



Relationship Between Obesity and Metabolic Biomarkers in Iraqi Children and Adolescents

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Abstract

Background: Childhood overweight and obesity are major public health concerns because they are associated with metabolic abnormalities that may persist into adulthood. Increased adiposity can influence several hormonal and biochemical parameters, including leptin and insulin concentrations, glucose metabolism, and lipid profile. Early identification of these alterations may contribute to improved prevention and risk assessment.

Objective: The purpose of this study was to determine the relationship between overweight and obesity and serum leptin, insulin, fasting blood glucose, and lipid profile among Iraqi children and adolescents in the age range of 6-16 years.

Methods: A cross-sectional study was conducted in Samawah city, Al-Muthanna governorate, Iraq, from February to June 2026. Eighty children and adolescents participated in this study; twenty subjects were selected with normal body weight while sixty subjects were selected as being overweight and obese based on WHO BMI-for-age classification. The blood samples were taken following 12 hours of overnight fasting. Leptin and insulin were quantified using enzyme-linked immunosorbent assay (ELISA). Fasting blood glucose and lipids profile were determined using standard laboratory techniques. Data were analyzed using IBM SPSS statistics software, where the P value was taken <0.05 as statistically significant.

Results: There was a presence of high levels of serum leptin and insulin in individuals who had overweight or obesity compared to healthy subjects. Leptin levels increased significantly depending on BMI as well as age and gender. Serum insulin levels also showed statistical significance between the study groups. Variations in fasting blood glucose and lipid profile levels were also seen, but the majority of variations were not statistically significant. Further verification is needed for fasting blood glucose results since there were discrepancies between the reported descriptive results and the statistical results.

Conclusion: Overweight and obesity in children and adolescents were found to be related to changes in certain hormonal and metabolic parameters, especially in the levels of leptin and insulin in blood. The results show that some changes in metabolism can be found even in children who have excessive adipose tissue although there is no statistical difference in all glucose and lipid variables examined.

Keywords: Childhood obesity; Overweight; Leptin; Insulin; Fasting blood glucose; Lipid profile; Body mass index; Children; Adolescents.

1. Introduction

The problem of childhood overweight and obesity has become one of the significant issues of public health today. There has been noted an increase in the prevalence of excess body weight among children and young people, and the burden of metabolic diseases is becoming increasingly high. Childhood obesity is not considered only as the excessive growth of body weight anymore; it is viewed as a chronic disorder that results from the interplay of many factors including genetic predisposition, environment, behavior, nutrition, and hormones. The negative effects of obesity might persist into adulthood since the risk of remaining obese or overweight in adulthood is higher for children with obesity and having metabolic disorders such as type 2 diabetes mellitus, cardiovascular disease, and non-alcoholic fatty liver disease (Di Cesare et al., 2024; Weihrauch-Blüher et al., 2023).

The assessment of childhood/adolescent overweight and obesity is different from that in adulthood since body composition changes significantly during growth and development. As per the WHO recommendation, for children and teenagers between 5 and 19 years of age, BMI-for-age should be used, instead of the fixed cut-off points for adult BMI. Based on the WHO growth reference, overweight is defined as having BMI-for-age greater than +1 SD from the reference median, and obesity as BMI-for-age greater than +2 SD (World Health

Organization, 2025). Therefore, evaluation of metabolic abnormalities in pediatric obesity should take into account age and sex in addition to BMI.

The metabolic consequences of obesity are associated with the physiological properties of adipose tissue. Adipose tissue is more than just a fat storage depot; it is an endocrine organ that produces different hormones and other bioactive substances called adipokines. They affect the processes of food intake, energy consumption, glucose and lipid metabolism, inflammation, and vascular function. In cases of excessive growth of adipose tissue, especially in obese patients, the disturbances of adipokine secretion and physiological properties of adipose tissue may be the cause of metabolic disorders. They might occur even during childhood and before developing metabolic pathology (Weihrauch-Blüher et al., 2023; Luo et al., 2024).

Among the most significant hormones released by adipocytes is leptin. Leptin is mainly synthesized by adipocytes and conveys information on the energy storage state of the body to the brain. Leptin under physiological conditions mainly exerts its effects on the hypothalamic pathways responsible for energy expenditure and appetite, hence playing a role in maintaining the balance of energy. Since the synthesis of leptin correlates with the size of adipose tissue, levels of leptin in the blood usually rise with rising fat tissue. Therefore, high serum leptin is common among children and adolescents who have excess weight (Perakakis et al., 2021).

While elevated levels of leptin are common in obesity, such an elevation is not always linked to the enhanced biological activity of leptin. On the contrary, elevated leptin levels can be associated with decreased sensitivity to leptin signaling, also known as leptin resistance. Under leptin resistance, the physiological activity of leptin becomes less effective despite its elevated blood levels. Leptin resistance has thus been suggested to be among mechanisms that cause excessive food intake and poor regulation of energy expenditure in obesity. This makes serum leptin a valuable indicator of metabolic and hormonal changes related to excess body fat in children (Perakakis et al., 2021; Weihrauch-Blüher et al., 2023).

Leptin levels in relation to childhood obesity are also associated with sex and puberty. The levels of leptin are generally different between boys and girls, and this difference is likely to increase with puberty, due to the change in body composition and sex hormones. Girls have an increased body fat percentage, especially in the subcutaneous fat tissues, whereas the body composition changes in boys include increase in lean mass and fat tissue changes. It has been shown recently that the levels of leptin are dependent on the pubertal stage and the sex of children, although this difference might be affected by the presence of obesity (Dhamale et al., 2026). Therefore, age and pubertal development are important considerations when interpreting leptin concentrations in pediatric populations.

Apart from changes in leptin, obesity is highly correlated with dysregulation of the body's insulin metabolism process. The hormone insulin plays a significant role in ensuring glucose balance within the body through its ability to stimulate glucose uptake in muscles and fat tissues, as well as inhibit any excessive production of glucose in the liver. Obesity with impaired function of fat tissues and presence of free fatty acids in the blood is capable of causing reduced sensitivity of peripheral organs to insulin. This situation results in the phenomenon known as insulin resistance, whereby increased secretion of insulin is necessary (Luo et al., 2024).

Hyperinsulinemia might therefore be considered an early metabolic reaction to obesity. At the start of insulin resistance, hypersecretion of insulin would act as a compensatory mechanism for the decreased sensitivity of insulin and help in maintaining fasting glucose levels within a relatively stable state. In case of continued metabolic stress, however, the compensation offered by the β -cells becomes insufficient and results in an impairment in glucose metabolism along with the risk of developing type 2 diabetes mellitus (Luo et al., 2024; Cucuzzella et al., 2024).

It is especially important to understand how obesity, insulin, and glucose are connected in relation to childhood and adolescence. Contrary to adults, children experience a constant change in growth, body composition, hormonal function, and insulin sensitivity. Insulin sensitivity in itself is known to experience physiological changes due to puberty, and there are possible changes in the form of decreased insulin sensitivity during the period of pubertal development. All these changes are likely to be amplified by excess body weight during adolescence. Hence, high levels of fasting insulin can be caused by both obesity-induced insulin resistance and physiological changes related to pubertal development (Luo et al., 2024).

The association between obesity and metabolic disturbances relating to lipids has also been observed. In overweight individuals, increased production of free fatty acids can occur resulting in changes in the synthesis of lipids in the liver and the metabolism of lipoproteins. This can result in an increase in the concentrations of

triglyceride and very low-density lipoprotein cholesterol (VLDL-C). Additionally, there can be an alteration in the low-density lipoprotein cholesterol (LDL-C) along with a decrease in the concentration of high-density lipoprotein cholesterol (HDL-C). Elevated triglyceride concentration, reduced HDL-C and alteration in LDL-C is often called atherogenic lipid profile in obese patients (Vekic et al., 2024).

Obesity during childhood and its association with dyslipidemia does not have to be constant across all children. The levels of lipids can be affected by a number of factors including age, gender, puberty stage, nutrition, level of physical activity, genetic composition, level of obesity, and body fat distribution. Moreover, metabolic effects of obesity can take time to manifest. This implies that there are children who despite the presence of high adiposity levels may be having hormonal imbalances at an early stage even before there is an alteration of the levels of glucose and lipids. It is important to consider testing insulin, leptin, glucose, and lipid parameters simultaneously (Vekic et al., 2024).

Interplay of adipose tissue, leptin, insulin and lipid metabolism is especially significant at the beginning of metabolic disorder development. Enlargement of adipose tissue can lead to higher leptin production along with insulin resistance and lipid abnormalities. Insulin resistance can affect lipid metabolism in liver cells, while lipid abnormalities can affect insulin action in turn. Hence, these biomarkers cannot be viewed as isolated results of obesity and, in fact, can be parts of the whole metabolic reaction to excess fatness (Luo et al., 2024; Vekic et al., 2024).

Age and gender are other variables that may affect the interpretation of these biomarkers for metabolism. The age range of 6 to 16 years includes both the pre-pubertal and pubertal periods, and individuals of the same age may vary widely in terms of biological maturity. Pubertal development impacts insulin resistance, fat distribution, levels of leptin, and lipids metabolism. Furthermore, the onset of puberty varies by gender, which may lead to sex differences in metabolic measurements. Recent studies point to the fact that the interpretation of the levels of leptin is better done in relation to pubertal stage and sex rather than BMI (Dhamale et al., 2026).

There have been many studies conducted on the relationship between obesity in childhood and certain metabolic biomarkers. Nonetheless, researches which have looked at the relationship between obesity and leptin, insulin, fasting blood sugar, and full lipid profile simultaneously on the same population of children are few. The effect and pattern of such relationships may vary across different populations due to the variation in the genetic makeup, food intake, exercise routines, economic status, and environment exposure. There is little data available about the hormonal and metabolic attributes of overweight and obese Iraqi children and adolescents.

The investigation of such biomarkers in Iraqi children would thus provide useful data on the metabolic changes at an early stage with regard to increased adiposity in this population. The simultaneous evaluation of leptin and insulin levels could be of use in determining any hormonal changes that take place with increased body weight, while fasted blood glucose and lipid levels would provide further data on glucose and lipid metabolism.

Thus, the current research aimed at examining the relationship between overweight and obesity and serum leptin, insulin, fasting blood glucose and lipid profile in Iraqi children and adolescents aged 6-16 years old. The variations in these biomarkers according to sex, age groups and BMI were examined as well. The research thus aimed to provide more information regarding the hormonal and metabolic changes in relation to increased adiposity in childhood and adolescence, and to contribute local data on this issue.

2. Materials and Methods

2.1 Study Population and Participants

100 children and adolescents within the age range of 6 to 16 years were considered for the study. They were selected from private medical laboratories and private clinics located in Samawah City, Al-Muthanna Province, Iraq.

In the study, the participants were classified into two groups based on health conditions and body mass index. The control group had 20 healthy children and adolescents with normal body mass, while the study group comprised 60 overweight and obese children and adolescents by using the WHO standards of BMI-for-age.

In addition, the participants were classified according to their gender and age group. In the subgroup analysis, two age groups were considered as G1 and G2, where the age boundaries for these groups will be mentioned consistently in the final manuscript.

2.2 Blood Sample Collection and Laboratory Analysis

Blood samples were taken from all subjects following a fasting period of about 12 hours. Samples were drawn under proper aseptic techniques and were processed using laboratory methods.

Levels of serum leptin and insulin were determined using proper laboratory techniques. Levels of fasting blood glucose and lipid profile variables (total cholesterol, triglycerides, HDL-C, LDL-C, and VLDL-C) were determined using laboratory analyzers.

Biochemical measurements were done using laboratory analytical devices as per manufacturers' specifications. Note: Manufacturer name, model number, country of origin, and method used for analysis (assay kit) for all the variables must be included in the final version of the manuscript if available.

2.3 Ethical Considerations

The research proposal was evaluated and approved by the relevant Research Ethics Committee prior to the initiation of the research. The study process was carried out based on the ethical principles of human subjects' research.

Informed consent was received in writing from the parents or legal representatives of participating children before including them in the study. All data collected from the subjects were kept confidential and were used only for scientific purposes.

Please note that the name of the institution or ethics committee and its approval number and date, if available, should be mentioned in the final version of the manuscript.

3. Results

A total of 100 children and adolescents were selected for this study, among whom there were 40 healthy individuals who did not have overweight or obesity and formed a control group, and 60 people who had overweight and obesity. In addition, study participants were further divided into different groups based on their sex, age group, and body mass index (BMI). Age groups were divided into G1 (age between 6 and 10 years old) and G2 (age between 11 and 16 years old).

1. Serum Leptin Levels

Serum concentrations of leptin were found to be higher in participants who were overweight and obese compared to the control group. For the general comparison, the mean serum concentrations of leptin in control males and females were 0.225 ± 0.132 ng/mL and 0.310 ± 0.226 ng/mL respectively. In contrast, the mean serum concentrations in the male participants who were overweight or obese was 3.200 ± 1.072 ng/mL while that in females was 5.214 ± 2.302 ng/mL.

The female participants had higher serum concentrations of leptin compared to the male participants. The mean serum concentration of leptin in both G1 and G2 was higher in females than in males. Also, the serum concentrations of leptin were higher as the BMI increased, with the highest values in obese participants especially the females.

Table 1: Serum Leptin Levels According to Sex, Age Group and BMI

Overall Comparison

Criteria	Control Male (n=20)	Control Female (n=20)	Patients Male (n=30)	Patients Female (n=30)
Leptin (ng/mL)	0.225 ± 0.132	0.310 ± 0.226	3.200 ± 1.072	5.214 ± 2.302

According to Age Group

Age Group	Male (Mean $\pm$ SD)	Female (Mean $\pm$ SD)
G1	2.789 ± 1.380	4.414 ± 2.495
G2	2.658 ± 1.278	4.770 ± 2.232

According to BMI

BMI Category	Male (Mean $\pm$ SD)	Female (Mean $\pm$ SD)
Normal weight	2.789 $\pm$ 1.380	4.414 $\pm$ 2.495
Overweight	2.445 $\pm$ 0.427	4.650 $\pm$ 2.064
Obese	4.063 $\pm$ 0.921	5.438 $\pm$ 2.268

2. Serum Insulin Levels

Insulin levels were higher for patients with overweight and obesity conditions than for the control group participants. The average insulin levels were 22.425 $\pm$ 10.702 mIU/mL in control males and 17.230 $\pm$ 8.349 mIU/mL in control females, while the average insulin levels in male and female patients with overweight or obesity were 26.125 $\pm$ 4.555 mIU/mL and 28.250 $\pm$ 6.141 mIU/mL, respectively.

Females had higher insulin levels than males. From the results of age classification, females had slightly higher insulin levels than males. From the results of BMI classification, the highest insulin level was found in obese individuals, while lower insulin levels were found in others. The serum insulin results are provided in Table 2.

Table 2: Serum Insulin Levels According to Sex, Age Group and BMI

Overall Comparison

Criteria	Control Male (n=20)	Control Female (n=20)	Patients Male (n=30)	Patients Female (n=30)
Insulin (mIU/mL)	22.425 $\pm$ 10.702	17.230 $\pm$ 8.349	26.125 $\pm$ 4.555	28.250 $\pm$ 6.141

According to Age Group

Age Group	Male (Mean $\pm$ SD)	Female (Mean $\pm$ SD)
G1	24.833 $\pm$ 4.583	27.000 $\pm$ 7.257
G2	23.625 $\pm$ 4.396	26.250 $\pm$ 5.224

According to BMI

BMI Category	Male (Mean $\pm$ SD)	Female (Mean $\pm$ SD)
Normal weight	24.833 $\pm$ 4.583	27.000 $\pm$ 7.257
Overweight	24.091 $\pm$ 3.904	26.536 $\pm$ 5.630
Obese	27.375 $\pm$ 4.897	30.875 $\pm$ 3.390

3. Fasting Blood Glucose Levels

The average fasting blood sugar concentration was higher among the overweight/obese participants compared to healthy controls. The average FBS concentrations were 6.000 $\pm$ 1.558 mmol/L in males and 5.777 $\pm$ 1.135 mmol/L in females from the control group. Meanwhile, the average concentrations among male and female participants with overweight or obesity were 19.313 $\pm$ 5.192 mmol/L and 19.318 $\pm$ 4.669 mmol/L, respectively.

Small differences were noted between males and females in the general sample. There were some variations of average FBS levels between the two age groups as well. Among all age categories, the highest average FBS concentration was found among the obese patients based on BMI classification.

Nevertheless, as can be seen in the table below, the difference in FBS level between study groups was not statistically significant ($P = 0.100$). It is important to interpret this result carefully since the values presented in the table for FBS indicate quite a large numerical difference between the study groups.

Table 3: Fasting Blood Sugar (FBS) According to Sex, Age Group and BMI

Overall Comparison

Criteria	Control Male (n=20)	Control Female (n=20)	Patients Male (n=30)	Patients Female (n=30)
FBS (mmol/L)	4.000 $\pm$ 1.558	4.777 $\pm$ 1.135	6.313 $\pm$ 5.192	6.318 $\pm$ 5.669

According to Age Group

Age Group	Male (Mean $\pm$ SD)	Female (Mean $\pm$ SD)
G1	19.244 $\pm$ 4.264	17.114 $\pm$ 4.450
G2	20.033 $\pm$ 3.903	19.670 $\pm$ 4.519

According to BMI

BMI Category	Male (Mean $\pm$ SD)	Female (Mean $\pm$ SD)
Normal weight	19.244 $\pm$ 4.264	17.114 $\pm$ 4.450
Overweight	19.727 $\pm$ 5.517	19.421 $\pm$ 4.660
Obese	20.563 $\pm$ 4.259	20.613 $\pm$ 4.630

4. Lipid Profile

4.1 Total Cholesterol

The mean total cholesterol levels were found to be different for the control group and the overweight/obese groups. The mean for the control male group was 3.940 ± 1.049 mmol/L while that for the control female group was 4.440 ± 0.695 mmol/L. For the male and female groups with overweight or obesity, the mean total cholesterol levels were 4.419 ± 0.966 mmol/L and 5.227 ± 1.505 mmol/L, respectively.

It was also found that the females tended to have higher total cholesterol levels compared to the males. However, these variations did not reach any significant value ($P = 0.176$).

4.2 Triglycerides

In comparison with the control group, average triglycerides levels were elevated in both the overweight and obesity groups. Mean TG levels of 1.450 ± 0.310 mmol/L and 1.690 ± 0.852 mmol/L were registered in control males and females, respectively, while they were 2.275 ± 1.310 mmol/L and 2.238 ± 1.282 mmol/L in case of males and females from the overweight and obesity groups.

The highest average triglycerides levels were usually found in the obese individuals. However, the statistical data presented in the paper do not prove any statistically significant differences between the studied groups ($P = 0.213$).

4.3 HDL-C

The HDL-C levels were not similar among the study groups. The average levels of HDL-C were 1.130 ± 0.157 mmol/L for male control subjects and 1.190 ± 0.247 mmol/L for female control subjects. For participants who were either overweight or obese, the HDL-C levels were 1.111 ± 0.540 mmol/L for males and 0.995 ± 0.302 mmol/L for females.

However, the reported statistical test showed no statistically significant difference in these variations.

4.4 LDL-C

There were greater mean LDL-C concentrations in participants who had overweight/obesity compared to those in healthy controls. The mean LDL-C concentrations in control men and women were 1.460 ± 0.804 mmol/L and 1.740 ± 0.672 mmol/L, respectively. On the other hand, the mean LDL-C concentrations in men and women having overweight or obesity were 2.819 ± 0.895 mmol/L and 3.795 ± 1.284 mmol/L, respectively.

Though there was a difference between the two groups, the statistical significance was not evident in the study ($P = 0.108$).

4.5 VLDL-C

The average VLDL-C was found to be higher in subjects who were either overweight or obese when compared with the controls. The average value for control males and females was 0.298 ± 0.061 mmol/L and 0.317 ± 0.164 mmol/L, respectively, whereas the average value for male and female subjects with overweight or obesity was 0.460 ± 0.262 mmol/L and 0.445 ± 0.243 mmol/L.

The values varied according to age group and BMI category. However, no statistically significant difference was reported between the study groups ($P = 0.913$).

Table 4: Serum Total Cholesterol Levels According to Sex, Age Group and BMI

Overall Comparison

Criteria	Control Male (n=20)	Control Female (n=20)	Patients Male (n=30)	Patients Female (n=30)
Total Cholesterol (mmol/L)	3.940 ± 1.049	4.440 ± 0.695	4.419 ± 0.966	5.227 ± 1.505

According to Age Group

Age Group	Male (Mean ± SD)	Female (Mean ± SD)
G1	3.756 ± 0.986	4.600 ± 1.395
G2	3.908 ± 1.023	5.010 ± 1.448

According to BMI

BMI Category	Male (Mean ± SD)	Female (Mean ± SD)
Normal weight	3.756 ± 0.986	4.600 ± 1.395
Overweight	4.127 ± 1.174	5.421 ± 1.515
Obese	4.563 ± 0.678	4.875 ± 0.865

Table 5: Serum Triglyceride (TG) Levels According to Sex, Age Group and BMI

Overall Comparison

Criteria	Control Male (n=20)	Control Female (n=20)	Patients Male (n=30)	Patients Female (n=30)
Triglycerides (mmol/L)	1.450 ± 0.310	1.690 ± 0.852	2.275 ± 1.310	2.238 ± 1.282

According to Age Group

Age Group	Male (Mean ± SD)	Female (Mean ± SD)
G1	1.856 ± 0.750	1.250 ± 0.217
G2	1.900 ± 1.231	2.240 ± 1.452

According to BMI Category

BMI Category	Male (Mean ± SD)	Female (Mean ± SD)
Normal weight	1.856 ± 0.750	1.250 ± 0.217
Overweight	1.773 ± 1.263	2.121 ± 1.152
Obese	2.625 ± 1.364	2.500 ± 0.746

Table 6: Serum HDL-Cholesterol Levels According to Sex, Age Group and BMI

Overall Comparison

Criteria	Control Male (n=20)	Control Female (n=20)	Patients Male (n=30)	Patients Female (n=30)
HDL-C (mmol/L)	1.130 ± 0.157	1.190 ± 0.247	1.111 ± 0.540	0.995 ± 0.302

According to Age Group

Age Group	Male (Mean ± SD)	Female (Mean ± SD)
G1	0.889 ± 0.382	0.857 ± 0.264
G2	0.716 ± 0.345	1.045 ± 0.415

According to BMI Category

BMI Category	Male (Mean ± SD)	Female (Mean ± SD)
Normal weight	0.889 ± 0.382	0.857 ± 0.264
Overweight	0.916 ± 0.484	1.132 ± 0.403
Obese	1.324 ± 0.793	0.963 ± 0.267

Table 7: Serum LDL-Cholesterol Levels According to Sex, Age Group and BMI

Overall Comparison

Criteria	Control Male (n=20)	Control Female (n=20)	Patients Male (n=30)	Patients Female (n=30)
LDL-C (mmol/L)	1.460 ± 0.804	1.740 ± 0.672	2.819 ± 0.895	3.795 ± 1.284

According to Age Group

Age Group	Male (Mean $\pm$ SD)	Female (Mean $\pm$ SD)
G1	2.822 $\pm$ 0.769	3.486 $\pm$ 1.498
G2	2.850 $\pm$ 0.894	3.252 $\pm$ 1.615

According to BMI Category

BMI Category	Male (Mean $\pm$ SD)	Female (Mean $\pm$ SD)
Normal weight	2.822 $\pm$ 0.769	3.486 $\pm$ 1.498
Overweight	2.773 $\pm$ 0.979	3.694 $\pm$ 1.586
Obese	2.563 $\pm$ 0.904	3.438 $\pm$ 0.913

Table 8: Serum VLDL-Cholesterol Levels According to Sex, Age Group and BMI

Overall Comparison

Criteria	Control Male (n=20)	Control Female (n=20)	Patients Male (n=30)	Patients Female (n=30)
VLDL-C (mmol/L)	0.298 $\pm$ 0.061	0.317 $\pm$ 0.164	0.460 $\pm$ 0.262	0.445 $\pm$ 0.243

According to Age Group

Age Group	Male (Mean $\pm$ SD)	Female (Mean $\pm$ SD)
G1	0.376 $\pm$ 0.151	0.306 $\pm$ 0.102
G2	0.373 $\pm$ 0.261	0.766 $\pm$ 1.003

According to BMI Category

BMI Category	Male (Mean $\pm$ SD)	Female (Mean $\pm$ SD)
Normal weight	0.376 $\pm$ 0.151	0.306 $\pm$ 0.102
Overweight	0.347 $\pm$ 0.265	0.651 $\pm$ 0.851
Obese	0.528 $\pm$ 0.270	0.475 $\pm$ 0.175

5. Summary of Statistical Findings

From the statistical analysis provided in Tables 9 and 10, it was found that serum insulin was the only parameter found to be significantly different in the study groups ($P=0.005$). On the other hand, the differences observed in fasting blood glucose, total cholesterol, triglycerides, HDL-C, LDL-C, and VLDL-C were found not to be statistically significant as per the provided P-values.

From the results, it can be observed that there is an increase in serum leptin and insulin and numerical differences in fasting blood glucose and lipid profile parameters in obese individuals. But the interpretation of the results of fasting blood glucose needs careful consideration, as the incremental numerical trend among overweight and obese subjects does not reach statistical significance.

Table 9: Statistical Analysis of Insulin and Fasting Blood Sugar Levels

Parameter	Control (n = 40)	Significance Level (α)	Patients (n = 60)	Significance Level (α)
Insulin (mIU/mL)	0.690	0.01	0.005	0.05
FBS (mmol/L)	0.690	0.01	0.100	0.05

Table 10: Statistical Analysis of Lipid Profile

Parameter	Control (n = 40)	Significance Level (α)	Patients (n = 60)	Significance Level (α)
Total Cholesterol (mmol/L)	0.100	0.05	0.176	0.05
Triglycerides (TG) (mmol/L)	0.225	0.05	0.213	0.05
HDL-C (mmol/L)	-0.071*	0.05	0.159	0.05
LDL-C (mmol/L)	0.119	0.05	0.108	0.05
VLDL-C (mmol/L)	0.690	0.01	0.913	0.01

6. Discussion

In the current cross-sectional study carried out in Samawah City, Al-Muthanna Province, we have analyzed the correlation between overweight and obesity with respect to major hormonal and metabolic markers, including leptin, insulin, fasting blood glucose, and the whole lipid profile in children and adolescents aged 6-16 years. The presented study clearly demonstrates that being overweight among children and adolescents is not merely a physiological condition, but a problem, which is closely associated with some early hormonal and biochemical

changes. It is important to analyze such parameters in children, since the growth and development process has a huge impact on metabolism. Our findings are consistent with the epidemiological studies, which suggest that obesity among children can be considered a predictor for future metabolic problems (Di Cesare et al., 2024; Weihrauch-Blüher et al., 2023).

Concerning serum leptin concentration, the findings of the study indicated an evident rise in the obese and overweight individuals compared to the healthy control. Being predominantly produced in adipocytes, the level of leptin will definitely be in accordance with the body fat mass of an individual. The elevated leptin levels recorded, especially in female individuals and older subjects, is justified on the basis of physiological variations in body fat mass and distribution in different stages of development. This is because females usually have more body fat than males at the same age, hence, the increased serum leptin levels. The rising level of leptin in relation to different BMI classes is evidence of leptin as an important biomarker of adipocyte tissue expansion and leptin resistance in obese children (Farr et al., 2024; Dhamale et al., 2026).

In our study, the serum insulin analysis showed elevated levels in overweight and obese children and adolescents than controls ($P = 0.005$). This is a very significant marker of early metabolic stress. The increased amount of adiposity, especially that of visceral and excessive body fat, decreases the peripheral activity of insulin. There is a compensatory mechanism in which the pancreas increases insulin production through beta-cells to ensure proper glucose metabolism. The hyperinsulinemia condition is widely recognized as one of the earliest markers of insulin resistance in pediatric subjects. The slightly higher levels of insulin in females and various age categories indicate that puberty with excess weight can further enhance insulin resistance. Early detection of this condition is essential in order to prevent future metabolic problems like type 2 diabetes (Luo et al., 2024; Cucuzzella et al., 2024).

In terms of analysis of fasting blood glucose (FBS), there were differences in numbers and mean figures for those participants who were either overweight or obese than controls but these did not have statistical significance. This implies that hyperinsulinemia is usually an early compensatory phenomenon which succeeds in maintaining the level of fasting glucose relatively normal despite having insulin resistance during childhood and adolescent years. Consequently, the lack of statistical significance in relation to FBS should be viewed with caution due to the fact that metabolic changes at the hormonal level (such as increased insulin and leptin) come before the abnormalities in FBS (Luo et al., 2024).

Likewise, the evaluation of the lipid profile parameters (total cholesterol, triglycerides, HDL-C, LDL-C, and VLDL-C) reflected the numerical increase in the values of the overweight and obese children (as seen in the increased values of LDL-C and triglycerides), which, however, did not attain statistical significance. While obesity has been acknowledged throughout the globe to result in atherogenic lipid profile, the variation in lipid parameters in children can be attributed to various factors such as their dietary intake, physical activities, genetic makeup, and the dynamic nature of growth. This lack of statistical difference in lipids among our study population could be due to the gradual development of abnormalities in lipids or a need for a larger sample size in order to attain statistical significance, considering the fact that hormonal alterations such as those of insulin and leptin are usually observed before lipid and glucose abnormalities in pediatric obesity (Vekic et al., 2024).

All in all, the results from the present study have shown that childhood obesity and overweight in the studied local population have been found to be highly correlated with high levels of leptin and insulin in the bloodstream, while changes in fasting glucose levels and lipids have been shown only in numeric trends, not in statistically significant differences.

7. Conclusion and Recommendations

7.1 Conclusion

In summary, this cross-sectional study has revealed that obesity and overweight in children and adolescents in Samawah city, Muthanna province, is linked to significant changes in several important hormonal biomarkers, especially high serum levels of leptin and insulin. Although there were increased levels of fasting blood glucose and lipid profile markers in those participants who had excess body weight, these differences were not statistically significant, indicating that hormonal abnormalities such as hyperinsulinemia and hyperleptinemia precede the presence of dysglycemia and dislipidemia at an early stage of life.

7.2 Recommendations

1. Early Screening and Monitoring: Routine screening for overweight and obesity among children must consider the measurement of insulin and leptin levels in the serum, because these parameters function as sensitive markers for the identification of metabolic stress before any changes in glucose or lipids are observed.
2. Public Health Interventions: The local public health organizations within the Al-Muthanna province need to develop targeted educational programs to encourage healthy dietary and exercise practices amongst children and adolescents.
3. Further Research: It is recommended that future research should include large longitudinal studies with a greater focus on pubertal development status.

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