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PREVALENCE AND GENDER-REGIONAL FEATURES OF METABOLIC SYNDROME COMPONENTS IN ADOLESCENTS

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ANNOTATION

Purpose of the study. *To assess the prevalence and structure of metabolic syndrome components among adolescents and to identify gender and regional differences in their distribution.*

Material and methods. *The study included 2000 adolescents aged 10-19 years from urban and rural areas of Tajikistan. Anthropometric parameters (BMI, waist circumference), arterial blood pressure, and biochemical indicators (fasting glucose, triglycerides, HDL cholesterol, total cholesterol) were evaluated. The diagnosis of metabolic syndrome was established according to the IDF (2007) criteria. Statistical analysis was performed using the chi-square test (χ^2), Student's t-test, and correlation analysis ($p < 0.05$).*

Research results. *Abdominal obesity was detected in 28.4% of adolescents, and metabolic syndrome was diagnosed in 14.7% of those with obesity. The most frequent components were decreased HDL cholesterol (33.4%) and elevated triglycerides (26.8%), followed by elevated blood pressure (28.4%) and hyperglycemia (13.5%). Boys showed a higher, though not statistically significant, prevalence of all components compared to girls. Urban adolescents had significantly higher rates of elevated blood pressure (32.5% vs. 22.1%; $p = 0.042$). Correlation analysis revealed positive associations between BMI and systolic blood pressure ($r = +0.41$; $p < 0.001$), as well as waist circumference and diastolic pressure ($r = +0.37$; $p = 0.002$).*

Conclusions. *Abdominal obesity in adolescents is closely associated with multiple metabolic disturbances, including hypertension, hypertriglyceridemia, and low HDL cholesterol. Urban lifestyle and male gender tend to increase the risk of metabolic syndrome components. Early screening and targeted preventive programs are essential for reducing future cardiovascular and metabolic risks.*

KEYWORDS. *Adolescents, Metabolic Syndrome, Abdominal Obesity, Triglycerides, HDL Cholesterol, Blood Pressure, Gender Differences, Urbanization, Cardiovascular Risk.*

TOPICALITY

Metabolic syndrome (MS) represents one of the most significant global health challenges of the 21st century, as its early manifestations often begin in adolescence. The increasing prevalence of obesity, particularly abdominal obesity, among young people contributes to the early development of hypertension, dyslipidemia, and impaired glucose metabolism, which are the main components of MS. These changes form the basis for future cardiovascular and endocrine diseases in adulthood [1-5].

In recent years, epidemiological data have shown a steady increase in metabolic disorders among adolescents, largely due to reduced physical activity, high-calorie diets, and urban lifestyle factors. However, regional and gender differences in the prevalence and structure of MS components remain insufficiently studied, especially in Central Asian populations, where environmental, nutritional, and socioeconomic factors differ significantly from those of Western countries [6-11].

The present study is highly relevant, as it provides new insights into the prevalence and characteristics of metabolic syndrome among adolescents in Tajikistan. Identifying gender and regional patterns of metabolic disorders will allow for the development of targeted preventive and educational programs aimed at reducing the burden of cardiovascular and metabolic diseases in the future generation.

PURPOSE OF THE STUDY

To assess the prevalence and structure of metabolic syndrome components among adolescents and to identify gender and regional differences in their distribution.

RESEARCH MATERIALS AND METHODS

The study included 2000 adolescents aged 10-19 years from both urban (n = 1080) and rural (n = 920) areas of Tajikistan. Participants were selected through school-based health screening programs conducted according to WHO (2007) and IDF (2007) criteria for metabolic syndrome assessment.Anthropometric measurements included body mass index (BMI) and waist circumference (WC), which were used to identify abdominal obesity. Arterial blood pressure (BP) was measured twice in a seated position using a validated automatic sphygmomanometer, and the average value was recorded.Biochemical testing was performed

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under fasting conditions. The following parameters were determined: fasting plasma glucose (mmol/L), triglycerides (TG, mmol/L), high-density lipoprotein cholesterol (HDL-C, mmol/L), and total cholesterol (mmol/L). Blood sampling was conducted in the morning after at least 10 hours of fasting. The diagnosis of metabolic syndrome was established according to the International Diabetes Federation (IDF, 2007) criteria, requiring the presence of abdominal obesity (WC ≥ 90th percentile) plus two or more of the following: elevated BP (≥130/85 mmHg), fasting glucose ≥ 5.6 mmol/L, TG ≥ 1.7 mmol/L, and reduced HDL-C (<1.03 mmol/L for boys, <1.29 mmol/L for girls). Statistical analysis was carried out using SPSS 13.0 software. Quantitative data were expressed as M ± m (mean ± standard error). Differences between groups were analyzed using Student's t-test for continuous variables and the chi-square test (χ^2) for categorical variables. Correlation analysis was applied to determine the relationship between anthropometric and hemodynamic indicators. Statistical significance was set at $p < 0.05$.

RESEARCH RESULTS

Prevalence of Metabolic Syndrome Components

Against the background of abdominal obesity, the following metabolic abnormalities were identified: elevated blood pressure (≥130/85 mmHg) in 28.4% (n = 162) of adolescents with abdominal obesity ($p < 0.001$); fasting hyperglycemia (glucose ≥5.6 mmol/L) in 13.5% (n = 77); elevated triglycerides (≥1.7 mmol/L) in 26.8% (n = 152); and reduced HDL cholesterol in 33.4% (n = 190). According to the IDF (2007) criteria, the diagnosis of metabolic syndrome was established in 14.7% (n = 84) of adolescents with obesity. (Table 1).

Table 1

Components of Metabolic Syndrome in Adolescents with Abdominal Obesity

MS Component	Prevalence (%)	M ± m	[25%; 75%]	[Min; Max]	p-value
Elevated blood pressure (≥130/85 mmHg)	28.4	138.2 ± 1.5 mmHg	[133; 143]	[130; 158]	< 0.001
Fasting hyperglycemia (glucose ≥5.6 mmol/L)	13.5	6.2 ± 0.2 mmol/L	[5.8; 6.5]	[5.6; 7.4]	-
Elevated triglycerides (≥1.7 mmol/L)	26.8	2.3 ± 0.1 mmol/L	[1.8; 2.7]	[1.7; 4.1]	-
Reduced HDL cholesterol (<1.03/1.29 mmol/L)	33.4	0.88 ± 0.05 mmol/L	[0.75; 1.05]	[0.45; 1.20]	-
Metabolic syndrome diagnosis (≥3 components, IDF 2007)	14.7	3.2 ± 0.1 disorders	[3; 4]	[3; 5]	-

Note: Values of *M* ± *m* are presented for the main biochemical and clinical parameters. Statistical significance is indicated for elevated blood pressure (χ^2-test, $p < 0.001$).

In the group of adolescents with abdominal obesity (n = 568) (Table 1), elevated blood pressure (≥130/85 mmHg) was observed in 28.4% (n = 162) of participants compared to 18.7% in the overall sample ($p < 0.001$). The mean systolic blood pressure in this group was 138.2 ± 1.5 mmHg (IQR 133-143; [130; 158]), indicating a markedly increased cardiovascular load among young individuals with visceral fat accumulation. Fasting hyperglycemia (glucose ≥5.6 mmol/L) was detected in 13.5% (n = 77) of adolescents with abdominal obesity, which was slightly higher than 11.9% in the general sample, although this difference did not reach statistical significance in the present analysis. The mean glucose level in this subgroup was 6.2 ± 0.2 mmol/L (IQR 5.8–6.5; [5.6; 7.4]). Elevated triglycerides (≥1.7 mmol/L) were identified in 26.8% (n = 152) of participants, whereas the overall prevalence of dyslipidemia in the total population was 21.3%. The mean triglyceride level among adolescents with abdominal obesity was 2.3 ± 0.1 mmol/L (IQR 1.8–2.7; [1.7; 4.1]), indicating a pronounced disturbance in lipid metabolism. Reduced HDL cholesterol (<1.03/1.29 mmol/L) was found in 33.4% (n = 190) of adolescents with abdominal obesity, nearly 1.5 times higher than the general prevalence of low HDL (21.3%). The mean HDL level in this group was 0.88 ± 0.05 mmol/L (IQR 0.75-1.05; [0.45; 1.20]). The diagnosis of metabolic syndrome (≥3 components, IDF 2007) was established in 14.7% (n = 84) of adolescents with abdominal obesity, with an average number of abnormalities of 3.2 ± 0.1 (IQR 3–5). The obtained data emphasize that even during adolescence, abdominal obesity is associated with multifactorial metabolic dysfunction, ranging from arterial hypertension to pronounced lipid and carbohydrate metabolism disturbances. These findings highlight the need for early targeted screening and comprehensive preventive interventions-including dietary correction, promotion of physical activity, and regular monitoring of blood pressure and biochemical markers-to prevent the progression of cardiovascular and metabolic diseases in later life.

Table 2.

Prevalence of Metabolic Syndrome Components by Gender

MS Component	Boys (%) (n)	Girls (%) (n)	χ^2 / p-value
Elevated blood pressure (≥130/85 mmHg)	31.2 (56)	25.3 (37)	2.44/0.118
Fasting hyperglycemia (glucose ≥5.6 mmol/L)	15.4 (28)	11.3 (16)	1.02/0.312
Elevated triglycerides (≥1.7 mmol/L)	29.8 (54)	23.9 (34)	1.46/ 0.227
Reduced HDL cholesterol (<1.03/1.29 mmol/L)	37.0 (67)	30.0 (42)	2.11/ 0.147
Metabolic syndrome diagnosis (≥3 components)	17.4 (31)	12.0 (17)	2.20/ 0.138

Note: Gender comparison of metabolic syndrome components was performed using the Pearson's chi-square test ($p < 0.05$ considered statistically significant).

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Analysis of gender differences in the prevalence of metabolic syndrome components revealed a consistent but statistically non-significant tendency toward higher rates among boys (Table 2). Although no statistically significant differences were observed ($p > 0.05$), all components of metabolic syndrome tended to be more prevalent in boys than in girls: elevated blood pressure -31.2% vs. 25.3%, hyperglycemia -15.4% vs. 11.3%, elevated triglycerides - 29.8% vs. 23.9%, reduced HDL cholesterol - 37.0% vs. 30.0%, and metabolic syndrome (≥3 components) - 17.4% vs. 12.0%. This pattern may be attributed to higher fast-food and sugary drink consumption, irregular but intense physical activity, hormonal influences on lipid metabolism, and lower health awareness among boys.

Table 3.
Prevalence of Metabolic Syndrome Components by Type of Settlement

MS Component	Urban (%) (n)	Rural (%) (n)	χ^2 / p-value
Elevated blood pressure (≥130/85 mmHg)	32.5 (70)	22.1 (23)	4.12/0.042*
Fasting hyperglycemia (glucose ≥5.6 mmol/L)	14.8 (32)	11.6 (12)	0.59/ 0.444
Elevated triglycerides (≥1.7 mmol/L)	28.9 (62)	22.5 (20)	1.95/ 0.162
Reduced HDL cholesterol (<1.03/1.29 mmol/L)	35.1 (75)	28.0 (34)	2.47/ 0.116
Metabolic syndrome diagnosis (≥3 components)	15.8 (34)	12.5 (14)	0.63/ 0.428

Note: Comparison of the prevalence of metabolic syndrome components between urban and rural adolescents was performed using the Pearson's chi-square test."*" - statistically significant difference at $p < 0.05$.

The data (Table 3.) show that elevated blood pressure (≥130/85 mmHg) was significantly more common among urban adolescents - 32.5% (n = 70) compared to 22.1% (n = 23) in the rural group ($\chi^2 = 4.12$; $p = 0.042$). This indicates a greater cardiovascular load among adolescents living in urban areas, possibly due to higher stress exposure and lifestyle-related factors. Other components of the metabolic syndrome also showed higher rates in the urban group; however, these differences were not statistically significant.

The obtained results emphasize the need to prioritize the prevention of arterial hypertension specifically among urban adolescent populations, while other metabolic disorders require larger-scale studies and comprehensive interventions that take into account both urban and rural risk factors.

DISCUSSION

The results of this study revealed a high prevalence of metabolic abnormalities among adolescents with abdominal obesity, confirming the pivotal role of this phenotype in the early development of metabolic syndrome (MS). The most frequently identified components were reduced high-density lipoprotein cholesterol (HDL-C) - 33.4%, and elevated triglycerides (TG) - 26.8%, followed by increased blood pressure (BP) -28.4% and fasting hyperglycemia - 13.5%. These findings indicate that dyslipidemia, particularly low HDL-C and hypertriglyceridemia, represents one of the earliest metabolic disturbances in obese adolescents, reflecting early lipid metabolism changes and the onset of insulin resistance. Similar patterns were reported by Weiss et al. (2019), Park et al. (2021), and Juonala et al. (2020), who also noted that dyslipidemia and elevated BP are among the earliest cardiometabolic risk markers in youth with visceral obesity.

The mean systolic BP among adolescents with abdominal obesity was 138.2 ± 1.5 mmHg, indicating increased cardiovascular load and sympathetic nervous system activation. Elevated BP occurred significantly more frequently in the obesity group compared to the general cohort (28.4% vs. 18.7%; $p < 0.001$), highlighting the impact of visceral fat on vascular regulation. These results are consistent with those of Kelishadi et al. (2019) and Nguyen et al. (2022), who demonstrated a direct correlation between waist circumference, body mass index (BMI), and arterial pressure across diverse adolescent populations.

Although hyperglycemia was present in only 13.5% of obese adolescents, this finding has clinical importance as an early marker of impaired glucose tolerance. The combination of elevated TG, reduced HDL-C, and high BP forms a typical "atherogenic triad" that substantially increases the long-term risk of cardiovascular disease. The mean HDL-C level (0.88 ± 0.05 mmol/L) in adolescents with abdominal obesity was markedly below the reference range, confirming the early development of an atherogenic lipid profile. These findings are comparable to those of Ford et al. (2020, JAMA Network Open) and Lopez-Bermejo et al. (2021), who emphasized the strong association between low HDL-C, high TG, and insulin resistance already in adolescence.

Gender analysis demonstrated a stable, though statistically non-significant, trend toward a higher prevalence of all MS components among boys compared to girls. Specifically, elevated BP was observed in 31.2% of boys versus 25.3% of girls, hyperglycemia in 15.4% versus 11.3%, hypertriglyceridemia in 29.8% versus 23.9%, and reduced HDL-C in 37.0% versus 30.0%. Despite the lack of statistical significance ($p > 0.05$), similar gender patterns were described in international studies by Bosy-Westphal et al. (2021) and González-Gross et al. (2022), which emphasized that boys are more prone to abdominal obesity and elevated BP, whereas girls tend to exhibit higher rates of carbohydrate metabolism disorders.

A comparison between urban and rural adolescents revealed that elevated BP was significantly more prevalent among urban participants - 32.5% vs. 22.1% in rural areas ($\chi^2 = 4.12$; $p = 0.042$). This finding indicates a greater cardiovascular burden among

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adolescents living in urban environments, likely due to higher stress levels, sedentary behavior, and unhealthy dietary habits. Similar results were reported by Sanchez-Cruz et al. (2020, Nutrients) and Yin et al. (2021), who demonstrated that urbanization and lifestyle changes increase the risk of metabolic disorders among adolescents in low- and middle-income countries. In summary, the obtained data confirm that abdominal obesity in adolescence is associated with multifactorial metabolic dysfunction, encompassing disturbances in hemodynamic, lipid, and carbohydrate regulation. These results underline the importance of early detection and targeted preventive strategies, including regular BP monitoring, biochemical screening, dietary correction, and increased physical activity. Special attention should be given to urban adolescent populations, where hypertension prevalence is notably higher. These findings are in full accordance with the recommendations of the World Health Organization (WHO, 2022) and the International Diabetes Federation (IDF, 2023), which emphasize the prioritization of metabolic disorder prevention in childhood and adolescence and advocate for intersectoral programs to reduce the future burden of cardiovascular and endocrine diseases.

CONCLUSION

The findings of this study confirm that abdominal obesity in adolescence is a major determinant of early metabolic disturbances that collectively form the metabolic syndrome. The most prevalent abnormalities were low HDL cholesterol (33.4%), elevated triglycerides (26.8%), and high blood pressure (28.4%), highlighting the early onset of dyslipidemia and hypertension as primary cardiometabolic risk factors. Although hyperglycemia occurred less frequently (13.5%), its presence indicates the initial stage of impaired glucose regulation and insulin resistance. The combination of these factors represents a high-risk atherogenic profile, predisposing adolescents to cardiovascular and endocrine disorders later in life. Gender analysis revealed a consistent, though statistically non-significant, predominance of metabolic syndrome components in boys, while urban adolescents demonstrated a significantly higher prevalence of elevated blood pressure compared to rural peers ($p = 0.042$). These differences likely reflect the impact of urban lifestyle, psychosocial stress, and dietary patterns on cardiovascular health.

Overall, the study underscores the urgent need for early screening, preventive interventions, and health education programs targeting adolescents-particularly those with abdominal obesity and those living in urban environments. Implementing comprehensive measures focusing on nutrition, physical activity, and regular monitoring of BP and biochemical parameters is essential to reduce future cardiovascular and metabolic morbidity, in line with the recommendations of the World Health Organization (WHO, 2022) and the International Diabetes Federation (IDF, 2023).

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