.5, and ≥ 3.0 with metabolic disturbances, hypertension and metabolic syndrome in 78 obese children and adolescents (42 girls, 36 boys)*

Tabela I. *Zależności pomiędzy BMI Z-score ≥ 2.0, ≥ 2.5, i ≥ 3.0 a zaburzeniami metabolicznymi, nadciśnieniem i zespołem metabolicznym u 78 otyłych dzieci i młodzieży (42 dziewczęta, 36 chłopców)*

	BMI Z-score ≥ 2.0	BMI Z-score ≥ 2.5	BMI Z-score ≥ 3.0
TC ≥ 200 mg/dL	–0.27	–0.27	0.05
TG ≥ 150 mg/dL	0.26	0.36*	0.48*
LDL ≥ 130 mg/dL	–0.45*	–0.02	0.29
Low HDL	0.20	0.27	0.18
Fasting GLU ≥ 100 mg/dL	0.43	0.25	0.60*
GLU 2-hours of OGTT ≥ 140 mg/dL	0.14	-0.03	0.23
Hypertension	0.20	0.45*	0.48*
Isolated diastolic hypertension	0.05	0.47*	0.58**
Isolated systolic hypertension	0.13	0.54**	0.53*
WC ≥ 90th	0.78***	0.83***	1.0*
Metabolic syndrome	0.66*	0.64**	0.75***

*p < 0.05; **p < 0.01; ***p < 0.001; TC — total cholesterol; TG — triglycerides; LDL — LDL cholesterol; low HDL — HDL cholesterol < 40 mg/dL in children aged 10–16, < 40 mg/dL for boys above the age of 16, < 50 mg/dL for girls above the age of 16; GLU — glucose; OGTT — oral glucose tolerance test; WC — waist circumference

statistically significant and 0.05 < p < 0.1 was considered as a trend toward statistical significance.

Results

In all studied children, BMI was above the 97th percentile for age and sex according to Polish criteria [6]. Metabolic syndrome was diagnosed in ten (12.8%) obese subjects. All but six (7.7%) of the children studied had at least one component of MS. Dyslipidaemia was noted in 34 (43.6%) obese children. An abnormal fasting GLU level was found in six (7.7%) and impaired GLU tolerance in 11 (14.3%) individuals. Hypertension was diagnosed in 12 (15.4%) children. In 42 (53.8%) obese children fasting and/or OGTT stimulated hyperinsulinaemia was present. Fasting INS concentration was increased in 32 (41%) subjects, and INS level in OGTT above 150 mIU/mL was noted in 27 (34.6%) children. In 17 (21.8%) studied individuals, both fasting and OGTT stimulated INS levels were elevated. FIGR exceeded 0.3 in eight (10.3%) individuals and in 49 (62.3%) studied children increased R-HOMA was found.

Since no significant difference was found in all the studied parameters between obese girls and boys, in further analysis all the children were studied as one group.

Correlations of BMI Z-score with metabolic disturbances, hypertension and MS are presented in Table I. BMI Z-score ranged from 1.68 to 3.55 (median: 2.37 ± ± 0.81). A significant linear correlation of BMI Z-score with systolic and diastolic BP was found (r = 0.3; p = 0.007; r = 0.3; p = 0.01, respectively). There were also significant correlations between BMI Z-score and fasting INS concentration (r = 0.23; p = 0.04) and R-HOMA (r = 0.23; p = 0.04). BMI Z-score ≥ 2.0 correlated significantly with MS only. There were significant correlations between BMI Z-score ≥ 2.5 and hypertension as well as isolated systolic and diastolic hypertension, hypertriglyceridaemia and MS. Moreover, BMI Z-score ≥ 3.0 correlated significantly also with fasting hyperglycemia.

Significant linear correlations between fasting INS and IR indices with TG (r = 0.31; p = 0.005, r = 0.27; p = 0.02; r = 0.32; p = 0.004, respectively), systolic (r = 0.31; p = 0.005; r = 0.33; p = 0.004; r = 0.29; p = 0.01, respectively) and diastolic BP (r = 0.27; p = 0.02; r = 0.27; p = 0.02; r = 0.25; p = 0.026, respectively) were found.

Correlations of hyperinsulinaemia and IR indices with metabolic disturbances, hypertension and MS are presented in Table II. MS occurrence correlated significantly with elevated fasting and stimulated INS levels, FIGR and R-HOMA. There were significant relationships between OGTT stimulated hyperinsulinaemia and increased FIGR and elevated TG concentration. The decreased HDL level correlated significantly with increased fasting and OGTT stimulated INS levels and elevated FIGR. Fasting and stimulated hyperinsulinaemia and elevated IR indices (FIGR, R-HOMA) correlated significantly with hypertension and isolated diastolic hypertension. The isolated systolic hypertension correlated also with increased fasting and stimulated INS levels and R-HOMA. Increased GLU concentration in 120′ of OGTT correlated significantly only with elevated R-HOMA. There were no significant correlations

Table II. *Correlation coefficients of hyperinsulinaemia and studied IR indices with metabolic disturbances, hypertension and metabolic syndrome in 78 obese children and adolescents (42 girls, 36 boys)*

Tabela II. *Zależności pomiędzy hiperinsulinemią i wskaźnikami insulinooporności a zaburzeniami metabolicznymi, nadciśnieniem i zespołem metabolicznym u 78 otyłych dzieci i młodzieży (42 dziewczęta, 36 chłopców)*

	Fasting INS > 15 mIU/mL	OGTT stimulated INS > 150 mIU/mL	FIGR > 0.3	R-HOMA >2.5
TC ≥ 200 mg/dL	–0.27	0.31	0.23	–0.11
TG ≥ 150 mg/dL	0.30	0.57***	0.63**	0.22
LDL ≥ 130 mg/dL	–0.42*	0.08	–0.31	–0.32
Low HDL	0.56**	0.87***	0.61**	0.1
Fasting GLU ≥ 100 mg/dL	–0.18	0.33	–1.0	0.52
GLU 2-hours of OGTT ≥ 140 mg/dL	–0.33	0.28	0.38	0.51*
Hypertension	0.70***	0.53**	0.61**	0.78***
Isolated diastolic hypertension	0.76***	0.70***	0.69**	0.73**
Isolated systolic hypertension	0.65***	0.45*	0.39	0.76**
WC ≥ 90th	0.14	0.38	–0.23	0.14
Metabolic syndrome	0.6**	0.82***	0.69**	0.73**

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; TC — total cholesterol; TG — triglycerides; LDL — LDL cholesterol; low HDL — HDL cholesterol < 40 mg/dL in children aged 10–16, < 40 mg/dL for boys above the age of 16, < 50 mg/dL for girls above the age of 16; GLU — glucose; OGTT — oral glucose tolerance test; WC — waist circumference

Table III. *Selected unadjusted, and adjusted for BMI Z-score, association between hyperinsulinaemia and studied IR indices and dyslipidaemia, hypertension and metabolic syndrome in 78 obese children and adolescents (42 girls, 36 boys)*

Tabela III. *Wybrane nieskorygowane i skorygowane dla BMI Z-score zależności pomiędzy hiperinsulinemią i wskaźnikami insulinooporności a dyslipidemią, nadciśnieniem i zespołem metabolicznym u 78 otyłych dzieci i młodzieży (42 dziewczęta, 36 chłopców)*

	Unadjusted for BMI Z-score	Adjusted for BMI Z-score
Fasting INS > 15 μIU/mL and isolated diastolic hypertension	OR 7.3; 95% CI 1.4–38.3; p = 0.02	OR 6.2; 95% CI 1.16–33.2; p = 0.03
Fasting INS > 15 μIU/mL and isolated systolic hypertension	OR 4.8; 95% CI 1.1–20.2; p = 0.03	OR 3.9; 95% CI 0.9–17.2; p = 0.07
Fasting INS > 15 μIU/mL and hypertension	OR 5.6; 95% CI 1.4–23.3; p = 0.02	OR 4.7; 95% CI 1.1–20.2; p = 0.03
OGTT stimulated INS > 150 μIU/mL and TG ≥ 150 mg/dL	OR 3.7; 95% CI 1.2–11.5; p = 0.02	OR 3.6; 95% CI 1.1–11.2; p = 0.03
OGTT stimulated INS > 150 μIU/mL and low HDL	OR 14.4; 95% CI 2.8–74.4; p = 0.001	OR 14.0; 95% CI 2.7–72.7; p = 0.001
OGTT stimulated INS > 150 μIU/mL and isolated diastolic hypertension	OR 5.6; 95% CI 1.3–24.4; p = 0.02	OR 5.5; 95% CI 1.2–24.8; p = 0.02
OGTT stimulated INS > 150 μIU/mL and metabolic syndrome	OR 10.3; 95% CI 1.95–54.5; p = 0.005	OR 11.6; 95% CI 2.0–68.1; p = 0.006
FIGR > 0.3 and isolated diastolic hypertension	OR 5.4; 95% CI 1.0–28.3; p = 0.04	OR 6.2; 95% CI 0.9–40.6; p = 0.07
FIGR > 0.3 and metabolic syndrome	OR 5.4; 95% CI 1.0–28.3; p = 0.04	OR 4.9; 95% CI 0.8–29.2; p = 0.07

INS — insulin; OGTT — oral glucose tolerance test; TG — triglycerides; low HDL — HDL cholesterol < 40 mg/dL in children aged 10–16, < 40 mg/dL for boys above the age of 16, < 50 mg/dL for girls above the age of 16; FIGR — fasting insulin to glucose ratio

between fasting and stimulated hyperinsulinaemia and IR indices and hypercholesterolaemia, increased fasting GLU level and WC above the 90th percentile.

Selected unadjusted, and adjusted for BMI Z-score, associations between fasting and stimulated hyperinsulinaemia, IR indices and dyslipidaemia, hypertension and MS in obese children and adolescents are shown in Table III.

In logistic regression analysis, the association between fasting hyperinsulinaemia and hypertension was significant and the risk of increased BP was 5.6 times higher in obese children with fasting hyperinsulinaemia

than without increased fasting INS level. This association did not change significantly after adjusting for BMI Z-score. Moreover, the increased fasting INS level was associated with a significant increase in the risk of isolated diastolic and systolic hypertension. The risk of isolated diastolic hypertension was significantly associated also with stimulated hyperinsulinaemia and increased FIGR. Significant associations between stimulated hyperinsulinaemia and hypertriglyceridaemia and low HDL level were found.

There was a significant association between stimulated hyperinsulinaemia and increased FIGR and MS occurrence. Moreover, the association between stimulated hyperinsulinaemia and MS did not change significantly after adjusting for BMI Z-score.

The relative odds of obese children having MS components did not increase significantly if BMI Z-score ≥ 2.5 or ≥ 3.0 was present. However, we found a significant association between BMI Z-score ≥ 2.5 and ≥ .3.0 and MS occurrence (OR 4.6; 95% CI 1.1–19.8; p = 0.024; OR 6.9; 95% CI 1.5–32.2; p = 0.01; respectively).

Discussion

Bacha et al. [17] demonstrated that despite similar BMI, there are obese adolescents who are moderately INS resistant and remain at lower risk of cardiovascular disease, and others who are severely INS resistant and are at greater risk of obesity-related co-morbidities. In our group of obese children and adolescents, 54% had fasting or OGTT stimulated hyperinsulinaemia. The occurrence of the elevated fasting INS level in our study (41%) was lower that the one noted by Galli-Tsinopoulou et al. [18], who reported fasting hyperinsulinaemia in 54% of obese children and up to 80% of obese adolescents. If considered as a whole, hyperinsulinaemia and/or IR were present in more than 70% of our patients.

BMI of all children was above the 97th percentile, but the degree of their obesity was relatively wide (BMI Z-score range 1.68–3.55). A significant association of the increase in BMI percentile with IR, increased BP and dyslipidaemia in children and adolescents has been reported by other authors [19–22]. However, they studied this relationship in the whole population, not only in obese subjects. In obese children and adolescents, the data are confusing. Viner et al. [23] found no significant relationship between severity of obesity and MS prevalence. On the other hand, Weiss et al. [19] and Sen et al. [9] reported a significant association between the risk of MS and severity of obesity.

The degree of obesity appears to be a poor predictor of lipid values in obese children, and modest in obese adolescents [24]. However, the risk of hypertension seems to correlate with the severity of obesity [25]. In our study, we found a linear relationship of BMI Z-score with isolated systolic and diastolic BP. Severe and morbid obesity (BMI Z-score ≥ 2.5) correlated significantly with many components of MS, although these relationships were weak or moderate. In children with morbid obesity (BMI Z-score ≥ 3.0), these correlations became stronger. However in logistic regression analysis, there were no significant associations between the degree of obesity and MS components. This could be because in obese children and adolescents, BMI status is not a straightforward determinant of glucose and lipid metabolism disturbances as well as increased BP, because of poor discrimination of a lean body mass from a fat mass and fat distribution. On the other hand, BMI Z-score correlated significantly with MS occurrence, as there was a significant gamma correlation and association in logistic regression analysis between BMI Z-score ≥ 2.5 and ≥ 3.0 and MS occurrence. These relationships could be interdependent because of the correlation of BMI Z-score with increased WC, and high WC is one of the metabolic syndrome components required for a MS diagnosis according to the IDF definition [13]. Additionally, the risk of MS occurrence was 4.6 times higher in obese subjects with a BMI Z-score ≥ 2.5, and 6.9 times higher when BMI Z-score was ≥ 3.0. The increase of risk related to increase of BMI Z-score is in agreement with the results of other authors. Sen et al. [9] found that a one point increase of BMI Z-score enhanced the prevalence of MS by nearly double. Weiss et al. [19] calculated that the risk of MS in obese children and adolescents increased by 50% with every 0.5-unit increment in the BMI Z-score.

There were weak correlations between a degree of obesity expressed as BMI Z-score and fasting INS concentration and R-HOMA. The weakness of this relationship may be due to the fact that BMI is considered by many authors as not a very accurate index of visceral fat content in a child's body [26, 27]. The other reason could be a genetically induced variability of IR and compensatory hyperinsulinaemia in studied children. It is also well known that fasting INS level is a rather weak index of INS action disturbances and compensatory hyperinsulinaemia. The single measurement of fasting INS level, among other reasons, is not reliable because of the cyclicity of its basal secretion [11]. Indices of IR derived from hyperinsulinaemic-euglycemic clamp studies and intravenous GLU tolerance test are much more accurate, and they provide more information about INS sensitivity of peripheral tissues [11]. Unfortunately these methods are invasive, complex, expensive and time-consuming. Clinicians therefore prefer simple tools such as fasting or OGGT GLU and INS levels. Conwell et al. [28], in a group of obese children and adolescents, observed high correlations between fasting INS level and

IR indices and INS sensitivity evaluated by intravenous GLU tolerance test. Yeckel et al. [5] found that INS sensitivity can be effectively estimated using indices derived from OGTT.

It is believed that IR and hyperinsulinaemia are progressive and contribute to atherogenic serum lipid profile [29–31]. In a state of IR and compensatory hyperinsulinaemia, hepatic synthesis of very-low-density lipoprotein (VLDL), from increased free fatty acids output from visceral fat tissue, is enhanced [30]. Consequently it contributes to the increased plasma LDL and TG levels [28]. Elevated VLDL-triacyloglycerol concentration causes a decrease in HDL level [32]. We found strong significant correlations between hyperinsulinaemia and/ /or elevated IR indices and increased TG and low HDL levels. Moreover, the risk of hypertriglyceridaemia and low HDL concentration were significantly higher if an obese child had stimulated hyperinsulinaemia. Fasting hyperinsulinaemia was associated with a 5.6 times higher risk of hypertension, while OGTT stimulated hyperinsulinaemia increased by 3.7 times the risk of hypertriglyceridaemia and by 14.4 times the risk of low HDL concentrations.

Similar results were published by Steinberger et al. [33], who found a relationship between degree of IR and increased TG and low HDL concentrations in obese adolescents. The results of the study by Cruz et al. [32] showed the associations between INS sensitivity and HDL, TG and BP. Significant correlation between BMI and fasting INS, as well as the strong influence of BMI on association between fasting INS and HDL and TG concentrations, was found by Sinaiko et al [34]. In our study, despite significant correlation between BMI Z-score and fasting INS level, and significant correlations between increased TG concentration and BMI Z-score ≥ 2.5 and ≥ 3.0, the relationships between hypeinsulinaemia and IR indices and lipid abnormalities did not change significantly after adjusting for BMI Z-score.

The relationship between IR and hypertension in adults and children is well known but its mechanism is unclear [35–37]. Nevertheless, IR or hyperinsulinaemia are risk factors of hypertension and subjects with coexistence of elevated BP and IR are at greater risk of cardiovascular disease [29]. In our study, we found correlations between hyperinsulinaemia and/or elevated IR indices and hypertension. In a logistic regression model, higher risk of diastolic hypertension was present when increased fasting and stimulated INS level existed, even after adjusting for BMI Z-score.

Weiss et al. [19] reported a simple correlation between IR assessed by R-HOMA and the prevalence of MS. Also, in a logistic regression model, increased R-HOMA was associated with elevated risk of MS. In our obese children, significantly strong correlations between fasting and OGTT stimulated hyperinsulinaemia, increased FIGR and R-HOMA and MS were also found. When a logistic regression model was used, significant associations between increased risk of MS in obese children and adolescents with elevated stimulated INS level and FIGR were found. The relationship between MS occurrence and stimulated hyperinsulinaemia was significant even after adjusting for BMI Z-score.

To conclude, our study shows that BMI Z-score, and OGTT stimulated hyperinsulinaemia, are good predictors of MS occurrence in obese children and adolescents. However, hyperinsulinaemia and IR, but not the degree of obesity, are the independent risk factors of dylipidaemia and hypertension.

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