

Body fat distribution and Its Association with Adipocytes and Cytokines among Adolescent School Children in Tirupati District, India

Adiposity, Adipokines, and Cytokines in Adolescents

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Highlights:

- Elevated BMI in adolescents is associated with increased pro-inflammatory markers.
- Anti-inflammatory markers like adiponectin and IL-10 decrease with higher BMI.
- Early metabolic inflammation is observable even in normal-weight adolescents with high fat distribution.

Abstract

Background: Body fat distribution is an indicator of adiposity and a predictor of metabolic risk in addition to altered adipokine and cytokine secretion.

Objective: To investigate the association between Body fat distribution and circulating adipokines and cytokines among the adolescents in Tirupati, India.

Methods: A cross-sectional study was conducted among 887 adolescents (442 boys and 445 girls) aged 12–16 years. Anthropometric measures including BMI, waist-to-hip ratio (WHR), and total fat were measured, calculated and categorized according to WHO growth references. Fasting blood samples were analyzed for leptin, adiponectin, ghrelin, obestatin, TNF- α , IL-6, IL-10, and C-reactive protein (CRP) using ELISA. Statistical analyses included ANOVA, independent t-tests, and correlation analyses to assess associations between adiposity markers and adipokine/cytokine levels.

Results: Girls had significantly higher total body fat and leptin levels than boys ($p < 0.05$), whereas boys exhibited greater muscle mass ($p < 0.001$). Leptin, obestatin, TNF- α , IL-6, and CRP increased with higher BMI, WHR, and total fat, while ghrelin, adiponectin, and IL-10 decreased ($p < 0.001$). Strong positive correlations were observed between adiposity markers and pro-inflammatory cytokines, whereas negative correlations were noted with anti-inflammatory cytokines.

Conclusion: Overweight and obese adolescents exhibited significantly altered adipokine and cytokine profiles compared to normal-weight peers, suggesting early subclinical inflammation. The observed

alterations in leptin, ghrelin, adiponectin, and inflammatory markers within the categories of body fat distribution underscore the early onset of metabolic inflammation in youth.

Keywords: Adipokines; Cytokines; BMI; Adolescents; Obesity; Inflammation; India

Abbreviations: BMI, Body Mass Index; CRP, C-Reactive Protein; FBG, Fasting Blood Glucose; HC, Hip Circumference; HDL-C, High-Density Lipoprotein Cholesterol; IL-6, Interleukin-6; IL-10, Interleukin-10; LDL-C, Low-Density Lipoprotein Cholesterol; RTE Foods, Ready-to-Eat Foods.

1. Introduction:

Over the past few decades, the prevalence of overweight and obesity among children and adolescents has risen globally, posing significant public health challenges (Anuradha et al., 2015). The prevalence of overweight and obesity among children and adolescents aged 5–19 years has increased dramatically from 4% in 1975 to over 18% in 2016, according to WHO estimates, reflecting a near fourfold rise. In India, recent studies report that 19–20% of adolescents are either overweight or obese, with higher rates observed in urban areas compared to rural counterparts (Anuradha et al., 2015). Research reports highlight that excess adiposity during adolescence may be linked to early onset of metabolic abnormalities, insulin resistance, cardiovascular risk, and systemic low-grade inflammation. Adipose tissue is recognized as an active endocrine organ that secretes a variety of bioactive molecules collectively called adipokines, including leptin, adiponectin, resistin, visfatin, and others, which modulate energy balance, glucose homeostasis, lipid metabolism, and inflammatory pathways (Leoni et al., 2010). In obesity, the secretory profile of adipose tissue shifts toward a pro-inflammatory state, with increased expression of cytokines such as tumor necrosis factor- α (TNF- α) and interleukin-6 (IL-6) and suppressed production of anti-inflammatory factors like adiponectin (Ellulu et al., 2016).

A growing body of evidence indicates that altered adipokine and cytokine levels are observable with increasing body mass index (BMI), highlighting the interplay between adiposity and systemic inflammation. As adipose tissue expands, its endocrine function becomes dysregulated, leading to changes in the secretion of several bioactive molecules that influence metabolic and vascular health. Among these, leptin and adiponectin are key regulators of energy balance and insulin sensitivity. An increased level of leptin coupled with a decrease in adiponectin concentration has been reported in obese individuals, contributing to insulin resistance, endothelial dysfunction, and impaired glucose metabolism (Gherlan et al., 2012). These hormonal alterations reflect a pro-inflammatory milieu that favors the development of metabolic complications. Furthermore, cross-sectional studies in overweight and obese youth have consistently documented significant associations between elevated inflammatory markers, such as C-reactive protein (CRP) and interleukin-6 (IL-6), and metabolic derangements, including dyslipidemia and glucose intolerance (Cura-Esquivel et al., 2023). Collectively, these findings underscore the importance of understanding the interrelationship between adiposity, adipokine imbalance, and low-grade inflammation during adolescence, a critical period for the early development of metabolic and cardiovascular risk. In the light of this background, the present study aimed to examine the relation of fat markers with serum adipocytes and cytokines in adolescent school children of Tirupati.

2. Method:

Study Population and Design

A prospective observational study in a cross-sectional design was undertaken among school-going adolescents aged 12 to 16 years in Tirupati District of Andhra Pradesh, India, and assessed social, lifestyle, anthropometric, clinical, and biochemical parameters, including adipokines and cytokines.

Sampling Technique

According to the District Educational Office (Tirupati), 59,376 adolescents in the target age range were enrolled in schools during the study period. A multistage random sampling technique was applied in the selection of subjects. As per the municipal administration, Tirupati was divided into 50 municipal wards. From this, eight wards were randomly selected using a lottery method. In each ward, two schools (government /private) were chosen at random. Probability Proportionate to Size (PPS) sampling was then employed to select children from each school, ensuring proportional representation across the study population.

Sample Size Estimation

The minimum required sample size was calculated using 95% confidence level with a 3% margin of error yielded a sample size of 544, which was rounded to 550 to ensure adequate statistical power. However, to enhance the representativeness of biochemical data and allow stratified subgroup analysis, 887 adolescents (442 boys and 445 girls) were ultimately enrolled and analyzed.

The study protocol received ethical approval from the Departmental Ethics Committee, Department of Anthropology, Sri Venkateswara University, Tirupati (Ref: SVU/DA/07-2020, dated 23rd May 2020). Written informed consent was obtained from parents or legal guardians after briefing them about the study objectives via school authorities. In addition, oral assents were also obtained from each participating child. Adolescents with known congenital abnormalities, metabolic disorders, or chronic illnesses, and those with irregular school attendance were excluded.

Data collection

A structured schedule was designed with prior validation through pilot study. The questionnaire consisted of information on the demographics, education, occupation and socioeconomic conditions of the parents. Parental education, occupation and income were recorded through their public distribution cards. Further children's self-reported sleep patterns, physical activity, video watching and eating habits were procured. Parents were randomly cross checked to ascertain the self-reported information provided by the child.

Information on subjects age, sex, religion, caste, area of living, family type, family size, parental education, occupation, socioeconomic condition, sleep patterns, stress, physical activity, water consumption & self-reported health were recorded. The children's age was documented using school records. Parental education was categorised in to higher education, secondary education, primary education and illiterates; Occupation as working and non-working; Annual income as low (<INR1Lakh), lower middle (INR1-3 Lakhs), middle(INR3-10 Lakhs), upper middle (INR10 to 20 Lakhs) and high income(>INR20 Lakhs) and area of living as urban and rural; family type as nuclear, joint, extended and single parent family. Self-reported health information was recorded as good, fair and poor. Physical

activity was graded as sedentary, moderate and heavy work based on the detailed activity both in school and at home. Sleep patterns and Video or TV watching was recorded based on the time duration. Eating of various fast foods was graded based on their consumption pattern. Children were asked about the type of sleep they have, such as sound or disturbed and duration of the sleep at night and in the daytime to calculate the amount of sleep (<7 hours, 7-9 hours & >9 hours). Smoking and Alcoholism: None of the children were smokers, alcoholics and with chewing habits

Anthropometry measurements were recorded through standard techniques (Weiner and Lourie, 1981). Height, waist circumference and hip circumference was measured using the measuring tape. WHR was calculated as waist circumference by hip circumference and WHtR as waist circumference by height of the sample. Weight, Body mass Index (BMI), percent total fat, percent fat in legs, arms, trunk & percent total muscle, percent muscle in legs, arms, trunk and resting metabolism were recorded using the Omron digital karada scan body composition monitor. All the measurements were taken twice on the subject with a gap of 5 min and the average was taken for the analysis. Overweight and obesity was considered as BMI above the 85th and 95th percentiles respectively as specified for age and sex by Centre for Disease Control and Prevention (CDC) 2000 (Gonzalez-Casanova et al., 2013). Further, the levels of WHR and Total fat above 95th percentile for age and sex were considered as abdominal obesity and elevated fat.

5 ml of fasting venous blood sample was procured and serum was separated upon collection. Serum levels of leptin, ghrelin, obestatin, adiponectin, TNF-alpha, IL-6, IL-10, C reactive protein was measured as per the manufacturer's protocol by using standard diagnostic kits.

Statistical Analysis

The data was coded and statistical analysis was carried out through SPSS version 16.0. Alpha levels were set at 0.05 as statistical significant. Continuous variables were provided with descriptive statistics and discontinuous variables with percentages. Chi square test was used to see the differences in the prevalence rates between groups. Students't' test was applied to see the difference between genders. One way analysis of variance was used to see the difference in descriptives across the categories of BMI, WHR and Total fat. Dunnett multiple comparison test was performed to see the mean changes across the categories of body mass index. Bivariate correlation coefficients were calculated for adipocytes and cytokines with body fat distribution markers.

3. Results

The socio-economic and lifestyle characteristics of adolescents were presented in Table 1. In the present study, majority of the sample population were from urban environment (85.2%). Father's education level differed significantly between boys and girls ($p < 0.05$). Overall, the parental illiteracy level was found to be around one percent only. Boys were more likely to report fathers with secondary education, while girls reported primary-level education. Household income varied by sex ($p < 0.05$), with a higher proportion of girls belonging to lower-middle-income families. Sleep duration differed significantly between genders ($p < 0.05$), as majority of the adolescent children sleep falls between 7-9 hours.

Anthropometric measurements were detailed in Table 2. Girls had significantly higher waist circumference, hip circumference, waist-to-height ratio, and total body fat, particularly elevated fat deposition in legs and arms. Conversely, boys had significantly higher muscle mass across all regions.

Data on Adipocytes and Cytokines of the Adolescents was shown in table 3. Leptin levels were significantly higher in girls than boys ($p = 0.027$). No significant sex differences were observed for ghrelin, obestatin, adiponectin, TNF- α , IL-6, IL-10, or CRP ($p > 0.05$).

Data on CHD risk factors prevalence among Adolescent boys and girls was shown in table 4. In the present sample, 8.8% of adolescents were overweight and 3.6% were obese, with no significant sex differences. Waist-to-hip ratio above the 95th percentile was more prevalent in boys (11.4%) than girls (6.5%, $p = 0.011$), while high total fat (>95th percentile) was more prevalent in girls (7.0%) compared to boys (3.2%, $p = 0.012$), with overall prevalence rates of 8.9% & 5.2% respectively.

The increase or decrease in the selected markers of adipocytes and cytokines within the categories of body mass index, WHR and Total fat were found to be significant ($p=0.001$). Table 5 presents the comparison of adipokine and cytokine levels across BMI categories (Normal, Overweight, and Obese) among adolescent boys and girls. Leptin levels increased progressively from normal weight to obesity, with mean differences of +9.78 ng/mL and +16.21 ng/mL in boys, and +10.72 ng/mL and +13.25 ng/mL in girls, indicating a strong positive association between adiposity and leptin secretion. In contrast, ghrelin and adiponectin levels decreased significantly with higher BMI, reflecting a negative correlation with increasing body fat. Obestatin, TNF- α , IL-6, and CRP levels were markedly elevated in overweight and obese adolescents compared to their normal-weight peers, whereas IL-10, an anti-inflammatory cytokine, decreased with increasing BMI. Adolescents with WHR >95th percentile had higher leptin, obestatin, IL-6, TNF- α , and CRP and lower ghrelin, adiponectin, and IL-10 compared to those with WHR <95th percentile. The mean difference in leptin level among the Boys and girls with WHR was found to be 7.49 ng/mL & 5.48ng/mL respectively.

Total fat >95th percentile was also associated with elevated leptin, obestatin, TNF- α , IL-6, and CRP and reduced ghrelin, adiponectin, and IL-10. In boys, leptin increased from 5.83 ± 5.21 ng/mL (<95th percentile) to 12.66 ± 7.28 ng/mL (>95th percentile), while in girls, from 6.14 ± 4.40 ng/mL to 16.47 ± 5.23 ng/mL.

Correlation co-efficients of adipocytes and cytokines with fat markers were detailed in table 6. Strong positive correlations were observed between BMI, WHR, and total fat with leptin, obestatin, IL-6, TNF- α , and CRP, while ghrelin, adiponectin, and IL-10 showed significant negative correlations ($p < 0.05$).

4. Discussion

This study highlights significant gender differences in anthropometry, body composition, and leptin level among adolescents, with implications for early cardiometabolic risk assessment. Girls exhibited higher BMI, waist and hip circumferences, and body fat percentages across all regions, whereas boys had higher lean body and regional muscle mass. These findings are consistent with previous research demonstrating that females accumulate more subcutaneous and total fat during adolescence, whereas males develop greater muscle mass due to androgenic influences and higher levels of physical activity (Daniels et al., 2019). The increased leptin levels in girls compared to boys, which aligns with prior studies linking leptin concentrations to adiposity and hormonal status during puberty (Maffeis et al., 2010). Thus,

sex-specific differences in body composition underscore the need for tailored interventions addressing obesity and metabolic health in adolescents.

In contrast, no significant gender differences were observed for ghrelin, obestatin, adiponectin, TNF-alpha, IL-6, IL-10, or CRP, suggesting that these biomarkers may be more sensitive to overall adiposity rather than sex at this developmental stage. Previous studies have reported similar findings, indicating that adiponectin and anti-inflammatory cytokines are inversely associated with fat mass, regardless of sex (Spranger et al., 2003; Oda et al., 2008). Analysis of cardiometabolic risk factors revealed that boys had a higher prevalence of elevated waist-to-hip ratios, whereas girls exhibited greater total body fat above the 95th percentile. This is consistent with other adolescent cohorts, which show sex-specific patterns in fat distribution, with boys accumulating more central fat and girls more peripheral and total fat (Lee et al., 2012).

Analysis of cardiometabolic risk factors revealed sex-specific differences in fat distribution among adolescents. In the present study, 10.4% of boys and 7.2% of girls were classified as overweight, while 4.5% of boys and 2.7% of girls were obese, with underweight prevalence of 4.8% in boys and 5.6% in girls, indicating no significant difference in BMI categories between sexes ($p=0.141$). However, measures of fat distribution showed sex-specific patterns. 11.4% of boys had elevated waist-to-hip ratios (WHR >95th percentile) compared to 6.5% of girls, reflecting higher central adiposity in boys, whereas 7.0% of girls had total body fat above the 95th percentile compared to 3.2% of boys, indicating greater overall fat accumulation in girls. These findings are consistent with previous research. Lee et al. (2012) reported that adolescent boys tend to accumulate more central fat, whereas girls accumulate more peripheral and total fat. Similarly, Choudhary et al. (2025) observed a higher prevalence of elevated WHR among Indian adolescent boys, and Nguyen et al. (2019) reported a greater proportion of girls with total body fat above the 95th percentile in a multi-ethnic adolescent cohort. Collectively, these results emphasize the importance of considering sex-specific fat distribution patterns, beyond BMI alone, when assessing cardiometabolic risk factors in adolescents.

Biomarker patterns across BMI, waist-to-hip ratio, and total fat besides correlation coefficients demonstrated that leptin, obestatin, IL-6, and CRP increased with higher adiposity, whereas ghrelin, adiponectin, and IL-10 decreased. These differences were statistically significant ($p < 0.001$) for all measured biomarkers, highlighting a shift toward a pro-inflammatory and metabolically dysregulated state in adolescents with higher BMI. Notably, the magnitude of change was often greater in boys for leptin and IL-6, whereas girls showed a higher absolute increase in total fat-associated leptin levels, suggesting sex-specific variations in adipokine response to adiposity. The observed mean differences, such as a 6.83 ng/mL increase in leptin for boys and a 10.33 ng/mL increase in girls for total fat >95th percentile, underscore the influence of both regional and total adiposity on inflammatory and metabolic biomarkers.

Overall, these findings reinforce the concept that central and total adiposity independently contribute to adverse adipokine and cytokine profiles during adolescence, emphasizing the importance of early identification and intervention. Leptin and obestatin levels were significantly higher in adolescents exceeding the 95th percentile for WHR and total fat, whereas ghrelin and adiponectin levels were notably lower, indicating that both central and overall adiposity are associated with endocrine and metabolic alterations. Pro-inflammatory markers, including TNF- α , IL-6, and CRP, were elevated in the >95th

percentile groups, while IL-10 levels were reduced, reflecting a pronounced shift toward a pro-inflammatory profile. These trends corroborate earlier evidences linking adiposity with pro-inflammatory and anti-inflammatory signaling imbalance in youth, reflecting early pathophysiological processes that may predispose to cardiovascular disease later in life (Reinehr, 2011; Ahima & Flier, 2000).

In summary, our study demonstrates that sex-specific differences in body composition and adipokine profiles emerge during adolescence and are closely linked to early markers of cardiovascular risk. Monitoring these parameters can inform targeted preventive strategies, emphasizing the importance of lifestyle interventions, including physical activity and nutrition, to mitigate future metabolic and cardiovascular disorders.

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Conflict of interest statement

The authors declare that they have no conflicts of interest, financial or otherwise, that could inappropriately influence the outcome or content of this article.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. Due to the sensitive nature of information related to human participants, the data is not publicly available.

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Ethics Approval:

Ethical approval was obtained from the Institutional Ethics Committee of Sri Venkateswara University, Tirupati, India, (SVU/DA/07-2020).

Consent to Participate:

Written informed consent was obtained from all participants and their parents/guardians prior to inclusion in the study.

Competing Interests:

The authors declare that they have no competing interests.

Authors' Contributions:

Sangaraju Manisha conceptualized the study, collected and analyzed the data, and prepared the manuscript.

Prof. R.K. Anuradha supervised the study design, interpretation and final approval.

Prof. Kanala Kodanda Reddy provided biochemical expertise, critical revisions, and final approval.

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Tables:

Table 1. Demographics of the Study Sample

S.No	Variable	Boys		Girls		Total		p-value*
		N	%	N	%	N	%	
1	Habitation							0.27
	Urban	371	83.90	385	86.50	756	85.20	
	Rural	71	16.10	60	13.50	131	14.80	
	Total	442	100.00	445	100.00	887	100.00	
3	Father's Education							0.01
	Higher	29	6.80	33	7.90	62	7.30	
	Secondary	195	45.60	146	34.90	341	40.30	
	Primary	199	46.50	233	55.70	432	51.10	
	Illiterate	5	1.20	6	1.40	11	1.30	
	Total	428	100.00	418	100.00	846	100.00	
4	Mother's Education							0.92
	Higher	28	6.40	24	5.50	52	5.90	
	Secondary	149	33.90	147	33.40	296	33.60	
	Primary	259	58.90	264	60.00	523	59.40	
	Illiterate	4	0.90	5	1.10	9	1.00	
	Total	440	100.00	440	100.00	880	100.00	
5	Annual Income in INR							0.03
	Low	90	20.40	108	24.40	198	22.40	
	Lower middle	212	48.00	232	52.50	444	50.20	
	Upper middle	109	24.70	79	17.90	188	21.30	
	High	31	7.00	23	5.20	54	6.10	
	Total	442	100.00	442	100.00	884	100.00	
6	Physical Activity							0.09
	Sedentary	44	10.00	38	8.50	82	9.20	
	Moderate	394	89.10	407	91.50	801	90.30	
	Heavy	4	0.90	0	0.00	4	0.50	
	Total	442	100.00	445	100.00	887	100.00	
7	Self-Reported Health							0.47
	Good	368	83.30	383	86.10	751	84.70	
	Fair	66	14.90	54	12.10	120	13.50	
	Poor	8	1.80	8	1.80	16	1.80	

	Total	442	100.00	445	100.00	887	100.00	
8	Sleep Duration							0.02
	< 7 hours	21	4.80	35	7.90	56	6.30	
	7-9 hours	394	89.10	369	82.90	763	86.00	
	> 9 hours	27	6.10	41	9.20	68	7.70	
	Total	442	100.00	445	100.00	887	100.00	

***Chi-square test**

Table 2. Data on Anthropometric Variables of the Adolescents

S.No	Variable	Gender	N	Mean	S. D	p- value*
1	Age in years	Boys	442	13.92	1.24	0.37
		Girls	445	13.84	1.23	
2	Body Mass Index kg/m ²	Boys	442	19.27	4.36	0.53
		Girls	445	19.82	4.02	
3	Waist Circumference cm	Boys	440	71.84	10.99	0.01
		Girls	445	74.24	10.61	
4	Hip Circumference cm	Boys	440	81.08	11.08	0.00
		Girls	445	83.99	11.43	
5	Waist to Hip Ratio	Boys	440	0.88	0.03	0.49
		Girls	445	0.88	0.03	
6	Waist to Height Ratio	Boys	440	0.45	0.07	0.00
		Girls	445	0.48	0.07	
7	Percent whole body fat	Boys	394	13.27	5.49	0.00
		Girls	443	20.37	4.83	
8	Percent fat in trunk	Boys	356	11.9	4.81	0.00
		Girls	443	16.08	4.86	
9	Percent fat in legs	Boys	411	20.05	8.88	0.00
		Girls	443	33.36	7.15	
10	Percent fat in arms	Boys	411	20.68	8.18	0.00
		Girls	442	36.14	5.77	
11	Total fat	Boys	409	18.4	6.82	0.00
		Girls	443	23.64	4.63	
12	Percent whole body muscle	Boys	435	36.11	4.63	0.00
		Girls	443	27.53	2.33	
13	Percent muscle in trunk	Boys	409	29.61	4.81	0.00
		Girls	443	23.37	2.69	
14	Percent muscle in legs	Boys	435	53.15	5.06	0.00
		Girls	443	38.45	2.61	
15	Percent muscle in arms	Boys	435	42.62	4.02	0.00
		Girls	442	32.47	4.41	

*** Independent t- test**

Table 3. Data on Adipocytes and Cytokines of the Adolescents

S.No	Variable	Gender	N	Mean	S. D	p- value*
1	Leptin ng/dl	Boys	241	5.83	5.31	0.027
		Girls	243	6.89	5.22	
2	Ghrelin ng/dl	Boys	241	6.92	3.22	0.618
		Girls	242	6.76	3.80	
3	Obestatin ng/dl	Boys	241	2.91	2.49	0.137
		Girls	242	3.23	2.21	
4	Adiponectin micrograms/dl	Boys	241	4.85	2.25	0.819
		Girls	242	4.81	2.33	
5	Tumor necrosis factor alpha pg/ml	Boys	241	2.42	0.82	0.145
		Girls	237	2.32	0.80	
6	Interleukin-6 pg/ml	Boys	239	1.72	1.10	0.317
		Girls	240	1.84	1.32	
7	Interleukin-10 pg/ml	Boys	241	4.23	1.12	0.668
		Girls	241	4.19	1.16	
8	C-reactive protein mg/L	Boys	241	2.81	1.79	0.505
		Girls	236	2.91	1.69	

* Independent t- test

Table 4. Data on CHD risk factors prevalence among the Adolescents boys and girls.

S.No	Variable	Gender of the subject						P-value*
		Boys		Girls		Total		
		N	%	N	%	N	%	
1	Body Mass Index							0.141
	Overweight	46	10.4	32	7.2	78	8.8	
	Obese	20	4.5	12	2.7	32	3.6	
	Under Weight	21	4.8	25	5.6	46	5.2	
2	Waist-Hip Ratio							0.011
	<95 th percentile	390	88.6	416	93.5	806	91.9	
	>95 th percentile	50	11.4	29	6.5	79	8.9	
3	Total Fat							0.012
	<95 th percentile	396	96.8	412	93.0	808	94.8	
	>95 th percentile	13	3.2	31	7.0	44	5.2	

*Chi-square test

Table 5. Mean values of Adipocytes and Cytokines with Risk Factors Classification

Variable	Sex	Body mass index				WHR			Total Fat		
		Normal	Overweight	Obese	p-value*	<95 th	>95 th	p-value@	<95 th	>95 th	p-value@

Leptin	Boys	3.97±2.28	13.75±4.61 ^a	20.18±3.01 ^{bc}	0.001	5.06±4.39	12.55±7.62	-7.35*	5.83±5.21	12.66±7.28	0.001
	Girls	5.66±3.47	16.38±4.22 ^a	18.91±3.10 ^c	0.001	6.46±4.77	11.94±7.46	-4.56*	6.14±4.40	16.47±5.23	0.001
Ghrelin	Boys	7.68±2.65	3.10±2.56 ^a	1.65±2.48 ^c	0.001	7.26±2.99	3.89±3.69	5.18*	6.91±3.21	3.63±3.61	0.001
	Girls	7.32±3.41	1.97±1.08 ^a	0.85±0.21 ^{bc}	0.001	7.00±3.73	3.88±3.47	3.50*	7.13±3.59	1.63±1.43	0.001
Obestatin	Boys	2.14±1.46	6.20±2.19 ^a	9.00±1.65 ^{bc}	0.001	2.57±2.13	5.90±3.29	-6.91*	2.90±2.38	6.37±4.32	0.001
	Girls	2.77±1.73	6.98±0.96 ^a	7.34±0.92 ^c	0.001	3.06±2.10	5.12±2.52	-4.02*	2.94±1.97	6.89±1.52	0.001
Adiponectin	Boys	5.48±1.75	1.50±0.74 ^a	0.91±0.24 ^{bc}	0.001	5.19±2.08	2.10±1.72	7.12*	4.86±2.07	2.23±1.61	0.001
	Girls	5.24±2.03	1.34±0.43 ^a	0.85±0.21 ^{bc}	0.001	4.95±2.25	3.04±2.48	3.51*	5.08±2.16	1.21±0.79	0.001
TNF-alpha	Boys	2.38±0.83	2.86±0.59 ^a	2.58±0.63	0.001	2.37±0.81	2.79±0.79	-2.42*	2.43±0.82	2.33±0.65	0.06
	Girls	2.27±0.79	2.77±0.68 ^a	2.75±1.01	0.001	2.29±0.78	2.59±0.98	-1.54	2.27±0.77	2.79±0.98	0.001
Interleukin 6	Boys	1.34±0.59	3.51±0.81 ^a	4.20±0.56 ^{bc}	0.001	1.55±0.95	3.15±1.22	-7.71*	1.70±1.07	3.01±1.62	0.001
	Girls	1.54±1.02	3.81±1.99 ^a	4.59±0.65 ^c	0.001	1.75±1.26	2.81±1.56	-3.43*	1.65±1.13	4.26±1.21	0.001
Interleukin 10	Boys	4.53±0.77	2.51±0.43 ^a	2.06±0.10 ^{bc}	0.001	4.40±1.01	2.72±0.84	7.99*	4.19±1.07	2.84±1.15	0.001
	Girls	4.37±0.97	2.63±0.67 ^a	2.05±0.11 ^{bc}	0.001	4.26±1.12	3.21±1.14	3.79*	4.33±1.04	2.29±0.59	0.001
CRP	Boys	2.32±1.33	5.23±0.95 ^a	6.35±0.65 ^{bc}	0.001	2.52±1.61	5.10±1.56	-7.58*	2.84±1.73	4.84±2.27	0.001
	Girls	2.55±1.30	5.51±1.06 ^a	6.54±0.43 ^{bc}	0.001	2.78±1.61	4.47±1.90	-4.20*	2.65±1.44	6.11±1.03	0.001

Variable	BMI		WHR		Total Fat	
	Boys	Girls	Boys	Girls	Boys	Girls
Leptin	0.846*	0.897*	0.350*	0.160*	0.509*	0.705*
Ghrelin	-0.661*	-0.685*	-0.235*	-0.148*	-0.377*	-0.622*
Obestatin	0.801*	0.880*	0.312*	0.162*	0.453*	0.736*
Adiponectin	-0.874*	-0.846*	-0.392*	-0.157*	-0.621*	-0.737*
TNF-alpha	0.271*	0.299*	0.182*	0.095	0.156*	0.312*
Interleukin-6	0.780*	0.746*	0.324*	0.163*	0.499*	0.590*
Interleukin-10	-0.898*	-0.915*	-0.410*	-0.130*	-0.567*	-0.810*
C-Reactive Protein	0.896*	0.934*	0.420*	0.172*	0.561*	0.804*

*ANOVA

@ Independent t- test

a=Dunnnett-c multiple comparison between Normal weight to Overweight

b= Dunnnett-c multiple comparison between Overweight to Obese

c= Dunnnett-c multiple comparison between Normal weight to Obese

Table 6. Correlation co-efficients of adipocytes and cytokines with fat markers

(*p<0.05)