

## Obesity in Egyptian Children: Influence of Oxidant-Antioxidant Status on Lipid and Glucose Homeostasis

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### Abstract

**Aim:** We aimed to assess antioxidant status in Egyptian children with obesity and investigate the mutual relationship between oxidative stress markers, body composition, and metabolic pattern.

**Methods:** This cross-sectional study included 52 obese and 20 healthy-weight children. Subjects underwent through clinical assessment. Serum lipid profile, fasting glucose, and serum insulin were measured in plasma. A range of antioxidant activities was tested. Steady state beta cell function (%B), insulin sensitivity (%S), and insulin resistance (IR) were calculated.

**Results:** Children with obesity had high prevalence of family history of obesity, hypertension and type 2 diabetes and 18 of them had hypertension. Sixteen (30.7%) children with obesity had high level (90<sup>th</sup> percentiles) of low-density lipoprotein (LDL-C) and triglycerides and 14 (24.9%) had low level (10<sup>th</sup> percentiles) of high-density lipoprotein (HDL-C). Plasma malondialdehyde (MDA), glutathione-S-transferase (GST) were significantly higher, whereas catalase, total antioxidant capacity (TAC), and vitamin E were significantly lower in children with obesity. Both MDA and GST correlated positively with anthropometric measures, triglycerides, fasting insulin, and HOMA-IR. Both catalase and TAC correlated negatively with anthropometric measures, and cholesterol. Furthermore, catalase correlated negatively with diastolic blood pressure, triglycerides, LDL, fasting insulin, and HOMA-IR, but positively with age.

**Conclusion:** There is a substantial burden of oxidative stress represented by the high level of oxidants (MDA, GST) and low level of antioxidants (catalase, TAC) in children with obesity necessitating improvement in the management of childhood obesity.

**Keywords:** Oxidant-antioxidant status; Glucose hemostasis; Childhood obesity; Egyptian children

### Introduction

Childhood obesity is one of the most alarming health problems in both developed and developing world [1], with distressing health consequences such as dyslipidemia, atherosclerosis, and cardiovascular disease (CVD) [2]. Oxidative stress represents an imbalance between tissue oxidants in form of free radicals or reactive oxygen species (ROS) and antioxidants. This imbalance may be a unifying mechanism in the development of major obesity-related comorbidities [3]. There are several potential contributors to oxidative stress in obesity, including hyperglycaemia, increased muscle activity to carry excessive weight, elevated tissue lipid levels, inadequate antioxidant defenses, chronic inflammation, and endothelial ROS production. Not all of these factors are equally involved, one contributor may exert a greater oxidative stress effect than the others [4].

Despite the increasing prevalence of obesity and obesity-related complications in Egyptian children, there are few studies on pre-pubertal children with obesity. In addition the oxidant-antioxidant

enzymes and their correlations with the glucose and lipid profile have not been fully studied. The present study aimed at assessment of oxidant and antioxidant activities in Egyptian children with obesity and comparison to their normal-weight counterparts. Furthermore, we aimed at investigating the mutual relationship between oxidative stress markers, body composition, and metabolic pattern in childhood obesity.

### Subjects and Methods

This was a cross-sectional study, conducted at the Paediatrics Hospital, Ain Shams University in Cairo, Egypt. Fifty-two children and adolescents with obesity, defined as a BMI at or above the 95<sup>th</sup> percentile for children and teens of the same age and sex [5] were recruited. Twenty age- and sex-matched healthy-weight children served as a control group, they were recruited from the General Outpatient Clinic with no family history of obesity, diabetes or hypertension. Children with hyperglycaemia and inherited obesity were excluded.

The study design and clinical and laboratory assessments were explained and informed consent was obtained from each child and/or

their legal guardians before enrolment in the study. The study was approved by the institutional regulatory board (IRB) of the Paediatrics Hospital, Ain Shams University and were in accordance with the code of ethics of the world medical association (Declaration of Helsinki) for experiments in humans, 1975.

### Medical history

It was obtained directly by interviewing the patient and their legal guardians with special emphasis on demographic characteristics, and family history of obesity, hypertension and diabetes.

### Anthropometric measures

Anthropometric measures of every patient and control were conducted by two trained investigators to overcome inter-rater error. Height was measured to the nearest centimeter with a portable stadiometer (Seca, Marsden, UK). Weight was measured to the nearest kilogram using electronic digital scales (Tanita Corporation, Tokyo, Japan). Body mass index (BMI) values were calculated using measured height and weight values [weight (kilograms)/height (meter<sup>2</sup>)]. Anthropometric Z-scores were calculated relative to age- and gender-specific norms produced by the Center for Disease Control (CDC) from National Health and Nutrition Examination Survey (NHANES) III data [6]. Waist-to hip ratio (WHR) were calculated as ratio of waist circumference at its smallest point between the iliac crest and the rib cage to hip circumference at its largest width over the greater trochanters.

### Blood pressure

It was measured using a proper pediatric cuff size mercury gravity manometer and the blood pressure percentiles were determined. Prehypertension was defined as an average systolic or diastolic blood pressure that fell between 90<sup>th</sup> to <95<sup>th</sup> percentile, hypertension was defined as an average systolic or diastolic blood pressure that was on the 95<sup>th</sup> percentile or greater based on at least three separate readings, according to The National High Blood Pressure Education Program [7]. Physical assessment was performed with special focus on obesity-related morbidities. Puberty was assessed and classified according to Tanner stage into pre-pubertal (Tanner stage 1), in puberty (Tanner stage 2-3), and completing puberty (Tanner stage 4-5) [8].

### Blood samples

These samples were freshly withdrawn following an overnight fasting on heparinized-tubes, placed in an icebox and immediately transferred to laboratory at the National Research Institute. Samples were centrifuged immediately at 4000 rpm at 4°C and plasma was stored at -20°C until analysis. Fifty microliter of RBC were lysed with 1.0 mL ice cold water, then the clear lysate obtained after spinning down the cell debris at 8500 g at 4°C for 10 min was used for the analysis.

Blood glucose concentration was measured spectrophotometrically (Boeco S-20 Spectrophotometer, Hamburg, Germany) using an enzymatic test kit (glucose oxidase, Biodiagnostic, Cairo, Egypt) [9].

Fasting serum insulin was quantitatively determined by an enzyme-linked immunosorbent assay (ELISA) kit (Ultrasensitive human Insulin ELISA from Mercodia).

The updated Homeostasis Model Assessment (HOMA2) was used to estimate steady state beta cell function (%B) and insulin sensitivity (%S), as percentages of a normal reference population, in addition insulin resistance (IR) was calculated using the HOMA calculator [10].

**Lipid Profile:** Serum cholesterol and triglycerides (TG) were estimated by enzymatic methods [11] using diagnostic kits (Beckman AU480). High-density lipoprotein (HDL-C) was measured in the serum after precipitation with phosphotungstic acid in presence of magnesium chloride. Low-density lipoprotein (LDL-C) was estimated using the formula of Friedewald et al. [12] with modification of Bachorik [13]. Quality control was maintained using quality control sera of Technicon (Bayer Corporation, USA). The intra assay and inter assay coefficient of variations were between 4% and 6% that was well within the recommended range, suggested by National Cholesterol Education Program (NCEP). Lipid profiles were classified According to NCEP Expert Panel on Cholesterol Levels in Children [14] as follows:

- LDL-C: Acceptable, borderline-high (75<sup>th</sup> percentiles), and high (90<sup>th</sup> percentiles) were <110, 110-129, and 130 mg/dL respectively.
- TG level for those from 0-9 years: Acceptable, borderline-high (75<sup>th</sup> percentiles), and high (90<sup>th</sup> percentiles) were <75, 75-99, and 100 respectively.
- TG level for those from 10-19 years: Acceptable, borderline-high (75<sup>th</sup> percentiles), and high (90<sup>th</sup> percentiles) were <90, 90-129, and 130 respectively.
- HDL-C: Acceptable, borderline-low (75<sup>th</sup> percentiles), and low (10<sup>th</sup> percentiles) were >45, 40-45, and <40 respectively.

**Measurement of oxidant and antioxidant activities:** Determination of plasma malondialdehyde (MDA) concentration was determined spectrophotometrically (Cary UV/VIS double beam spectrophotometer, 100 V/VIS, Agilent, Australia) using the biodiagnostic MAD assay kit, by the method of Satoh [15]. Thiobarbituric acid (TBA) reacts with MDA in acidic medium at 95°C for 30 min to form thiobarbituric acid reactive product. The absorbance of the resulting pink product can be measured at 534 nm.

Catalase activity was determined spectrophotometrically using the biodiagnostic catalase assay kit, determination necessitates that first catalase reacts with a known quantity of H<sub>2</sub>O<sub>2</sub> and then the reaction to be stopped after exactly one minute with catalase inhibitor

In the presence of peroxidase (HPR), the remaining H<sub>2</sub>O<sub>2</sub> reacts with 3,5-Dichloro-2-hydroxybenzene sulfonic acid (DHBS) and 4-aminophenazone (AAP) to form a chromophore with a color intensity inversely proportional to the amount of catalase in the original sample [16].

Glutathione S transferase (GST) activity was assessed spectrophotometrically [17]. The biodiagnostic GST assay kit measures total GST activity (cytosolic and microsomal) by measuring the conjugation of 1-chloro-2, 4-dinitrobenzene (CDNB) with reduced glutathione (GSH). The conjugation is accompanied by an increase in absorbance at 340 nm. The rate of this increment is directly proportional to the GST activity in the sample.

Serum Total Antioxidant Capacity (TAC) was assessed colorimetrically [18]. The biodiagnostic TAC assay kit measured the capacity of the biological fluids to inhibit the production of thiobarbituric acid reactive substances (TBARS) from sodium benzoate under the influence of free ROS derived from Fenton's reaction.

Vitamin E was determined using competitive-ELISA, vitamin E in the sample or standard competes with a fixed amount of vitamin E on the solid phase supporter for sites on the Biotinylated Detection Antibody specific to vitamin E. After washing excess conjugate and unbound sample or standard, Avidin conjugated to Horseradish Peroxidase (HRP) is added and incubated. Then a TMB substrate solution is added and the enzyme-substrate reaction is terminated after sulphuric acid solution was added and the color change is measured spectrophotometrically at a wavelength of 450 nm ± 2 nm. In children, normal level is 3-18.4 µg/mL [19].

### Statistical analysis

Data were collected, verified, coded and fed to the Statistical Package for Social Science (IBM SPSS) version 20 (Armonk, NY: IBM Corp 2011). Qualitative data presented as number and percentages while quantitative data presented as mean, standard deviations and ranges when parametric and median with interquartile ranges (IQR) when non parametric. The comparison between two groups with qualitative data were done by using Chi-square test and/or Fisher exact test was used when the expected count in any cell was found less than five. Independent t-test and Mann-Whitney test was used to compare between two groups regarding parametric and non-parametric quantitative data respectively. Spearman correlation coefficients were used to assess the correlation between two quantitative parameters in the same group. The confidence interval was set to 95% and the margin of error accepted was set to 5%, therefore, the p-value was considered significant <0.05.

### Results

Fifty-two children and adolescents with obesity, defined as a BMI at or above the 95<sup>th</sup> percentile for children and teens of the same age and sex were recruited. Twenty four (46.2%) patients were pre-pubertal (Tanner stage 1), 13 (25%) in puberty (Tanner stage 2-3), 15 (28.8%) were completing puberty (Tanner stage 4-5).

There was a prevalence of positive family history of obesity, hypertension, and type2 diabetes (96.2, 76.9, and 55.8% respectively). Nearly all the studied obese children had positive family history of obesity (96.2%), as illustrated in Table 1.

Clinico-demographic characteristics	Children with obesity (N=52)
Age (years)*	10.96 ± 3.75
Gender, Boys: Girls N (%)	30 (57.7%): 22 (42.3%)
Family History of obesity: N (%)	50 (96.2%)
Family History of type 2 DM: N (%)	29 (55.8%)
Family History of HTN, N (%)	40 (76.9%)
Height (cm)*	137.87 ± 18.25
Height Percentile*	41.56 ± 36.80
Height SDS <-2, N (%)	9 (17.3%)
Weight (kilogram)*	66.94 ± 30.79
Weight SDS <2, N (%)	9 (17.3%)
Weight SDS 2-3, N (%)	38 (73.1%)

Weight SDS >3, N (%)	5 (9.6%)
BMI*	33.60 ± 9.78
BMI Percentile*	98.52 ± 1.11
BMI z-score >2-<3, n %	49 (94.2%)
BMI z-score > 3, n %	3 (5.8%)
Waist circumference (cm)*	87.85 ± 17.86
Hip circumference (cm)*	91.10 ± 18.63
Waist/hip ratio*	0.98 ± 0.12
Systolic blood pressure (mmHg) <sup>†</sup>	115.10 ± 13.63
<90 <sup>th</sup> percentile n %	26 (50.0%)
90 <sup>th</sup> to<95 <sup>th</sup> percentile n %	6 (11.5%)
≥ 95 <sup>th</sup> percentile n %	20 (38.5%)
Diastolic blood pressure (mmHg)	74.62 ± 11.37
<90 <sup>th</sup> percentile n %	26 (50.0%)
90 <sup>th</sup> to<95 <sup>th</sup> percentile n %	8 (15.4%)
≥ 95 <sup>th</sup> percentile n %	18 (34.6%)

**Table 1:** Clinical and demographic characteristics of the studied children with obesity.

Most of the studied obese children does not have short stature, only nine (17.3%) were short. Three children (5.8%) had BMI more than three. There was a high prevalence of hypertension in the studied obese children. Laboratory characteristics of the studied obese subjects are illustrated in Table 2.

Laboratory characteristics*	Children with obesity (N=52)
Serum cholesterol (mg/dl)	172.13 ± 30.45 (110-250)
Serum triglyceride (mg/dl)	110.19 ± 46.11 (50-353)
Low-density lipoprotein (mg/dl)	113.25 ± 28.37 (77-189)
High-density lipoprotein (mg/dl)	45.08 ± 9.52 (26-70)
Fasting blood sugar (mg/dl)	89.00 ± 9.01 (75-120)
Fasting serum insulin (mIU/L)	9.04 ± 3.21 (4-18)
HOMA-IR <sup>#</sup>	1.17 ± 0.42 (0.5-2.27)
HOMA-%B <sup>#</sup>	108.17 ± 26.41 (75-223)
HOMA-%S <sup>#</sup>	97.19 ± 35.49 (44-201)
Plasma malondialdehyde (MDA) (nmol/ml)	9.44 ± 3.07 (4-17)
Catalase (U/L)	57.37 ± 18.18 (23-90)
Glutathione S Transferase (U/L)	10.19 ± 4.41 (4-22)
Serum Total Antioxidant Capacity (TAC) (mM/L)	0.83 ± 0.34 (0.32-1.65)

Vitamin E (µg/mL)	7.88 ± 3.15 (2.69-16)
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**Table 2:** Laboratory characteristics of the studied children with obesity.

According to NCEP Expert Panel on Cholesterol Levels in Children; there were 29 (55.8%), 7 (13.5%), 16 (30.7%) patients who had acceptable, borderline-high (75<sup>th</sup> percentiles), and high (90<sup>th</sup> percentiles) LDL-C respectively. There were 4 (14.8%), 1 (40.8%), 12 (44.4%) patients aged 0-9 years (27 patients) who had acceptable, borderline-high (75<sup>th</sup> percentiles), and high (90<sup>th</sup> percentiles) TG

levels respectively. There were 7 (28%), 14 (56%), 4 (16%) patients aged 10-19 years (25 patients) who had acceptable, borderline-high (75<sup>th</sup> percentiles), and high (90<sup>th</sup> percentiles) TG levels respectively. In contrast, there were 23 (44.2%), 15 (28.8%), 14 (24.9%) patients who had acceptable, borderline-low (75<sup>th</sup> percentiles), and low (10<sup>th</sup> percentiles) HDL-C. Only one patient had vitamin E below the normal level. Plasma malondialdehyde (MDA), GST were significantly higher in obese children. Whereas catalase, TAC, and vitamin E were significantly lower in obese children in comparison to healthy-weight children as depicted in Table 3.

Variables	Control group N=20	Children with obesity N=52	Test value	P-value
Sex; Female: Male n (%)	10 (50.0%): 10 (50.0%)	22 (42.3%): 30 (57.7%)	0.346*	0.556
Age*	10.70 ± 4.08 (4-16)	10.96 ± 3.75 (3-17)	-0.259*	0.797
Plasma malondialdehyde (MDA) (nmol/ml)*	2.35 ± 1.18 (1-4)	9.44 ± 3.07 (4-17)	-10.012*	<0.001
Catalase (U/L)*	119.15 ± 24.48 (80-164)	57.37 ± 18.18 (23-90)	11.689*	<0.001
Glutathione S Transferase (U/L)*	1.90 ± 0.97 (1-4)	10.19 ± 4.41 (4-22)	-8.297*	<0.001
Serum Total Antioxidant Capacity (TAC) (mM/L)*	1.28 ± 0.67 (0.6-2.98)	0.83 ± 0.34 (0.32-1.65)	3.803*	<0.001
Vitamin E (µg/mL)*	14.90 ± 4.81 (9-25)	7.88 ± 3.15 (3-16)	7.256*	<0.001

**Table 3:** Comparison of oxidant and antioxidant markers between obese children and healthy-weight controls.

The correlations of the relationships between the oxidative-antioxidative status of the obese children and clinical-laboratory characteristics are illustrated in Table 4. Both MDA and GST correlated positively with anthropometric measures (weight, height,

BMI, waist circumference, hip circumference), triglyceridess, fasting insulin, and HOMA-IR. Whereas MDA correlated positively with cholesterol, and GST correlated positively with LDL.

	Malondialdehyde		Catalase		Glutathione S Transferase		Total Antioxidant Capacity		Vitamin E	
	r	P	r	P	r	P	r	P	r	P
Age (Years)	-0.13	0.359	0.196	0.163	-0.149	0.292	0.279	0.045	0.038	0.79
Weight (Kg)	0.763	0	-0.694	0	0.686	0	-0.605	0	-0.476	0
Height (cm)	0.491	0	-0.453	0.001	0.407	0.003	-0.397	0.004	-0.251	0.073
BMI (Kg/m <sup>2</sup> )	0.755	0	-0.668	0	0.684	0	-0.588	0	-0.506	0
Waist circumference (cm)	0.5	0	-0.401	0.003	0.474	0	-0.326	0.018	-0.288	0.038
Hip circumference (cm)	0.531	0	-0.461	0.001	0.473	0	-0.358	0.009	-0.186	0.186
Waist/hip ratio	-0.099	0.486	0.134	0.343	-0.033	0.817	0.099	0.483	-0.052	0.715

Systolic blood pressure (mmHg)	0.353	0.01	-0.215	0.125	0.293	0.035	-0.14	0.321	-0.187	0.184
Diastolic blood pressure (mmHg)	0.429	0.002	-0.3	0.031	0.273	0.05	-0.223	0.112	-0.218	0.121
Serum cholesterol (mg/dl)	0.45	0.001	-0.474	0	0.363	0.008	-0.367	0.007	-0.199	0.158
Serum triglyceride (mg/dl)	0.363	0.008	-0.315	0.023	0.338	0.014	-0.272	0.051	-0.204	0.147
Low-density lipoprotein (mg/dl)	0.243	0.083	-0.383	0.005	0.307	0.027	-0.262	0.061	-0.134	0.343
High-density lipoprotein (mg/dl)	-0.055	0.699	0.144	0.308	-0.081	0.567	-0.007	0.959	-0.012	0.932
Fasting blood sugar (mg/dl)	0.105	0.459	-0.205	0.145	0.237	0.09	-0.127	0.371	-0.141	0.319
Fasting serum insulin (mIU/L)	0.279	0.045	-0.275	0.048	0.296	0.033	-0.262	0.06	-0.145	0.304
HOMA-IR <sup>#</sup>	0.274	0.049	-0.277	0.047	0.298	0.032	-0.254	0.069	-0.153	0.278
HOMA-%B <sup>#</sup>	0.199	0.156	-0.116	0.415	0.116	0.415	-0.15	0.288	-0.041	0.774
HOMA-%S <sup>#</sup>	-0.17	0.227	0.213	0.13	-0.229	0.102	0.206	0.142	0.093	0.511

**Table 4:** Correlation between the oxidative and anti-oxidative markers of the obese children and selected clinical and laboratory characteristics.

Both catalase and TAC correlated negatively with anthropometric measures (weight, height, BMI, waist circumference, hip circumference), and cholesterol. Furthermore, catalase correlated negatively with diastolic blood pressure, triglyceridess, LDL, fasting insulin, and HOMA-IR, but positively with the age. Vitamin E only correlated with anthropometric measures (weight, BMI, waist circumference).

## Discussion

Childhood obesity is a rapidly increasing worldwide health problem with serious social and medical consequences [20]. The World Health Organization (WHO) in 2012 reported that around 44 million (6.7%) children aged <5 years old worldwide were overweight or obese [21]. The prevalence of overweight and obesity among adolescents in Arab countries ranged from 18% to 44% [22]. In general, overweight has been found to be more prevalent than obesity in both genders. This does not apply to adolescents where obesity was higher among Egyptian girls than boys [23].

Oxidative stress, a condition of imbalance between oxidant and antioxidant systems in favor of the oxidative system [24], may be the stem-root of obesity. Adipose tissue is metabolically active and secretes hormones and cytokines, consequently excess fat tissue with ROS generation triggers the oxidative stress and pro-inflammatory cytokine release [25]. Furthermore, excess free fatty acids (FFA) in children with obesity leads to compromised glucose metabolism, resulting in mitochondrial overload with energy substrates [26].

Increased levels of oxidants produced in pathophysiological conditions, antioxidant systems such as catalase (CAT), vitamin E have been developed in order to protect biomolecules from the deleterious effects of ROS [20]. The high production of ROS is an contributing factor in destroying the antioxidant enzymes resulting in depletion of

the antioxidant activities in children with obesity [27] which may have deleterious effects on RBC membranes, resulting in lipid peroxidation enhancing the production of MDA concentrations, which in turn has additional toxic effects on antioxidant enzymes [28].

In the current study, the common approach in the measurement of oxidative stress which is the determination of MDA was followed. In addition the practical parameter, total antioxidant status (TAS), was also measured. We reported that oxidative markers in the form of plasma MDA and GST were significantly higher in obese children, whereas antioxidants in the form of catalase, TAC, and vitamin E were significantly depleted in obese children in comparison to healthy-weight children. This finding is in agreement with the work of Ustundag and his colleagues who reported elevation of plasma MDA in prepubertal obese children when compared with healthy controls and MDA was well correlated with BMI. In contrast to the increase in oxidative stress, antioxidant activities of glutathione peroxidase were decreased in obese prepubertal children [28].

Childhood obesity is an alarming condition that predisposed to chronic adulthood diseases such as CVD, insulin resistance, type 2 diabetes mellitus, metabolic syndrome and adulthood obesity (Kilic et al.). In the current study there was a high prevalence of positive family history of obesity, hypertension, and type 2 diabetes (96.2%, 76.9%, and 55.8% respectively) and high prevalence of hypertension in the studied obese children.

Long-term accumulation of energy substrates causes FFA passage especially from visceral adipose tissue to the blood. The increased FFA causes increased cell differentiation and mitochondrial workload, consequently increased the release of ROS products, which are especially destructive for specific organelles and DNA [26]. In our study, lipid profiles in the obese children were assessed and we found that 16 (30.7%) had high levels (90<sup>th</sup> percentiles) of low-density

lipoprotein (LDL-C) and triglycerides and 14 (24.9%) had low levels (10<sup>th</sup> percentiles) of high-density lipoprotein (HDL-C).

In the current Egyptian study correlation analysis was used to investigate the mutual relationship between the oxidative status of obese children and their clinical-laboratory characteristics to highlight those at risk. Both MDA and GST correlated positively with anthropometric measures, triglycerides, fasting insulin, and HOMA-IR. Both catalase and TAC correlated negatively with anthropometric measures, and cholesterol. Furthermore, catalase correlated negatively with diastolic blood pressure, triglycerides, LDL, fasting insulin, and HOMA-IR, but positively with the age. Our findings highlight that the oxidative stress augments insulin resistance which decreases insulin release from the pancreas. Furthermore, we reported that obese children showed an increase in serum concentrations of LDLs and triglycerides, GST, HOMA-IR and HOMA-%B indices, as well as a reduction in the HOMA-%S.

A Mexican study investigated the relationship between obesity, oxidative stress, heme oxygenase-1 (HO-1), and insulin in children aged 3 to 5 years. The authors concluded that obese preschool children showed a chronic state of oxidative stress, an increase of HO-1, and an incipient state of insulin resistance. This increased ROS could be one of the leading factors involved in insulin resistance and Ox-LDL increase from the preschool stage [29].

A Spanish study similarly evaluated the presence of oxidative stress in 68 obese children aged between 6 and 14 years without comorbidities. They found that the levels of MDA and CG were significantly higher in children with SDS-BMI  $\geq$  3. The glutathione peroxidase (GPx) activity was increased, while the erythrocyte-reduced glutathione [GSH] concentration was lower in obese children compared with non-obese children. MDA was the sole marker of oxidative damage that was positively correlated with SDS-BMI and negatively correlated with HDL-C. In multiple regression analysis, they confirmed that SDS-BMI and HDL-C were determinants of MDA. The authors recommended that providing foods with high antioxidant capacity in addition to a hypocaloric diet is crucial for the treatment of obese children [30].

A cross-sectional Mexican study evaluated the relationship between micronutrient status and obesity, lipids, insulin resistance and chronic inflammation in 197 school-aged children. They found that vitamin E: lipids were negatively associated with BMI, waist-to-height ratio (WHR) and body and abdominal fat and also negatively associated with insulin and CRP. Interaction analysis showed that children who were overweight and obese who also had low concentrations of vitamin E had significantly lower glucose and triglycerides and higher LDL concentrations [31]. Major limitation of the present study were the small numbers of recruited patients, the cross-sectional nature of the study without follow-up, and the lack of assessment of the physical activities and diet.

## Conclusions

There is a substantial burden of oxidative stress in the obese children which necessitates improving the understanding and management of its influence on childhood obesity.

## Key Messages

- The prevalence of children with obesity is rapidly increasing worldwide.

- In the current study demonstrated a high prevalence of positive family history of obesity that may indicate that environmental factors play an important role.
- In the current study there was a high prevalence of hypertension and type 2 diabetes in children with obesity.
- Existing approaches to prevention and interventions have limited success.

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