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ORIGINAL RESEARCH

Utility of Adipokines and IL-10 in Association with Anthropometry in Prediction of Insulin Resistance in Obese Children

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Aim: This is a case-controlled study, with two hundred children enrolled. They were divided into an obese group of 100 children who had BMI ≥ 95th percentile according to CDC criteria and a group of 100 children with normal weight. All enrolled children were subjected to detailed medical history and clinical examination, in addition to measuring fasting blood sugar, fasting serum insulin, HOMA-IR calculation, lipid profile analysis, total serum cholesterol, low- and high-density lipoproteins (LDL and HDL), and serum triglyceride (TG). Two adipokines (lipocalin-2 and adipsin) serum levels plus IL-10 serum level were assessed.

Results: Higher *Z* score of weight, MI, and waist/height ratio and high serum cholesterol, LDL, TG, and low HDL were observed in obese children. Higher levels of serum lipocalin-2 and adipsin and lower IL-10 blood level were observed in the obese group in comparison with the normal weight children. Higher insulin resistance index was observed in the obese group, with positive correlation of HOMA-IR with the anthropometric measurements and lipocalin serum level, while negative correlation was observed between IL-10 and fasting insulin in obese children.

Conclusion: Simple measurement of general and central adiposity markers and serum lipocalin-2 can predict insulin resistance in obese children while serum adipsin and IL-10 had no association with insulin resistance.

Keywords: adipokines, IL10, insulin resistance, obesity

Introduction

Obesity and overweight have become a serious global dietary concern in recent years, and they are now recognized as risk factors for developing the metabolic syndrome in both children and adults in both high- and low-income nations. Lack of physical exercise, consumption of high-calorie foods and sugary beverages, and a more sedentary lifestyle have all contributed to the rapid rise in obesity rates worldwide.[1]

During childhood and adolescence, obesity is a key risk factor for the development of insulin resistance. Insulin resistance is defined as a reduction in the capacity of insulin to increase glucose consumption by muscles and adipose tissue while suppressing hepatic glucose synthesis and output. It also accounts for insulin resistance in protein and lipid metabolism, as well as vascular endothelial function and gene expression. Insulin resistance could be owing to beta cell malfunction produced by ectopic fat deposition. However, beta cell dysfunction can occur before fasting glucose levels become compromised.[2]

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Adipocytes perform a critical function in regulating metabolism and energy homeostasis as the endocrine organs. They have a relationship between normal immune system function and metabolism. Nevertheless, in obesity, their dysregulation contributes to chronic low-grade inflammation and disease pathology.[3]

Adipsin is produced primarily in adipose tissue, and it has a lipogenic property by activating alternative pathways of the complement through its unique factor D and inducing triglyceride synthesis and adipocyte differentiation.[4]

Adipocytes and immune cells including neutrophils and macrophages release lipocalin-2, which was first thought to have a function in innate immunity. Lipocalin-2 levels are linked to inflammatory markers such as high-sensitivity C-reactive protein. Lipocalin-2 has been thought to act as a potential link between obesity, inflammation, cardiovascular illness, and obesity-associated metabolic dysfunction, such as insulin resistance (IR).[5]

Insulin resistance can be caused by proinflammatory cytokines blocking insulin signal transduction in adipose tissue, skeletal muscle, and the liver. IL-10 is a key player in immune response regulation and inflammation control. IL-10 down regulates the inflammation via inhibiting the synthesis of proinflammatory cytokines including IL-12 and TNF-α or via physical interactions with T lymphocytes and enhances regulatory T cell function; it also promotes activation and proliferation of CD8+ T cells, NK cells, mast cells and B cells.[6]

The down regulation of reactive oxygen and nitrogen intermediates, the regulation of antigen presentation capacity and immunological tolerance, and the suppression of proliferative and cytotoxic T cell responses are all significant functions of IL-10.[6]

Th17 cells have been identified as the IL-10 cellular source. In various metabolic organs, Th17 cells are expected to play a substantial role in the propagation of inflammation and immune metabolism, which can be easily altered with a hyper caloric diet that increases the enrichment of pathogenic Th17 cells.[7]

The present work aimed to assess the levels of serum adipsin and lipocalin-2 in addition to serum level of IL-10 in obese children and their relation to insulin resistance in those children.

Subjects and Methods

Participants

A case-control study was conducted on 200 Egyptian children who were chosen randomly from Al-Azhar University Hospital during the period from August 2021 to May 2022. According to the Centers for Disease Control and Prevention (CDC)[8] standards, children were divided into two groups based on their BMI percentile. One hundred children with BMI ≥ 95th percentile (obesity group) were compared to 100 children with BMI ≥5th and <85th percentiles (control group). Age and sex were matched to the obese group. Children with chronic diseases, congenital anomalies, or genetic diseases were excluded from the study.

Sample Size

Based on evidence from Hung et al[9] and by considering the mean IL10 comparison between normal and severely obese children as primary outcome measure, G Power program 3.1.9.4 was used to calculate the sample size with independent *t* test comparison between the two groups. Assuming 80% power, effect size is mean difference 0.4, 0.05 level of significance and median and IQR of IL10 was 6.14 (1.23–8.66) in normal weight and 11.67 (2.23–25.67) in obese children and after transformation of median and IQR to mean and SD and with ratio of 1:1. The minimum required sample size to detect statistical significance difference will be = 186 participants (93 in each group); as this is the minimum required number needed for this study, so the researcher decides to include 100 in each group of the study.

Design

During a hospital visit, participants were assessed for family medical history, dietary history, medication usage, and demographic information. Physical examinations, including height and weight measures, as well as BMI (body mass index), were also required.

For weight measurement, after emptying the urine and gastrointestinal systems, the body weight was measured on a Seca scale to the nearest 0.1 kg, with the children barefoot and in light clothing (Seca Model 770, Hamburg, Germany).

Waist circumference was measured using a plastic tape wrapped around the body in a horizontal position. It was measured midway between the lower rib edge and the iliac crest.

Blood Pressure Measurements

A mercury sphygmomanometer with an adequate cuff size was utilized for measuring systolic and diastolic blood pressure readings, with the patient sitting in the proper position. Three measurements were taken from all the participants at 2 min intervals, and the average of the last two measurements was recorded. According to the American Academy of Pediatrics for SBP and DBP in the pediatric population, values >95th percentile are considered elevated.[10]

Laboratory Analysis

Blood sample was obtained after fasting for 10 hours in order to measure fasting blood sugar (FBS), lipid profile, uric acid, adipsin, lipocalin-2, IL-10, fasting insulin and HOMA-IR.

Six mL of venous blood was withdrawn and divided into two serum-separator tubes and centrifuged at 3500 rpm for 10 min. 3 mL serum was used for the measurement of fasting blood glucose, total cholesterol, triglycerides, high-density lipoprotein (HDL), low-density lipoprotein (LDL), and uric acid. The remaining three mL serum was frozen at −20°C for analyzing adipsin, lipocalin-2, IL-10, and fasting insulin. Measurement of lipid profile and uric acid were performed using Cobas C311 (Germany) and kits of Roche (Germany). The following measures were considered lipid profile abnormalities: total cholesterol ≥170 mg/dL, LDL-C ≥130 mg/dL, HDL-C ≤45 mg/dL, and triglycerides ≥130 mg/dL.[11]

Measurement of Serum Adipsin, Lipocalin-2, and IL-10

Measurement was done through the use of the quantitative double-antibody sandwich ELISA kit, supplied by Sun Red Biotechnology Company, Shanghai, with lot no. 202201. ELISA reader 1851 Das: Italy and Bio Tek: USA washer was used. The assay range was 0.5–100 ng/mL, 12–3000 ng/mL, and 0.10–3000 pg/mL for Adipsin, lipocalin-2, and IL-10, respectively.

Measurement of Serum Fasting Insulin and Calculation of HOMA-IR

Measurement of serum fasting insulin was conducted through the use of the quantitative double-antibody sandwich ELISA kit, supplied by DiaMetra Company, Italy, with lot no. 5626A. ELISA reader 1851 Das: Italy and Bio Tek: USA washer were used. The assay range was 3–200 IU/mL.

HOMA-IR was calculated using fasting blood sugar and fasting insulin through the following formula: HOMA-IR = FBS × fasting insulin / 405.[12]

Ethical Approval

The parents of each child signed a written informed consent form. Approval to the study protocol was obtained from the Local Ethics Committee at Al-Azhar University, Faculty of Medicine for Girls (council number 202,106,969). All procedures were carried out in line with the Helsinki Declaration.

Statistical Analysis

Data were collected, revised, coded and entered to the Statistical Package for Social Science (Released 2015. IBM SPSS Statistics for Windows, Version 23.0. Armonk, New York: IBM Corporation). The normality of distribution of quantitative parameters was assessed using Kolmogorov–Smirnov test. The quantitative data were presented as mean, standard deviations and ranges when parametric and median, inter-quartile range (IQR) when data found non-parametric. Also, qualitative variables were presented as number and percentages. The comparison between groups with qualitative data was done by using Chi-square test. The comparison between two groups with quantitative data and parametric distribution was done by using independent *t*-test while the comparison between two groups with quantitative data and non-parametric distribution was done by using Mann–Whitney test. Receiver operating characteristic curve (ROC) was used to assess the best cut-off point with its sensitivity, specificity, positive predictive value (PPV), negative predictive

value (NPV) and area under curve (AUC). The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p-value was considered significant at the level of <0.05.

Results

The descriptive statistics of the study groups are illustrated in Table 1. Both groups were matched for the mean of both age and gender with significant increase in BMI *Z* score, waist circumference, and waist/height ratio in obese children. 84% of them had waist circumference above 90th centile.

There was a significant increase in blood pressure in obese children in comparison with the control group. In obese children, 57% and 38% had blood pressure above 95th centile for systole and diastole, respectively (Table 2).

Compared to the normal weight children, obese children had a significant increase in serum blood level of adipsin, lipocalin-2, cholesterol, triglyceride, and LDL. There was also a significant increase in fasting blood glucose, fasting insulin, and insulin resistance index (HOMA-IR) in obese children versus the control. A significant decrease in serum blood level of IL-10 and HDL was observed in obese children in comparison with the controls (Table 3).

In obese children, 47%, 96%, and 36% had high cholesterol, triglycerides, and LDL levels, respectively, while 35% of them had low HDL (Table 4).

Looking to the correlation of the studied markers with the other variables, serum adipsin level was positively correlated with the triglyceride level while IL-10 was negatively correlated with the triglyceride level. Lipocalin-2, serum insulin, and HOMA-IR were positively correlated with *Z* score of the weight, BMI, and waist circumference (Table 5).

Table 1 Demographic and Anthropometric Data of the Studied Groups

		Control Group	Obese Group	Test Value	P-value
		No. = 100	No. = 100		
Age/year	Mean ± SD Range	11.66 ± 3.16 6–17	11.62 ± 2.90 6–18	0.105˙	0.917
Sex	Female Male	50 (50.0%) 50 (50.0%)	50 (50.0%) 50 (50.0%)	0.000*	1.000
Z-score (Weight)	Median (IQR) Range	−0.77 (−0.99–−0.33) −1.52–0.29	0.51 (0.05–1.38) −0.90–4.09	−10.403≠	<0.001
Z-score (Height)	Median (IQR) Range	−0.12 (−0.91–0.84) −2.28–1.63	0.25 (−0.50–1.01) −2.22–1.70	−1.755≠	0.079
BMI	Mean ± SD Range	17.48 ± 2.22 12.16–26.37	30.84 ± 5.30 20–52	−23.281˙	<0.001
Z-score (BMI)	Median (IQR) Range	−0.89 (−1.02–−0.68) −1.53–0.28	0.75 (0.41–1.23) −0.53–3.56	−12.139≠	<0.001
Waist circumference	Mean ± SD Range	59.75 ± 7.78 42–73	95.38 ± 11.19 70–140	−26.146˙	<0.001
Z-score: Waist circumference	Median (IQR) Range	−0.97 (−1.12–−0.53) −1.76–−0.23	0.85 (0.53–1.05) −0.38–3.07	−12.169≠	<0.001
Waist / height ratio	Mean ± SD Range	0.42 ± 0.03 0.33–0.5	0.65 ± 0.06 0.52–0.84	−35.121˙	<0.001
Z-score: Waist / height ratio	Median (IQR) Range	−0.90 (−1.07–−0.76) −1.57–−0.23	0.82 (0.62–1.16) −0.11–2.39	−12.217≠	<0.001
Waist circumference on centile	<90th >90th	-	16.0% 84.0%		

P > 0.05: Non-significant; P < 0.05: Significant; P < 0.01: Highly significant. ˙Independent *t*-test; ≠Mann–Whitney test; *Chi-square test.

Table 2 Blood Pressure Measurements in the Two Studied Groups

		Control Group	Obese Group	Test Value*	P-value
		No. = 100	No. = 100		
Vitals					
SBP/mmHg	Mean ± SD Range	111.50 ± 7.54 90–120	123.58 ± 7.93 100–140	−11.039*	<0.001
DBP/mmHg	Mean ± SD Range	71.47 ± 7.05 60–86	80.98 ± 5.61 60–90	−10.556*	<0.001
SBP according to 95th centile	<95th No./ % >95th	-	43.0% 57.0%		
DBP according to 95th centile	<95th No./ % >95 th		62.0% 38.0%		

Notes: P > 0.05: Non significant; P < 0.05: Significant; P < 0.01: Highly significant. *Independent *t*-test.

Table 3 Chemical Data of the Two Studied Groups

Variable		Control Group	Obese Group	Test Value	P-value
		No. = 100	No. = 100		
Uric acid mg/dl	Mean ± SD Range	4.58 ± 0.64 3.6–5.8	4.75 ± 0.93 2.6–6.4	−1.501*	0.135
Adipsin ng/mL	Median (IQR) Range	1.79 (1.25–2.56) 0.46–14	4.56 (3.31–5.93) 0.87–323	−8.481≠	<0.001
Lipocalin 2 ng/mL	Median (IQR) Range	102.8 (79.65–155.3) 18.8–622.7	193.85 (134.3–355.7) 1.04–1445.4	−6.877≠	<0.001
IL10 pg/mL	Median (IQR) Range	134 (100–188.5) 72.8–986	101.6 (73.75–120) 30–198	−5.956≠	0.481
Fasting insulin	Median (IQR) Range	6.6 (3.9–8) 1.1–9.8	12.7 (7.8–21.35) 1.1–103.5	−7.753≠	<0.001
Fasting blood glucose	Mean ± SD Range	76.89 ± 5.20 67–90	84.80 ± 8.03 69–106	−8.266*	<0.001
HOMA-IR	Median (IQR) Range	1.23 (0.74–1.49) 0.19–1.98	2.54 (1.6–4.31) 0.24–25.56	−8.290≠	<0.001
Cholesterol mg/dl	Mean ± SD Range	140.46 ± 21.34 103–185	160.81 ± 36.22 84–234	−4.840*	<0.001
Triglycerides mg/dl	Mean ± SD Range	100.96 ± 23.79 43–144	140.26 ± 33.39 80–240	−9.585*	<0.001
HDL mg/dl	Mean ± SD Range	41.69 ± 3.91 28–49	39.30 ± 3.78 29–48	−4.404*	<0.001
LDL mg/dl	Mean ± SD Range	80.97 ± 21.02 38.4–126.4	120.26 ± 20.08 39.4–146	−13.515*	<0.001

Notes: P > 0.05: Non significant; P < 0.05: Significant; P < 0.01: Highly significant. *Independent *t*-test; ≠Mann–Whitney test.

Table 4 Distribution of Abnormal Lipoproteins Levels in Obese Children

Total Cholesterol in mg/dl		
Normal (<170 mg/dl)	53	53.0%
High (≥200 mg/dl)	47	47.0%
Triglycerides in mg/dl		
Normal (35–135 mg/dl)	4	4.0%
High (≥135mg/dl)	96	96.0%
HDL in mg/dl		
Normal (45–65mg/dl)	23	23.0%
High (≥65mg/dl)	42	42.0%
Low (<40mg/dl)	35	35.0%
LDL in mg/dl		
Normal (<130mg/dl)	64	64.0%
High (≥130mg/dl)	36	36.0%

Table 5 Correlation Between the Studied Variables

	Adipsin		Lipocalin 2		IL10		Fasting Insulin		HOMA-IR	
	r	P-value	r	P-value	r	P-value	r	P-value	r	P-value
Age/year	−0.049	0.631	−0.180	0.073	0.005	0.964	0.184	0.067	0.214	0.033
Weight/kg	−0.066	0.513	−0.231	0.021	0.059	0.558	0.221	0.027	0.242	0.015
Z-score (Weight)	−0.066	0.513	−0.231	0.021	0.059	0.558	0.221	0.027	0.242	0.015
Height	−0.079	0.434	−0.187	0.063	−0.016	0.876	0.134	0.182	0.159	0.114
Z-score (Height)	−0.079	0.434	−0.187	0.063	−0.016	0.876	0.134	0.182	0.159	0.114
BMI	−0.059	0.560	0.230	0.021	0.095	0.349	0.291	0.003	0.309	0.002
Z-score (BMI)	−0.059	0.560	0.230	0.021	0.095	0.349	0.291	0.003	0.309	0.002
Waist circumference	−0.008	0.938	−0.227	0.023	0.105	0.298	0.197	0.050	0.209	0.037
Z-score: Waist circumference	−0.008	0.938	−0.227	0.023	0.105	0.298	0.197	0.050	0.209	0.037
Waist / height ratio	0.027	0.792	−0.049	0.629	0.068	0.504	−0.027	0.790	−0.035	0.730
Z-score: Waist / height ratio	0.027	0.792	−0.049	0.629	0.068	0.504	−0.027	0.790	−0.035	0.730
SBP/mmHg	0.003	0.980	−0.123	0.225	−0.015	0.885	0.148	0.142	0.168	0.095
DBP/mmHg	−0.042	0.682	−0.104	0.301	0.013	0.899	0.077	0.446	0.099	0.327
F.B.S mg/dl	0.028	0.779	−0.097	0.335	−0.174	0.083	0.044	0.661	0.168	0.094
Cholesterol mg/dl	0.104	0.304	−0.031	0.762	−0.060	0.551	−0.057	0.571	−0.064	0.529
Triglycerides mg/dl	0.204	0.042	0.031	0.758	−0.222	0.027	0.041	0.685	0.046	0.653
HDL mg/dl	0.044	0.661	−0.057	0.575	−0.100	0.323	0.036	0.719	0.018	0.860

(*Continued*)

Table 5 (Continued).

	Adipsin		Lipocalin 2		IL10		Fasting Insulin		HOMA-IR	
	r	P-value	r	P-value	r	P-value	r	P-value	r	P-value
LDL mg/dl	0.111	0.273	0.078	0.440	0.172	0.087	0.070	0.492	0.061	0.549
Uric acid mg/dl	0.089	0.376	0.024	0.816	0.006	0.953	0.079	0.435	0.080	0.430

Note: Spearman correlation coefficients.

Table 6 Correlation Between the Studied Adipokines and IL10 with the Serum Fasting Insulin and HOMA-IR

	Adipsin		Lipocalin- 2		IL10		Fasting Insulin		HOMA-IR	
	r	P-value	r	P-value	r	P-value	r	P-value	r	P-value
Adipsin ng/mL	-	-	0.573	0.000	0.146	0.148	−0.106	0.292	−0.108	0.283
Lipocalin 2 ng/mL	0.573	0.000	-	-	0.132	0.191	0.614**	<0.001	0.723	0.000
IL10 pg/mL	0.146	0.148	0.132	0.191	-	-	−0.265**	0.001	0.186	0.064
Fasting insulin mg/dl	−0.106	0.292	−0.225	0.025	0.211*	0.035	-	-	0.988	0.000
HOMA-IR	−0.108	0.283	−0.250	0.012	0.186	0.064	0.988**	<0.001	-	-

Notes: Spearman correlation coefficients. *Significant at P ≤ 0.05. **Highly significant at P ≤ 0.001.

Lipocalin-2 was positively correlated with fasting insulin and insulin resistance index while IL-10 was negatively correlated with fasting insulin level only. Serum adipsin level had no association with fasting insulin or insulin resistance index (Table 6).

Table SI: the cut-off level of serum adipsin, lipocalin 2, IL10, and HOMA index discriminating the two studied groups.

Discussion

A case-control study was conducted on 200 children who were divided into two groups: 100 obese children with body weights ≥95th centile based on CDC criteria and 100 healthy children as a control group. They were matched in age and gender.

The present study aimed to assess the serum level of two adipokines (adipsin and lipocalin-2), besides; the cytokine IL-10, to evaluate the insulin resistance in those children, and explore the relation between the measured markers and insulin resistance in those children.

The waist/height ratio has been promoted as a useful and simple measure of central adiposity that may be more accurate than BMI alone in predicting cardio metabolic risk.[13]

In the current study, obese children exhibited a substantial rise in *Z* score waist-to-height ratio, with 84% having waist circumferences above the 90th centile. Similar results were reported in previous studies, such as Soliman et al[14] who stated that waist-to-height ratio was considered as a reliable clinical predictor for cardiovascular risk in obese children and adolescents.

Excess weight in childhood and adolescence is one of the commonest causes of hypertension.[15] We recorded a significant increase in blood pressure in obese children with 57% and 38% of the studied children having blood pressure above 95th centile for systole and diastole, respectively. Elevated blood pressure in obese children was previously reported by Rosaneli et al.[15]

On the evaluation of lipid abnormality in the studied obese children, 47%, 96%, and 36% had high cholesterol, triglycerides, and LDL levels, respectively, while 35% of them had low HDL. Dyslipidemia among overweight, obese children, and adolescents was previously recorded in many studies.[16,17]

The role of IL-10 in the pathophysiology of pediatric obesity and associated disorders is still unclear.[18] In the present study, low serum level of IL-10 was observed in obese children in comparison with the normal weight children. A previous study by Chang et al[19] reported that low IL-10 concentration was associated with overweight and obesity in young adolescents.

Abdelhamid et al[7] also demonstrated that overweight and obese diabetic children had a lower level of IL-10 than non-obese diabetic children. Lauridsen et al[20] stated that down regulation of mRNA expression of the anti-inflammatory cytokine IL-10 occurred with a gradual increase in BMI. Abnormal low IL-10 concentrations associated with auto-immune and inflammatory disorders were reported by Yao et al.[21] Another study by Kupèa et al[22] reported that high level of IL-10 was observed in obese children and adolescents. These discrepancies may be explained as IL-10 may play a dual role in inflammations.

In the present work, we observed a negative correlation of IL-10 with serum triglyceride level and cholesterol blood level. Liu et al[23] reported that obese children with hypertriglyceridemia had lower serum IL-10 than obese children without hypertriglyceridemia and non-obese children. Moreover, Calcaterra et al[24] found no association between IL-10 and HDL cholesterol or the triglycerides. The mechanism by which elevated IL-10 modulates lipoprotein levels is not clear, but could be explained by the non-hepatocyte liver cells that do express IL10R1, such as tissue macrophages, endothelial cells, and hepatic stellate cells, could potentially interact with canonical IL-10 receptors in vivo and signal to hepatocytes and modulate the lipoprotein synthesis.[25]

No significant correlation was observed for IL-10 with the anthropometry in the present work. Similar finding was observed by Kupèa et al.[22] Abdelhamid et al[7] stated that low serum level of IL-10 had a significant association with high BMI in diabetic obese children.

Lipocalin-2 acts as an acute phase protein, which can be induced by proinflammatory processes produced predominantly from enlarged adipocytes and activated macrophages in adipose tissue and liver.[26]

Results showed high serum lipocalin-2 in obese children in comparison with the normal weight control. Previous studies mentioned that obese children had significantly high serum concentration of lipocalin-2.[27,28]

We demonstrated that lipocalin-2 was associated with the general adiposity as it was positively correlated with BMI *Z* score. This raises the possibility that different amounts of lipocalin-2 were secreted from different body fat compartments. Furthermore, Wang et al[29] reported that lipocalin-2 concentrations were positively correlated with BMI and waist circumference.

We observed that lipocalin-2 was not associated with the studied lipoproteins or the measured blood pressure, while Zaki et al[27] reported a positive correlation of lipocalin-2 with blood pressure in obese children.

Adipsin was considered as a complement factor D playing an essential role in alternative pathway activation of the complement. It is primarily produced in adipose tissue, in the liver, and other soluble complement components are mostly made.[2]

High serum adipsin level was observed in the studied obese children compared to the normal weight control, and high adipsin level in obese children was observed previously by Gonzalez-Gil et al,[30] as well as in adult obesity.[31]

We demonstrated that serum adipsin was positively correlated with serum triglyceride, but not associated with the central or general adiposity markers (WC and BMI). Gonzalez-Gil et al[30] found that serum adipsin was positively correlated with triglyceride in obese children and BMI *Z* score.

Early detection of insulin resistance is important to prevent obesity complications. HOMA-IR was found to be a much more reliable and easily applicable parameter in clinical research in determining insulin resistance in obese children.[32]

Elevated fasting blood glucose level and hyperinsulinemia were observed in the studied obese children in comparison with the normal weight control. HOMA-IR cutoff values for insulin resistance were calculated to be >1.98 (sensitivity 66.0%, specificity 100%).

There was a positive correlation of HOMA-IR and fasting insulin with the *Z* score (weight, BMI, and waist circumference). These findings suggested that obesity-related insulin resistance in children can be predicted by simple anthropometric measurements of general obesity and central obesity, and this was previously reported by Lim et al[33] in study of obesity indices and insulin resistance among the healthy Korean adolescents.

We observed no association of insulin resistance with the studied lipoproteins or the recorded blood pressure, while a positive correlation of HOMA-IR with low level of HDL was reported by Romualdo et al.[34]

Furthermore, there was an association between increased lipocalin-2 blood level and insulin resistance in the studied obese children. Zhang et al[35] stated that, in adipocytes, lipocalin-2 expression and secretion are stimulated by insulin, while Liu et al[36] demonstrated that lipocalin-2 was not correlated with insulin resistance.

In the present work, we observed that serum level of IL-10 was negatively correlated with fasting serum insulin level but not with the HOMA-IR. Han et al[37] concluded that, in experimental study on obesity, the effect of hyperinsulinemia on T-regulatory cells was remarkable by inhibiting IL-10 production. While Acosta et al[6] observed that IL-10 was up regulated in obesity and insulin resistance, Charles et al[38] and Calcaterra et al[24] indicated that IL-10 had no association with insulin resistance.

No association was observed in the present study between serum adipsin and insulin resistance. While Zhang et al[4] reported that circulating adipsin had a negative association with HOMA-IR in non-alcoholic fatty liver obese adults, Taşdemir et al[4] showed that plasma adipsin level was negatively correlated with insulin resistance in diabetic rats.

In conclusion, simple measurement of general and central adiposity markers and serum lipocalin-2 can predict insulin resistance in obese children while serum adipsin and IL-10 had no association with insulin resistance.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical Approval

Written informed consent was completed by each child's parents. The study protocol was approved by AL-Azhar University Local Ethics Committee, Faculty of Medicine (for Girls), the council number is 202106969 and all procedures were in accordance with the Helsinki Declaration.

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Author Contributions

El Sehmawy A.A, Diab F.A, Hassan D.A, Mohammed D.S, Al Anany M.G.E, Eldesoky N.A, Elamir R.Y: All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors have no conflict of interest to declare.

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