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Physiological Foundations Of The Development Of Metabolic Syndrome In The Body

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Abstract: The prevalence of metabolic syndrome is increasing year by year, and this is a serious threat to global health. Abdominal fat accumulation, including visceral fat mass, increases inflammatory mediators and increases metabolic dysfunction through adipokine imbalance. Some variables play an important role in the probability of developing heart disease in a person. These variables are called risk factors. Some of these risk factors for heart disease accumulate in certain individuals. Such a cluster of risk factors is called metabolic syndrome.

Keywords: Insulin, arterial hypertension, triglycerides, glucose, lipid metabolism.

Introduction: Metabolic syndrome (MS) is a complex set of metabolic disorders common in modern society, based on clinical indicators such as visceral fat accumulation, insulin resistance (IR), arterial hypertension, elevated triglycerides, and low HDL cholesterol. The combination of these factors has a profound impact on glucose and lipid metabolism, vascular tone, and energy adaptability in the body. Insulin resistance is considered the main factor of metabolic syndrome: it disrupts the PI3K-Act pathway, which regulates metabolic processes, sharply reduces glucose absorption, thereby contributing to the development of dysglycemia, dyslipidemia, and hypertension.

The presence of a constant low level of inflammation directly contributes to the formation of insulin resistance, which causes morphofunctional changes not only in glucose metabolism, but also in the regulation of blood pressure and lipid metabolism. For this reason, metabolic syndrome is often considered a syndrome that significantly increases the risk of atherosclerosis, myocardial infarction, stroke, and other cardiovascular diseases.

The formation of metabolic syndrome is not limited to traditional clinical factors, but includes a wide range of changes related to the entire systemic metabolism. Studies conducted to assess metabolic changes show that low concentrations of amino acids, such as serine and glycine, are more associated with indicators of metabolic syndrome and greater abdominal obesity, which is explained by the active orientation of amino acids in the pathway of new sphingolipid synthesis. These findings once again confirm that complex biochemical processes lie behind the clinical manifestations.

Insulin resistance (IR) is one of the most important pathogenic indicators of metabolic syndrome, the mechanisms of its formation are realized at several levels - molecular signaling, intracellular metabolism, vascular response, and tissue interaction.

Physical exercises serve as the main biological stimulus for restoring metabolic adaptability. Exercises at high intensity lead to strong activation of PGC-1α and AMPK signaling in skeletal muscles; this process occurs to almost the same extent even under conditions with varying glycogen levels.

One of the most dangerous epidemiological factors of the current lifestyle is a sharp decrease in physical activity and an increase in sitting work throughout the day. Inactivity is one of the main factors leading to insulin resistance (IR), visceral fat accumulation, and impaired glycemic control, which plays a central role in the development of metabolic syndrome (MS). Prolonged inactivity disrupts the flexibility of energy metabolism processes, reduces mitochondrial potential, and limits the physiological exchange between glucose-fat substrates. As a result, the body's metabolic reactions slow down, its ability to oxidize fats

decreases, and insulin signaling systems weaken.

The association of sedentarism with insulin resistance is shaped by many molecular-level mechanisms. In skeletal muscles, GLUT4 translocation, IRS-1 and Act activity decrease, several structural elements of the PI3K-Act pathway are weakened. Even a short period of bed rest or in sedentary conditions reduces the activation of genes such as GLUT4, HK2, GS, and disrupts insulin signaling-dependent processes. These changes stop the entry of glucose into muscle tissue, disrupt glucose transport, and do not return to normal until physical activity is restored. The study results show that even complete inactivity for 6-10 days significantly reduces insulin sensitivity in skeletal muscles and causes the initial stages of insulin resistance.

Chronic low-grade inflammation, observed in metabolic syndrome, is one of the main pathobiological changes in the body. Pathological dilation of visceral adipose tissue is accompanied by hypertrophy of adipocytes, their hypoxia and mechanical stress, which leads to the regular release of pro-inflammatory mediators.

METHODS

The object of the study were athletes and active youth aged 18-21 years, regularly engaged in physical activity.

In our study, the determination of metabolic parameters in the blood is the main part of assessing the influence of exercise on insulin sensitivity, glucose utilization, and lipid metabolism. All laboratory analyses were performed under standardized conditions after 8-10 hours of fasting. The glucose level was determined by the enzymatic method using photometric analysis, and the insulin concentration was measured by the enzyme immunoassay (ELISA) method. Based on these indicators, the HOMA-IR index (glucose × insulin / 22.5) was calculated. HOMA-IR was a practical and reliable criterion for assessing the level of insulin resistance and was used as a key indicator in the selection of participants with a high metabolic risk from the cohort for the randomized (RCT) stage of the study.

To assess lipid metabolism, the levels of total cholesterol, triglycerides, high-density lipoproteins (HDL), and low-density lipoproteins (LDL) were determined using enzymatic-colorimetric methods on automated analyzers. The lipid profile served as an important indicator in assessing the influence of sports load on energy expenditure, adipose tissue metabolism, and overall metabolic stability. An increase in HDL levels, a decrease in triglycerides, or a decrease in LDL were analyzed as indicators that indirectly reflect the metabolically positive effect of physical activity.

The registration of metabolic indicators at the 0-, 6-, and 12th months of the cohort stage and at the 0-, 12-, and 24th weeks of the experimental stage allowed for a consistent assessment of the short-term and long-term effects of physical activity.

RESULT

During the study, changes in glucose, insulin levels, and the HOMA-IR index were assessed at 0-, 6-, and 12 months in weightlifting, football, long-distance runners, and normal groups. These indicators reflect metabolic responses associated with various types of physical activity and allow for an objective description of the dynamics of carbohydrate metabolism. All indicators are presented in the form of the mean ± standard deviation.

Glucose, insulin, and HOMA-IR levels at 0-, 6-, and 12 months (Mean ± SD)

Table 1

Indicator	Time	Heavy Lifting	Football	Long-distance running	Normal
Glucose (mmol/L)	0 oy	4.58 ± 0.22	4.60 ± 0.17	4.39 ± 0.13	4.89 ± 0.14
	6 oy	4.47 ± 0.15	4.47 ± 0.17	4.30 ± 0.08	4.99 ± 0.14
	12 oy	4.64 ± 0.47	4.75 ± 0.64	4.33 ± 0.35	5.17 ± 0.20
Insulin (µU/mL)	0 oy	7.7 ± 1.9	7.37 ± 0.93	4.83 ± 0.63	11.17 ± 1.20
	6 oy	6.61 ± 1.33	6.38 ± 0.77	3.80 ± 0.80	11.97 ± 1.20
	12 oy	7.39 ± 2.78	6.95 ± 2.48	3.65 ± 1.8	12.44 ± 1.28
HOMA-IR	0 oy	1.58 ± 0.36	1.51 ± 0.25	0.94 ± 0.15	2.44 ± 0.34
	6 oy	1.37 ± 0.22	1.33 ± 0.22	0.72 ± 0.14	2.66 ± 0.35

	12 oy	1.57 ± 0.66	1.53 ± 0.77	0.74 ± 0.46	2.97 ± 0.44

At the initial stage, glucose levels were recorded in physiological normal in all groups, but the distribution differed slightly. The lowest glucose level was observed in the group of long-distance runners (4.39±0.13 mmol/L), and the highest in the normal group (4.89±0.14 mmol/L). Average values were observed in the weightlifting (4.58±0.22 mmol/L) and football (4.60±0.17 mmol/L) groups. By the 6th month, the glucose level further decreased in all sports groups: weightlifters - 4.47±0.15 mmol/L, football players - 4.47±0.17 mmol/L, long-distance runners - 4.30±0.08 mmol/L. In the normal group, on the contrary, the glucose level slightly increased and amounted to 4.99±0.14 mmol/L. By the end of the 12th month, the indicators in all groups remained stable: in long-distance runners - 4.33±0.35 mmol/L, in weightlifters - 4.64±0.47 mmol/L, in football players - 4.75±0.64 mmol/L, and in the normal group the highest value was recorded - 5.17±0.20 mmol/L.

The dynamics of insulin also repeated general trends. At the baseline level, the lowest insulin levels were observed in the group of long-distance runners (4.83±0.63 μU/mL), and the highest in the group of normal runners (11.17±1.20 μU/mL). Intermediate values were recorded in weightlifters - 7.7 ± 1.9 μU/mL, in football players - 7.37 ± 0.93 μU/mL. At the 6th month, insulin levels decreased in sports groups: weightlifters - 6.61±1.33 μU/mL, football players - 6.38±0.77 μU/mL, long-distance runners - 3.80±0.80 μU/mL. In the normal group, the insulin level increased to 11.97 ± 1.20 μU/mL. By the 12th month, insulin was still below or close to baseline values (7.39±2.78 and 6.95±2.48 μU/ml), although it was slightly elevated in groups of weightlifters and football players. In the group of long-distance runners, the insulin level decreased again and amounted to 3.65±1.8 μU/ml. In the normal group, the increase continued and reached 12.44 ± 1.28 μU/mL.

Changes in the HOMA-IR index developed in accordance with the dynamics of glucose and insulin. At the initial stage, the lowest HOMA-IR was recorded in the group of long-distance runners (0.94±0.15), and the highest in the Normal group (2.44±0.34). Groups of weightlifters (1.58±0.36) and football players (1.51±0.25) showed average values. At the 6th month, HOMA-IR further decreased in sports groups: weightlifters - 1.37±0.22, football players - 1.33±0.22, long-distance runners - 0.72±0.14. In the normal group, the indicator, on the contrary, increased to 2.66 ± 0.35. By the end of the 12th month, although the HOMA-IR in the sports groups was slightly elevated, it remained below or close to the initial values (HL - 1.57 ± 0.66; FB - 1.53 ± 0.77; LDR - 0.74 ± 0.46). In the normal group, the index reached its highest value - 2.97 ± 0.44.

During long-term observation, lipid metabolism indicators were assessed according to four groups - weightlifters, football players, long-distance runners, and Normal, including triglycerides (TG), high-density lipoproteins (HDL), low-density lipoproteins (LDL), and total cholesterol (TC) levels at 0-, 6-, and 12 months. These parameters reflect the metabolic adaptation associated with various types of physical activity, allowing for systematic observation of changes in the lipid profile in each group. All values are presented in the average ± standard deviation format.

Lipid profile indicators (TH, HDL, LDL, TC) at 0, 6 and 12 months

Table 2

Indicator	Time	Heavy Lifting	Football	Long-distance running	Normal
TG (mmol/L)	0 oy	1.08 ± 0.17	1.05 ± 0.11	0.80 ± 0.08	1.53 ± 0.14
	6 oy	0.96 ± 0.13	0.94 ± 0.11	0.57 ± 0.06	1.64 ± 0.15
	12 oy	1.07 ± 0.41	1.10 ± 0.52	0.64 ± 0.30	1.73 ± 0.20
HDL (mmol/L)	0 oy	1.12 ± 0.11	1.22 ± 0.08	1.52 ± 0.06	1.04 ± 0.05
	6 oy	1.22 ± 0.09	1.31 ± 0.08	1.61 ± 0.06	1.01 ± 0.05
	12 oy	1.18 ± 0.15	1.23 ± 0.26	1.61 ± 0.16	0.98 ± 0.05
LDL (mmol/L)	0 oy	2.34 ± 0.23	2.21 ± 0.15	2.00 ± 0.09	2.91 ± 0.20

	6 oy	2.27 ± 0.15	2.15 ± 0.14	1.93 ± 0.07	2.96 ± 0.20
	12 oy	2.30 ± 0.19	2.13 ± 0.19	1.93 ± 0.08	3.05 ± 0.21
TC (mmol/L)	0 oy	4.54 ± 0.23	4.43 ± 0.20	4.11 ± 0.10	5.21 ± 0.18
	6 oy	4.40 ± 0.14	4.29 ± 0.15	4.02 ± 0.08	5.26 ± 0.18
	12 oy	4.45 ± 0.24	4.28 ± 0.27	4.02 ± 0.12	5.36 ± 0.19

At the initial stage, it was observed that the levels of triglycerides (TG) differed significantly between the groups. The lowest TG was noted in the group of long-distance runners (0.80±0.08 mmol/L), and the highest - in the group of normal runners (1.53±0.14 mmol/L). Groups of weightlifters (1.08±0.17 mmol/L) and football players (1.05±0.11 mmol/L) showed average values. By the 6th month, a decrease in the TG level was observed in all sports groups: long-distance runners showed a sharp decrease to 0.57±0.06 mmol/L, weightlifters (0.96±0.13 mmol/L) and football players (0.94±0.11 mmol/L) also showed a significant improvement. In the normal group, on the contrary, TG increased to 1.64 ± 0.15 mmol/L. At the 12th month, the EG in the sports groups slightly increased, but in general dynamics remained below or close to the baseline level; In the normal group, TG increased to 1.73 ± 0.20 mmol/L, reaching its highest value during the observation period.

HDL levels also had a significant difference at the initial stage. In the group of long-distance runners, HDL was the highest (1.52±0.06 mmol/L), in the groups of football players (1.22±0.08 mmol/L) and weightlifters (1.12±0.11 mmol/L) it was average, and in the group of Normal it was the lowest (1.04±0.05 mmol/L). By the 6th month, an increase in HDL was noted in sports groups: weightlifters - 1.22 ± 0.09 mmol/L, football players - 1.31 ± 0.08 mmol/L, long-distance runners - 1.61 ± 0.06 mmol/L. In the normal group, the indicator decreased to 1.01 ± 0.05 mmol/L. At 12 months, HDL levels remained relatively stable in the sports groups and remained within the high range, while in the Normal group they decreased to 0.98±0.05 mmol/L, which is the lowest value of observation.

LDL levels demonstrated a more stable dynamic compared to TG and HDL. At the initial level, long-distance runners had the lowest LDL (2.00 ± 0.09 mmol/L), while Normal demonstrated the highest (2.91 ± 0.20 mmol/L). Weightlifters (2.34±0.23 mmol/L) and footballers (2.21±0.15 mmol/L) showed intermediate values. At 6 months, a slight decrease in LDL was observed in the sports groups, especially in the long-distance runners (1.93±0.07 mmol/L). In the normal group, LDL increased to 2.96 ± 0.20 mmol/L. At 12 months, LDL levels remained relatively stable in sports groups, continuing the trend that persisted throughout the year; In the normal group, LDL increased to 3.05 ± 0.21 mmol/L, reaching its highest value during the observation period.

Dynamics of total cholesterol (TC) were formed in accordance with LDL. Initial TC was highest in the Normal group (5.21±0.18 mmol/L), and lowest in the long-distance runners (4.11±0.10 mmol/L). The groups of weightlifters (4.54±0.23 mmol/L) and football players (4.43±0.20 mmol/L) were in the intermediate range. At the 6th month, TC decreased slightly in the sports groups, while in the Normal group it increased to 5.26 ± 0.18 mmol/L. By the end of the 12th month, the sports groups stabilized in the range of approximately 4.40-4.45 mmol/L, while in the Normal group, the TC increased to 5.36±0.19 mmol/L - the highest indicator during the observation period.

CONCLUSION

Metabolic syndrome is complex, multifactorial, and reduces the correlation between insulin resistance, visceral obstruction, inflammation, hormonal dysregulation, and lifestyle factors. Early detection, preventive measures, and personalized treatment approaches are important for reducing the global burden of cardiovascular diseases and diabetes. Future research should focus on specific drugs, genetic compatibility, and new treatment methods.

REFERENCES

1. Djurayeva Ra'no Xayrulloyevna Metabolic syndrome: etiology, pathogenesis, clinic alfeatures, prevention, andtreatment. American Academic Publisher. International Journal of medical sciences. ISSN Number: 2692-5206 Volume 5. No 12. December, 2025.
2. Alberti, K.G.M.M., Zimmet, P., & Shaw, J. (2005). The metabolic syndrome—anewworldwide definition. The Lancet, 366(9491), 1059–1062.
3. S.A.Saidov, S.B.Azimova, A.B.Bekmuratova, J.A.Mirsultanov Metabolik sindrom patogenezining zamonaviy tushunchalari. Academic Research in

Educational Sciences ISSN: 2181-1385 Volume 5 | Issue 5 | 2024

4. Welty F.K., Alfaddagh A., Elajami T.K. Targeting inflammation in metabolic syndrome // Transl. Res. – 2016. – Vol. 167, No. 1. – P. 257–280. – DOI: 10.1016/j.trsl.2015.06.017.
5. Barber T.M., Kyrou I., Randeva H.S., Weickert M.O. Mechanisms of insulin resistance at the crossroad of obesity with associated metabolic abnormalities and cognitive dysfunction // Int. J. Mol. Sci. – 2021. – Vol. 22, No. 2. – 546. – DOI: 10.3390/ijms 22020546.
6. Palmnäs M.S.A., Kopciuk K., Shaykhutdinov R.A., et al. Serum metabolomics of activity energy expenditure and its relation to metabolic syndrome and obesity // Sci. Rep. – 2018. – Vol. 8. – 3308. – DOI: 10.1038/s41598-018-21585-6.
7. Hearris M.A., Owens D.J., Strauss J.A., et al. Graded reductions in pre-exercise glycogen concentration do not augment exercise-induced nuclear AMPK and PGC-1α protein content in human muscle // Exp. Physiol. – 2020. – Vol. 105. – P. 1882–1894. – DOI: 10.1113/EP088866.
8. Goodpaster B.H., Sparks L.M. Metabolic flexibility in health and disease // Cell Metab. – 2017. – Vol. 25, No. 5. – P. 1027–1036. – DOI: 10.1016/j.cmet.2017.04.015.
9. Yaribeygi H., Maleki M., Sathyapalan T., Jamialahmadi T., Sahebkar A. Pathophysiology of physical inactivity-dependent insulin resistance: a theoretical mechanistic review emphasizing clinical evidence // J. Diabetes Res. – 2021. – Article ID 7796727. – 12 p. – DOI: 10.1155/2021/7796727.
10. D.F.Sultonova Functional Adaptation Effectiveness of Students with Different Levels of Preparedness for Training During the Adaptation Process. International Journal of Genetic Engineering 2024, 12(2): 17-20

    DOI: 10.5923/j.ijge.20241202.02