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ORIGINAL ARTICLE

Insulin resistance in obese pre-pubertal children: Relation to body composition

Heba Elsedfy [a,1], **Nermine Hussein Amr** [a,*], **Omar Hussein** [b,2], **Mohamed El Kholy** [a,1]

[a] *Paediatrics Department, Ain Shams University, Cairo, Egypt*
[b] *Radiology Department, Ain Shams University, Cairo, Egypt*

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KEYWORDS

Obesity;
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Abstract *Background:* Abdominal obesity is a strong determinant of obesity related metabolic complications. Data about pre-pubertal children are scarce.

The aim of this study is to assess the presence of insulin resistance using different insulin sensitivity indices and investigate its relationship with abdominal fat distribution by Dual energy X-ray absorptiometry scan (DXA). Secondary outcome is to determine the frequency of the metabolic syndrome components.

Subjects and methods: Twenty-three pre-pubertal obese children were recruited (14 females, 9 males). Height, weight, body mass index (BMI), waist and hip circumferences, waist to hip ratio, and blood pressure were measured. Fasting blood samples were withdrawn for glucose, insulin, lipid profile, thyroid and liver functions. Patients underwent oral glucose tolerance testing (OGTT) and DXA scan for body composition. Insulin sensitivity was determined using homeostasis model assessment for insulin resistance (HOMA-IR), fasting glucose to insulin ratio, Matsuda, and Cederholm indices.

Results: All patients had BMI, waist circumference, and DXA trunk fat more than 2 SDS. Mean fasting glucose, insulin, fasting glucose to insulin ratio, 120 min glucose and HOMA-IR were within normal limits, but mean Matsuda and Cederholm indices exceeded cut off limits. Dyslipidaemia was detected in 13 patients (56.5%), disturbed glucose homeostasis in 8 patients (34.8%), and systolic

* Corresponding author. Address: Ain Shams University, Faculty of Medicine, Paediatric Department, Abbassyia, Cairo, Egypt. Tel.: +20 1227709226.
E-mail addresses: hebased@yahoo.com (H. Elsedfy), nerminehamr@hotmail.com (N.H. Amr), hossam_fahem@gmail.com (O. Hussein), elkholym@link.net (M. El Kholy).
[1] Address: Ain Shams University, Faculty of Medicine, Paediatric Department, Abbassyia, Cairo, Egypt.
[2] Address: Ain Shams University, Faculty of Medicine, Radiology Department, Abbassyia, Cairo, Egypt.

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hypertension in 1 patient (4.3%). Metabolic syndrome diagnosis was established in three patients (13%). More insulin resistant patients were detected by Matsuda index. Trunk fat SDS correlated with Matsuda and Cederholm indices only.

Conclusion: Dysglycaemia and dyslipidaemia are common among pre-pubertal obese children. Insulin sensitivity indices based on OGTT are superior to fasting indices in identifying at risk children. OGTT should be included in assessing obese children with BMI > 2 SDS. DXA scanning has limited value for this purpose in clinical settings.

1. Introduction

The prevalence of childhood obesity has considerably increased in the Middle East and Eastern Europe [1]. Insulin resistance is associated with adiposity in an ethnic dependant fashion [2]. There is no universal agreement on the definition of cardio-metabolic risk factors or elements of metabolic syndrome associating obesity in childhood in contrast to adults [3]. Obesity as determined by body mass index (BMI) and/or waist circumference (WC) has been proven to be closely related to the occurrence of the metabolic syndrome and type 2 diabetes in later life. However, children remain under-represented in such studies [3]. BMI had been criticized in this regard due to inability to differentiate between fat and fat-free mass and direct measures of abdominal obesity such as waist circumference and body fat mass by Dual energy X-ray absorptiometry (DXA) scan had been proposed to be superior to BMI in some studies [4]. DXA scan detects abdominal fat accurately, and android fat distribution determined by it, is associated with negative metabolic predictors in pubertal adolescents and adults [5,6]. Accumulation of visceral fat starts in childhood and thus early detection of at risk children is important [7].

The aim of this study is to assess the presence of insulin resistance using different insulin sensitivity indices in a sample of pre-pubertal obese children, and to investigate the relationship between insulin resistance and abdominal fat distribution measured by DXA scan. Secondary outcome is to determine the frequency of the components of the metabolic syndrome in the same sample of patients.

2. Materials and methods

Twenty-three children (14 females and 9 males) were prospectively recruited during the period from 1st May 2012 to 28th November 2012. Obesity was defined according to Cole et al. in children with BMI > 95th percentile for age and sex [7]. Pubertal staging was defined according to Tanner and Whitehouse [8]. Exclusion criteria included Tanner stage 2 or more, patients with eating disorders, endocrine causes of obesity such as hypothyroidism or Cushing, intake of steroid or anti-epileptic medications, weight losing drugs, or patients currently enrolled in a weight losing program. All participants and their guardians or parents signed an informed consent for participation in the study. The study protocol was approved by the local ethics committee of Ain-Shams University. This work has been carried out in accordance with the code of ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

2.1. Anthropometric assessment

Standing height was measured without shoes, to the nearest 0.1 cm, using Harpenden stadiometer (Holtain ltd, Croswell, Crymych, UK) and weight was measured using a digital scale, to the nearest 0·1 kg, wearing light clothing and without shoes. BMI was calculated using the formula kg/m^2. Weight to height ratio was calculated by dividing weight by height. Standard deviation scores (SDS) for weight, height, weight to height ratio, and BMI were calculated [7,8]. Waist and hip circumferences were measured using a flexible tape to the nearest 0.1 cm. Waist circumference (WC) was measured at the end of expiration midway between the lower rib margin and the iliac crest, and hip circumference (HC) was measured at the level of greater trochanter [3]. Waist hip ratio (WHR) was calculated by dividing WC by HC, and standard deviation scores for WC and WHR were estimated [9]. All measurements were taken twice. Blood pressure was measured by a standard mercury sphygmomanometer, after the subject had rested for 5 min in the sitting position, using the appropriate cuff size and the 5th Korotkoff sound was taken for diastolic blood pressure categorization.

2.2. Laboratory assessment

All participants performed an oral glucose tolerance test (OGTT) as follows: after a 12 h overnight fast, a venous catheter was inserted in an ante-cubital vein; fasting blood sample was withdrawn for estimation of fasting plasma insulin (FI), and fasting blood glucose (FBG). The venous blood sample was also analyzed for lipid profile: total cholesterol (TC), triglycerides (TG), low density lipoprotein (LDL), and high density lipoprotein-cholesterol (HDL), alanine transferase (ALT), free thyroxine (FT4), and thyroid stimulating hormone (TSH).

Participants then ingested 1.75 mg/kg glucose (maximum 75 g), and blood samples were withdrawn again after 30, 60, 90 and 120 min for estimation of plasma insulin and blood glucose. Blood glucose was measured using the glucose oxidase method (Glucose & Lactate Analyzer 2300 Stat Plus; Yellow Springs Instruments, Yellow Springs, OH). Insulin was determined by commercially available radioimmunoassy kit (Pharmacia Diagnostics, Uppsala, Sweden). A fasting glucose $\geqslant$100 mg/dl was indicative of impaired fasting glucose, [10] and 120 min blood glucose $\geqslant$140 mg/dl was indicative of impaired glucose tolerance [11]. Fasting glucose insulin ratio was calculated by dividing fasting glucose by fasting insulin values. A ratio less than 5.6 was considered the cut off level for insulin resistance [12]. Insulin sensitivity indices were calculated as proposed by Matthews et al. for homeostasis model assessment for insulin resistance (HOMA-IR), Matsuda and

DeFronzo (ISI Matsuda), and Cederholm and Wibell (ISI Cederholm) [13–15]. Cut off level for diagnosing insulin resistance/impaired insulin sensitivity with HOMA-IR was >2.7 [12], with ISI (Matsuda) was >5 and with ISI (Cederholm) >75 [16]. The diagnosis of metabolic syndrome was made using the criteria proposed by the WHO for adolescents [17]: diagnosis was made in the presence of obesity (BMI > 95th percentile) plus two or more of the following risk factors: Glucose Homeostasis (pre-pubertal hyperinsulinaemia >15 mU/L, fasting glucose ⩾100 mg/dl and impaired glucose tolerance: 120 min ⩾140 mg/dl), elevated blood pressure (systolic blood pressure (SBP) >95th percentile for age, sex and height), dyslipidaemia (TG > 105 mg/dl for children <10 years and >136 mg/dl for children ⩾ 10 years, HDL-Cholesterol <35 mg/dl) [18].

2.3. Dual energy X-ray absorptiometry (DXA)

Body composition was measured by DXA machine (GE Lunar Prodigy, DPX; Lunar Corp, Madison, WI, USA). Body scans were analyzed using software provided by the manufacturer (enCORE software version 12.2). Scanning was done in 1 cm slices from head to toe by using the 20-min scanning speed. The whole body scan included total body and three regional fat measures: trunk (chest, abdomen, and pelvis), arms, and legs. The trunk region was delineated by an upper horizontal border below the chin, vertical borders lateral to the ribs, and a lower border formed by oblique lines passing through the femoral necks. The leg region was defined as the tissue below the oblique lines passing through the femoral necks [19]. The android and gynoid abdominal fat distribution were calculated using the provided software. Only the android region was used in comparison because it was previously proved that adults and adolescents with android fat distribution and excess central abdominal fat have increased cardio-metabolic risk as compared to subjects with gynoid fat distribution [5]. Android fat >50%, central to peripheral fat% ratio >1, and trunk fat SDS >2 were chosen as arbitrary cut-off limits to define high abdominal fat mass.

2.4. Statistical analysis

The data were analyzed by SPSS statistical software (version 17.0, SPSS Inc., Chicago, IL, USA). Descriptive statistics are expressed as mean and standard deviation (SD). Student's *t* test was performed for comparison between the mean values of the different groups for parametric data. Mann–Whitney test for non-parametric data was used. Pearson correlation was used for correlation between different variables. For all tests a probability (*p*) less than 0.05 was considered significant.

3. Results

The mean (SD) age of the studied group was 9 (3.1) years [range: 4.7–13.5 years]. All were of Tanner stage 1. Body mass index SDS and waist circumference SDS were >2 in all patients. Waist to hip ratio SDS was >2 in 10 (43.5%) patients (5 females (35.7%) and 5 males (55.5%)). Mean (SD) weight SDS of the studied patients was 8.9 (5.2), BMI SDS was 3.6 (0.9), WC SDS was 7.2 (2.9), and WHR SDS was 1.5 (1.3). The anthropometric data of the studied patients are shown in Table 1. DXA scan showed that mean (SD) total body fat% was 46.5 (4.7), trunk fat SDS was 4.7 (2.1), android fat percentage was 51.4 (5.7), and central: peripheral fat% ratio was 0.92 (0.1), (Table 2).

Table 1 Anthropometric characteristics of the patients.

	Total (n = 23)	Females (n = 14)	Males (n = 9)
Age (yrs)	9.0 (3.1)	8.4 (3.1)	9.8 (3.2)
Weight SDS	8.9 (5.2)	7.9 (6.1)	8.1 (7.1)
Wt: ht SDS	8.5 (4.6)	8.1 (4.5)	9.3 (5)
BMI SDS	3.6 (0.9)	3.6 (0.9)	3.6 (0.8)
WC SDS	7.2 (2.9)	7.6 (2.8)	6.6 (3.3)
WHR SDS	1.5 (1.3)	1.3 (1.4)	1.8 (1.3)

Data are presented as mean (SD).
Yrs: years, wt: weight, ht: height, BMI: body mass index, WC: waist circumference, WHR: waist hip ratio, SDS: standard deviation score.

The mean fasting glucose, 120 min glucose, fasting insulin, fasting glucose to insulin ratio, and HOMA-IR were within normal limits, but the mean ISI (Matsuda) and ISI (Cederholm) exceeded the cut off limits. Mean fasting lipid profile, thyroid function, and ALT values were within normal range (Table 3).

No significant difference was found between males and females in anthropometric measures, DXA measures, or laboratory parameters. ($p > 0.05$).

The frequency of patients exceeding the cut off limits for each insulin sensitivity index is presented in Table 4. The biggest number was detected using the Matsuda index (21/23, 91%) followed by HOMA-IR (7/23, 30.4%), then Cederholm index (4/23, 17.4%), and lastly FGIR (2/23, 8.7%). Two patients (8.7%) were insulin resistant on all three insulin sensitivity indices [HOMA-IR, ISI (Matsuda), ISI (Cederholm)]. Dyslipidaemia (abnormal TG or HDL) was detected in 13 patients (56.5%): 9 had low HDL, and 4 had high TG. Eight patients had disturbed glucose homeostasis (34.8%) as previously described in the methodology for the diagnosis of metabolic syndrome. Only one patient (4.3%) had systolic hypertension. The diagnosis of metabolic syndrome was established in three patients (13%) (Table 4).

All patients had trunk fat SDS > 2 while only 13 patients (56.5%) had android fat more than 50% while central to peripheral fat% ratio was more than one in three patients (13%). No significant difference was noted between males and females ($p > 0.05$), (Table 4). In patients with android fat > 50%, 2 (2/13, 15.4%) had disturbed glucose homeostasis, one (7.7%) was insulin resistant by all three insulin sensitivity indices, and 7 (7/13, 53.8%) showed dyslipidaemia.

A negative correlation was found between trunk fat SDS and insulin sensitivity measured by both ISI (Matsuda) and ISI (Cederholm) but not with HOMA-IR, fasting glucose, fasting insulin, or fasting glucose insulin ratio. Trunk fat SDS did not correlate with triglycerides or HDL-Cholesterol. Neither android fat nor central to peripheral fat ratio correlated with any of the lipid parameters, glucose homeostasis measures or insulin sensitivity indices, (Table 5).

4. Discussion

The most striking finding in this study is the relatively large percentage of children found to have disturbed glucose and

Table 2 DXA scan data of the studied patients.

	Total (n = 23)	Females (n = 14)	Males (n = 9)
Total body fat%	46.5 (4.7)	47.1 (4.7)	45.5 (5.1)
Trunk fat (kg)	12.8 (4.6)	11.9 (4)	14.2 (5.4)
Trunk fat SDS	4.7 (2.1)	4.2 (1.7)	5.6 (2.5)
Trunk fat%	46.4 (4.2)	46.9 (4.2)	45.5 (4.4)
Android fat%	51.4 (5.7)	52 (5.9)	50.5 (5.6)
Gynoid %	51 (4.2)	52.2 (3.6)	49.3 (4.7)
Central: peripheral fat% ratio	0.92 (0.1)	0.9 (0.1)	0.9 (0.1)
Leg Fat (kg)	10.8 (3.8)	10.3 (3.7)	11.5 (4.3)
Leg fat%	48 (5.2)	48.9 (4.6)	46.6 (6.1)
Leg fat SDS	3.8 (1.9)	4.4 (2.2)	3.5 (1.8)

Data are presented as mean (SD).

Table 3 Biochemical profile of the studied patients.

	Total (n = 23)	Females (n = 14)	Males (n = 9)
TC (mg/dl)	161.3 (40)	169.2 (44.6)	149 (29.1)
HDL (mg/dl)	44.8 (18.9)	47.6 (18.5)	40.1 (19.8)
LDL (mg/dl)	91.7 (30.6)	98 (32.5)	81.9 (26.2)
TG (mg/dl)	95.1 (29.8)	88.9 (31.6)	104.8 (24.5)
ALT (U/L)	17.2 (2.2)	17.4 (1.9)	16.8 (2.6)
FT_4 (ng/dl)	1.1 (0.2)	1.2 (0.2)	1.1 (0.2)
TSH (mIU/L)	2.5 (1)	2.8 (1.1)	2.1 (0.8)
FBG (mg/dl)	90.4 (11.8)	88 (12.3)	94.9 (10.2)
Glucose 60 min (mg/dl)	138 (32)	141.3 (33.7)	131.9 (30)
Glucose 120 min (mg/dl)	107.6 (21.3)	105.8 (19.1)	111 (26.4)
Fasting insulin (μU/ml)	10.5 (4.3)	10.4 (4.2)	10.7 (5)
Insulin 60 min (μU/ml)	87.5 (73.2)	77.4 (42)	106.9 (113)
Insulin 120 min (μU/ml)	65.5 (52.1)	58.2 (26.6)	78.8.3 (83)
FGIR	10.8 (5.8)	9.7 (4)	12.8 (8.2)
HOMA-IR	2.4 (1.2)	2.3 (1)	2.6 (1.4)
ISI (Matsuda)	9.8 (4.7)	9.5 (3.9)	10.3 (6.1)
ISI (Cederholm)	59.3 (18.8)	57.6 (15.5)	62.3 (25)

Data are presented as mean (SD).
TC: total cholesterol, HDL: high density lipoprotein, LDL: low density lipoprotein, TG: triglycerides, ALT: alanine transferase, FT_4: free thyroxine, TSH: thyroid stimulating hormone, FBG: fasting blood glucose, FGIR: fasting glucose insulin ratio, HOMA-IR: homeostasis model assessment for insulin resistance, ISI (Matsuda): insulin sensitivity index by Matsuda and De Fronzo, 1999, ISI (Cederholm): insulin sensitivity index by Cederholm and Wibell, 1990, min: minutes during oral glucose tolerance test.

Table 4 Number and frequency of patients above cut off limits for disturbed lipid, and glucose homeostasis.

	Total (n = 23) n (%)	Females (n = 14) n (%)	Males (n = 9) n (%)
HDL < 35 mg/dl	9 (39.1)	4 (28.6)	5 (55.5)
TG > 105 (< 10 yrs), > 136 (> 10 yrs) mg/dl	4 (17.4)	2 (14.3)	2 (22.2)
Fasting insulin > 15 mU/L	5 (21.7)	3 (21.4)	2 (22.2)
IFG ⩾ 100 mg/dl	4 (17.4)	2 (14.3)	2 (22.2)
IGT@ 120 min ⩾ 140 mg/dl	2 (8.7)	1 (7.1)	1 (11.1)
HOMA-IR > 2.7	7 (30.4)	5 (35.7)	2 (22.2)
FGIR < 5.6	2 (8.7)	2 (14.3)	0 (0)
ISI (Matsuda) > 5	21 (91)	13 (92.9)	8 (88.9)
ISI (Cederholm) > 75	4 (17.4)	2 (14.3)	2 (22.2)
Android fat > 50%	13 (56.5)	8 (57.1)	5 (55.5)
Central: peripheral fat% > 1	3 (13)	2 (14.3)	1 (11.1)
Trunk fat > 2 SDS	23 (100)	14 (100)	9 (100)
Systolic BP ⩾ 95th centile	1 (4.3)	0 (0)	1 (11.1)
Diastolic BP ⩾ 95th centile	0 (0)	0 (0)	0 (0)

HDL: high density lipoprotein, TG: triglycerides, IFG: impaired fasting glucose, IGT: impaired glucose tolerance, HOMA-IR: homeostasis model assessment for insulin resistance, FGIR: fasting glucose insulin ratio, SDS: standard deviation score, BP: blood pressure.

Table 5 Correlation between insulin sensitivity and DXA indices of adiposity.

	FBG	FI	FGIR	HOMA-IR	ISI (Matsuda)	ISI (Cederholm)
Trunk fat SDS	$r = 0.173$ $p = 0.508$	$r = 0.397$ $p = 0.114$	$r = -0.130$ $p = 0.619$	$r = 0.421$ $p = 0.093$	$r = -0.524$ $p = \mathbf{0.03}^{*}$	$r = -0.562$ $p = \mathbf{0.018}^{*}$
Central: peripheral fat%	$r = -0.106$ $p = 0.684$	$r = -0.170$ $p = 0.515$	$r = -0.317$ $p = 0.216$	$r = -0.171$ $p = 0.512$	$r = 0.359$ $p = 0.157$	$r = 0.250$ $p = 0.333$
Android fat	$r = -0.223$ $p = 0.390$	$r = 0.081$ $p = 0.757$	$r = -0.419$ $p = 0.094$	$r = 0.011$ $p = 0.966$	$r = -0.151$ $p = 0.564$	$r = -0.324$ $p = 0.205$

FBG: fasting blood glucose, FI: fasting insulin, FGIR: fasting glucose insulin ratio, HOMA-IR: homeostasis model assessment for insulin resistance, ISI (Matsuda): insulin sensitivity index by Matsuda and De Fronzo, 1999, ISI (Cederholm): insulin sensitivity index by Cederholm and Wibell, 1990, SDS: standard deviation score.

* Statistically significant. $p < 0.05$ is clinically significant.

lipid metabolism. More than one third and more than half had disturbed glucose and lipid homeostasis respectively. This indicates the severity of the problem among the population. It has been suggested that ethnic differences play a role in the prevalence of obesity related cardio-metabolic complications. Most studies focused on Caucasian, African-American, and Asian populations [20]. Further, most studies were carried on pubertal children [21]. To the best of our knowledge, there is paucity in the literature regarding the prevalence of obesity related metabolic complications in obese pre-pubertal children in the region of the Middle East and North Africa. Recent reports show that the Middle East and North Africa have the highest obesity and diabetes prevalence among young adults [22].

The overall prevalence rate of metabolic syndrome is 3–4%, with a wide variation in the reported rates among children and adolescents ranging from 1.7% to 14% [18,23–31]. The rate found in our sample (13%) is thus comparable with some of the reported rates, and in view of the limited number of the studied patients, such rate provides a warning sign to the extent of the problem among Egyptian children which possibly outweighs that reported for other ethnic populations. In a study conducted on Egyptian adolescents, the prevalence of metabolic syndrome was 7.4% [25].

The lack of a uniform definition for metabolic syndrome in pediatrics in the literature [32], the fact that its risk increases with every 0.5 unit increment in BMI, the finding that the prevalence of impaired fasting serum glucose and insulin and impaired glucose tolerance increase significantly with BMI > 2 SDS [26], were the reasons to choose all our patients with BMI > 2 SDS and not only BMI > 95th percentile. Not every obese patient with BMI > 95th percentile will have BMI > 2 SDS. Furthermore, all had waist circumference >2 SDS, a cut off value that ensures that all studied patients had WC values above the 90th percentile. Waist circumference is an indirect measure of visceral fat and a predictor of cardio-metabolic risk in obese children [32]. Thus combining BMI and waist circumference cut offs >2 SDS would ensure that the studied patients are at especially high risk of obesity related cardio-metabolic complications [25,32].

A significant proportion of the patients were found to be insulin resistant using different insulin sensitivity indices. The biggest number was detected using the insulin sensitivity index developed by Matsuda which reflects whole body insulin sensitivity, followed by HOMA-IR (reflects basal hepatic glucose production and hepatic insulin sensitivity). Insulin sensitivity index introduced by Cederholm and Wibell reflecting peripheral insulin sensitivity and muscular glucose uptake identified insulin resistance in 17.4% of our patients while fasting glucose insulin ratio identified the least number of patients. However, only a small number proved to be insulin resistant on the three insulin sensitivity indices together. This suggests the inadequacy of any of the individual insulin sensitivity indices proposed in the literature. They are however important as predictors of impaired insulin sensitivity which commonly precede the development of type 2 diabetes [33]. da Silva et al. showed that the likelihood of metabolic syndrome increases with high insulin and HOMA-IR [34]. HOMA-IR >2.5 increased the prevalence of metabolic syndrome from 7.4% to 35.9% [25], and HOMA-IR was more reliable than FGIR when both were compared to OGTT in obese pubertal adolescents [35]. However, indices based on OGTT including Matsuda index were found superior to HOMA-IR in predicting insulin sensitivity [36]. While OGTT derived tests consider glucose–insulin interactions that occur in vivo after glucose load [37], HOMA-IR and other tests based on fasting samples do not take into account the peripheral insulin sensitivity. They assess hepatic insulin action only which is reflected by the early glucose response and correlates with fasting glucose [37,38]. OGTT derived indices could detect "subtle changes" in glucose metabolism that are not detected by the simpler fasting indices [39]. Many studies demonstrated a stronger correlation of insulin sensitivity indices derived from glucose tolerance test with the golden reference techniques such as hyperinsulinaemic euglycaemic clamp, and hence more reliability of these indices than simple fasting indices for insulin sensitivity [37]. This confirms the findings of this study.

Despite the fact that all patients had trunk fat SDS > 2, only 56.6% had excess android fat defined by our arbitrary cut off. This cut off identified less number of patients with disturbed glucose homeostasis, insulin resistance, and dyslipidaemia compared to trunk fat SDS > 2. We therefore recommend that it would be inappropriate to use such a cut off particularly in children before puberty.

No correlation existed between trunk fat and fasting glucose, insulin, and lipids. He et al. previously reported a positive correlation between trunk fat and insulin and triglycerides [6]. The correlation found in our sample between trunk fat and insulin sensitivity indices based on the standard oral glucose tolerance test (ISI Matsuda and Cederholm) and the lack of correlation between it and indices depending on fasting

samples (HOMA-IR, FGIR) suggest the superiority of OGTT in this young age group. It would thus be more appropriate to perform OGTT in obese children with BMI SDS > 2 in order to detect those at risk for type 2 diabetes. This would definitely allow early intervention and prevention of future adverse metabolic complications. It was previously reported that children with normal HOMA-IR and fasting insulin were found to have insulin resistance on OGTT thereby confirming the need to perform OGTT in such patients [40].

Android fat distribution was not beneficial in identifying high risk obese children. All patients with BMI SDS and waist circumference SDS exceeding two had trunk fat SDS > 2. We therefore believe that body composition by DXA does not offer extra information and that there is no need to use DXA scan to identify obese children with obesity related metabolic complications in clinical settings. DXA scan remains unable to differentiate between subcutaneous and visceral fat and therefore suitable only for research settings [32].

We believe that the main limitation of this study is the small sample size. Despite this, a significant number of children were identified with insulin resistance emphasizing the need to carry larger studies on this high risk population.

In conclusion, we believe that the findings of this study should be taken as a warning sign and drive further studies on a large population of obese pre-pubertal children. Although the diagnosis of the metabolic syndrome was established in a small percentage of patients, its components were identified in a considerable number of them. This confirms that disturbed glucose and lipid homeostasis start early in obese subjects and therefore increase the likelihood of type 2 diabetes and cardiovascular disease at a young age. Further, oral glucose tolerance test should be included as part of the formal assessment of children with BMI > 2 SDS. Lastly, assessment of body composition by DXA scan should be limited to research settings as it does not seem to offer extra or early information regarding the obesity related metabolic adverse effects.

Conflict of interest

The authors declare no conflict of interest. There is no financial or personal relationship with other people or organizations that could inappropriately influence this work.

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