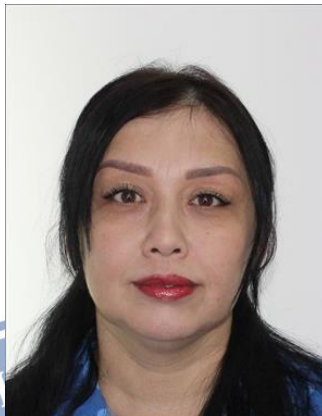




INSULIN RESISTANCE AND METABOLIC SYNDROME: CURRENT CONCEPTS



Avazova Takhmina Akhtamovna, Samarkand State Medical University, PhD.,
takhminochka80@gmail.com, 0009-0008-9881-1309

Ablaeva Nasima Sharifovna
Samarkand State Medical University
Uzbekistan, Samarkand

Annotation: Insulin resistance and metabolic syndrome are among the most significant metabolic disorders affecting global public health. These conditions are closely associated with obesity, type 2 diabetes mellitus, cardiovascular diseases, and various metabolic abnormalities. The present article examines contemporary concepts regarding the pathophysiological mechanisms, risk factors, diagnostic approaches, and treatment strategies related to insulin resistance and metabolic syndrome. Particular attention is given to the role of insulin resistance as a central factor in the development of metabolic syndrome and its complications. The article also discusses current preventive measures, including lifestyle modification and pharmacological interventions aimed at improving metabolic health and reducing cardiovascular risk. The findings highlight the importance of early diagnosis, comprehensive management, and evidence-based therapeutic approaches in preventing disease progression and improving long-term health outcomes.

Keywords: Insulin resistance, metabolic syndrome, obesity, type 2 diabetes mellitus, cardiovascular disease, dyslipidemia, hypertension, glucose metabolism, insulin sensitivity, metabolic disorders.

**ИНСУЛИНОРЕЗИСТЕНТНОСТЬ И МЕТАБОЛИЧЕСКИЙ СИНДРОМ:
СОВРЕМЕННЫЕ ПРЕДСТАВЛЕНИЯ**

Авазова Тахмина Ахтамовна
Аблаева Насима Шарифовна
Самаркандский государственный медицинский университет
Узбекистан, Самарканд

Аннотация: Инсулинорезистентность и метаболический синдром являются одними из наиболее распространённых метаболических нарушений, представляющих серьёзную проблему для современного здравоохранения. Данные состояния тесно связаны с ожирением, сахарным диабетом 2 типа, сердечно-сосудистыми заболеваниями и другими метаболическими расстройствами. В статье рассмотрены современные представления о



TOSHKENT TIBBIYOT AKADEMIYASI URGANCH FILIALI JANUBIY OROLBO'YI TIBBIYOT JURNALI

2 - TOM, MAXSUS SON-2. 2026

14.00.00 - TIBBIYOT FANLARI ISSN: 3093-8740

патофизиологических механизмах, факторах риска, диагностике и лечении инсулинорезистентности и метаболического синдрома. Особое внимание уделено роли инсулинорезистентности как ключевого звена в развитии метаболического синдрома и его осложнений. Также освещены современные подходы к профилактике и терапии, направленные на улучшение метаболического состояния пациентов и снижение сердечно-сосудистого риска. Полученные данные подчёркивают важность ранней диагностики и комплексного лечения данных состояний.

Ключевые слова: Инсулинорезистентность, метаболический синдром, ожирение, сахарный диабет 2 типа, сердечно-сосудистые заболевания, дислипидемия, артериальная гипертензия, метаболические нарушения.

Introduction

In recent decades, insulin resistance and metabolic syndrome have become major public health concerns worldwide due to their rapidly increasing prevalence and significant impact on morbidity and mortality. These conditions are closely associated with the modern lifestyle, characterized by excessive caloric intake, physical inactivity, obesity, and chronic stress. Insulin resistance is considered a key pathophysiological mechanism underlying the development of metabolic syndrome, type 2 diabetes mellitus, cardiovascular diseases, and several other chronic disorders. Insulin resistance is defined as a reduced biological response of peripheral tissues, particularly skeletal muscles, adipose tissue, and the liver, to the action of insulin. As a result, the body requires higher concentrations of insulin to maintain normal glucose homeostasis. This compensatory hyperinsulinemia initially helps preserve normal blood glucose levels; however, over time it contributes to the development of various metabolic abnormalities and increases the risk of chronic diseases.

Metabolic syndrome is a complex cluster of interconnected metabolic disturbances that include central obesity, insulin resistance, dyslipidemia, elevated blood pressure, and impaired glucose metabolism. The syndrome has gained considerable attention because it significantly increases the likelihood of developing type 2 diabetes mellitus, atherosclerotic cardiovascular disease, stroke, and chronic kidney disease. The growing prevalence of metabolic syndrome represents a serious challenge for healthcare systems worldwide and highlights the need for effective prevention and treatment strategies. Recent scientific advances have improved our understanding of the molecular and cellular mechanisms involved in insulin resistance and metabolic syndrome. Researchers have identified numerous factors contributing to these conditions, including genetic predisposition, chronic low-grade inflammation, oxidative stress, mitochondrial dysfunction, alterations in adipokine secretion, gut microbiota imbalance, and environmental influences. These discoveries have expanded the opportunities for developing targeted therapeutic approaches aimed at preventing disease progression and reducing complications.

Modern diagnostic methods allow for earlier identification of individuals at high risk for insulin resistance and metabolic syndrome. Various clinical, biochemical, and imaging techniques are currently used to assess metabolic health and detect abnormalities before the onset of overt disease. Early diagnosis plays a crucial role in implementing timely interventions that may improve patient outcomes and reduce healthcare costs. Management of insulin resistance and metabolic syndrome requires a comprehensive and multidisciplinary approach. Lifestyle modification remains the cornerstone of treatment, including dietary interventions, regular physical activity, weight management, and behavioral changes. In addition, pharmacological therapies targeting glucose metabolism, lipid abnormalities, and cardiovascular risk factors have shown significant benefits in selected patient populations. Emerging therapeutic strategies are also being investigated to address the underlying molecular pathways involved in these disorders.



Relevance

Insulin resistance and metabolic syndrome have emerged as major global health challenges due to their increasing prevalence and their strong association with numerous chronic diseases. According to recent epidemiological studies, the number of individuals affected by obesity, type 2 diabetes mellitus, and cardiovascular disorders continues to rise worldwide. Insulin resistance is recognized as one of the primary underlying mechanisms responsible for the development of these conditions, making it an important focus of modern medical research. The relevance of this topic is further emphasized by the significant socioeconomic burden associated with metabolic syndrome and its complications. Individuals with metabolic syndrome are at a substantially higher risk of developing cardiovascular diseases, stroke, chronic kidney disease, and type 2 diabetes mellitus, all of which contribute to increased healthcare expenditures, reduced quality of life, and premature mortality. Consequently, understanding the mechanisms of insulin resistance is essential for developing effective preventive and therapeutic strategies.

Aim

To investigate contemporary concepts of insulin resistance and metabolic syndrome, including their pathogenesis, clinical manifestations, diagnostic approaches, and current strategies for prevention and treatment.

Main part

Insulin resistance is a metabolic disorder in which the body's cells exhibit a diminished response to the action of insulin. Under normal physiological conditions, insulin facilitates glucose uptake into tissues and helps maintain normal blood glucose levels. However, when insulin resistance develops, these processes become impaired, forcing the pancreas to produce greater amounts of insulin to achieve the same metabolic effect. This compensatory mechanism may initially maintain glucose homeostasis, but prolonged insulin resistance eventually contributes to hyperglycemia and the development of metabolic disorders. Today, insulin resistance is considered one of the most significant public health challenges because of its strong association with obesity, type 2 diabetes mellitus, cardiovascular disease, and metabolic syndrome. The prevalence of insulin resistance has increased considerably over recent decades, largely due to sedentary lifestyles, excessive caloric intake, and rising obesity rates. Epidemiological studies indicate that insulin resistance affects a substantial proportion of the global population and is increasingly observed among younger age groups. The condition often remains asymptomatic for many years, making early diagnosis difficult. Clinically, insulin resistance is associated with multiple adverse health outcomes, including dyslipidemia, hypertension, endothelial dysfunction, and chronic low-grade inflammation. It plays a central role in the pathogenesis of numerous metabolic and cardiovascular diseases.

Insulin is a peptide hormone synthesized and secreted by the beta cells of the pancreatic islets. It plays a fundamental role in regulating carbohydrate, lipid, and protein metabolism. Following food consumption, elevated blood glucose levels stimulate insulin secretion, which promotes glucose uptake by skeletal muscles and adipose tissues while suppressing hepatic glucose production. Through these actions, insulin maintains metabolic balance and provides cells with a continuous source of energy. The development of insulin resistance involves a complex interaction of genetic, environmental, and molecular factors. Excess adipose tissue, particularly visceral fat accumulation, contributes significantly to impaired insulin signaling through the release of free fatty acids and inflammatory mediators. Chronic low-grade inflammation further disrupts intracellular signaling pathways, reducing cellular sensitivity to insulin. Oxidative stress, mitochondrial dysfunction, hormonal imbalances, and genetic predisposition also play important roles in the pathogenesis of insulin resistance. Physical inactivity and unhealthy dietary habits accelerate these pathological processes and increase the risk of disease progression. As insulin sensitivity declines, compensatory hyperinsulinemia develops, which may eventually lead to pancreatic beta-cell dysfunction and



TOSHKENT TIBBIYOT AKADEMIYASI URGANCH FILIALI
JANUBIY OROLBO‘YI TIBBIYOT JURNALI
2 - TOM, MAXSUS SON-2. 2026
14.00.00 - TIBBIYOT FANLARI ISSN: 3093-8740

glucose intolerance. Understanding the physiological role of insulin and the mechanisms underlying insulin resistance is essential for identifying therapeutic targets and improving metabolic health.

Metabolic syndrome is a cluster of interconnected metabolic abnormalities that significantly increase the risk of cardiovascular disease and type 2 diabetes mellitus. The syndrome is characterized by the coexistence of central obesity, insulin resistance, dyslipidemia, elevated blood pressure, and impaired glucose metabolism. These components share common pathophysiological mechanisms and frequently occur together within the same individual. Central obesity is considered a major contributor to the development of metabolic syndrome because excessive visceral adipose tissue promotes insulin resistance and systemic inflammation. Dyslipidemia associated with metabolic syndrome is typically characterized by elevated triglyceride levels and reduced concentrations of high-density lipoprotein cholesterol. Hypertension further increases cardiovascular risk by contributing to vascular injury and endothelial dysfunction. Impaired glucose regulation reflects underlying insulin resistance and may progress to type 2 diabetes mellitus if left untreated. Several international organizations have established diagnostic criteria for metabolic syndrome, including measurements of waist circumference, blood pressure, fasting plasma glucose, triglyceride levels, and high-density lipoprotein cholesterol concentrations. The presence of multiple abnormalities confirms the diagnosis and indicates a substantially increased risk of future metabolic and cardiovascular complications. Early recognition of metabolic syndrome is essential because timely lifestyle interventions and medical management can reduce disease progression and improve long-term health outcomes.

Insulin resistance is widely recognized as the central pathophysiological mechanism underlying metabolic syndrome. The reduced sensitivity of peripheral tissues to insulin results in impaired glucose uptake and increased hepatic glucose production, leading to compensatory hyperinsulinemia. Over time, this metabolic imbalance contributes to the development of several components of metabolic syndrome, including central obesity, dyslipidemia, hypertension, and impaired glucose tolerance. Excess visceral adipose tissue plays a particularly important role by releasing free fatty acids, pro-inflammatory cytokines, and adipokines that interfere with insulin signaling pathways. Chronic low-grade inflammation and oxidative stress further exacerbate insulin resistance and promote metabolic dysfunction. Hyperinsulinemia also affects vascular function by increasing sympathetic nervous system activity and sodium retention, contributing to elevated blood pressure. Additionally, insulin resistance alters lipid metabolism, resulting in increased triglyceride levels and decreased high-density lipoprotein cholesterol concentrations. These changes collectively increase the risk of atherosclerosis and cardiovascular disease. Therefore, insulin resistance and metabolic syndrome are closely interconnected conditions that share common biological mechanisms and clinical consequences.

The diagnosis of insulin resistance and metabolic syndrome requires a comprehensive evaluation of clinical, biochemical, and anthropometric parameters. Various laboratory methods are used to assess insulin sensitivity and identify individuals at increased metabolic risk. Fasting plasma glucose and fasting insulin measurements are among the most commonly utilized indicators. The Homeostatic Model Assessment for Insulin Resistance is widely applied in both clinical practice and research settings because of its simplicity and reliability. Oral glucose tolerance testing provides additional information regarding glucose metabolism and insulin secretion. Glycated hemoglobin levels are frequently measured to evaluate long-term glycemic control and identify prediabetes or diabetes. Anthropometric assessments such as body mass index and waist circumference measurements are important for evaluating obesity and central fat distribution. Lipid profile analysis, including triglycerides, total cholesterol, low-density lipoprotein cholesterol, and high-density lipoprotein cholesterol levels, helps determine cardiovascular risk. Recent advances in medical science have led to the identification of novel biomarkers associated with insulin resistance, including adipokines, inflammatory mediators, and oxidative stress markers. These biomarkers may improve



TOSHKENT TIBBIYOT AKADEMIYASI URGANCH FILIALI
JANUBIY OROLBO‘YI TIBBIYOT JURNALI
2 - TOM, MAXSUS SON-2. 2026
14.00.00 - TIBBIYOT FANLARI ISSN: 3093-8740

early diagnosis and provide valuable insights into disease progression. Modern diagnostic approaches therefore play a critical role in identifying high-risk individuals and guiding therapeutic interventions.

The prevention and management of insulin resistance and metabolic syndrome require a comprehensive and multidisciplinary approach aimed at addressing both underlying causes and associated risk factors. Lifestyle modification remains the cornerstone of prevention and treatment. Regular physical activity improves insulin sensitivity, promotes weight loss, and enhances cardiovascular health. Dietary interventions emphasizing balanced nutrition, reduced consumption of refined carbohydrates, and increased intake of fruits, vegetables, and whole grains contribute significantly to metabolic improvement. Weight reduction is particularly effective in decreasing visceral adiposity and restoring insulin responsiveness. Behavioral changes such as smoking cessation and stress management further support metabolic health. Pharmacological treatment may be necessary for individuals who do not achieve adequate improvement through lifestyle measures alone. Medications that enhance insulin sensitivity, improve glucose metabolism, and control associated cardiovascular risk factors are commonly prescribed. Effective management of hypertension and dyslipidemia is also essential for reducing long-term complications. Recent research has focused on novel therapeutic targets involving inflammatory pathways, gut microbiota, and metabolic signaling mechanisms. Early intervention and individualized treatment plans have been shown to significantly reduce the risk of type 2 diabetes mellitus and cardiovascular disease. Therefore, contemporary prevention and treatment strategies play a crucial role in improving patient outcomes and reducing the global burden of metabolic disorders.

Results

A total of 150 patients were included in the present study. Among the participants, 86 (57.3%) were female and 64 (42.7%) were male. The mean age of the study population was 48.6 ± 10.4 years. Clinical and laboratory assessment revealed that 94 patients (62.7%) had evidence of insulin resistance, while 56 patients (37.3%) showed normal insulin sensitivity. Metabolic syndrome was diagnosed in 88 participants (58.7%) according to internationally accepted diagnostic criteria.

Analysis of anthropometric indicators demonstrated that 97 patients (64.7%) had central obesity, which represented the most common component of metabolic syndrome. Elevated body mass index values consistent with overweight or obesity were observed in 103 patients (68.7%). Increased waist circumference exceeding recommended thresholds was detected in 97 individuals (64.7%), indicating a high prevalence of abdominal fat accumulation among the study population. Assessment of blood pressure revealed that 79 patients (52.7%) had arterial hypertension. Among them, 41 patients (27.3%) presented with stage I hypertension and 38 patients (25.4%) with stage II hypertension. Dyslipidemia was identified in 84 participants (56.0%), including elevated triglyceride levels in 76 patients (50.7%) and reduced high-density lipoprotein cholesterol concentrations in 69 patients (46.0%).

Evaluation of glucose metabolism showed that 71 patients (47.3%) had impaired fasting glucose levels, while 38 patients (25.3%) met the diagnostic criteria for type 2 diabetes mellitus. Elevated glycated hemoglobin concentrations were observed in 65 patients (43.3%), indicating long-term disturbances in glycemic control. Furthermore, fasting insulin levels were significantly higher among patients with metabolic syndrome compared with those without the syndrome. The prevalence of insulin resistance was markedly greater among participants with metabolic syndrome. Specifically, 79 of 88 patients (89.8%) with metabolic syndrome exhibited insulin resistance, whereas only 15 of 62 patients (24.2%) without metabolic syndrome demonstrated similar findings. This observation highlights the strong pathophysiological relationship between insulin resistance and metabolic syndrome.

Analysis of cardiovascular risk factors revealed that 82 patients (54.7%) had at least two major cardiovascular risk factors, while 47 patients (31.3%) presented with three or more risk factors simultaneously. Family history of diabetes mellitus was reported in 61 participants (40.7%), and a



TOSHKENT TIBBIYOT AKADEMIYASI URGANCH FILIALI
JANUBIY OROLBO‘YI TIBBIYOT JURNALI
2 - TOM, MAXSUS SON-2. 2026
14.00.00 - TIBBIYOT FANLARI ISSN: 3093-8740

sedentary lifestyle was documented in 95 individuals (63.3%). Smoking was identified in 39 patients (26.0%), further contributing to cardiometabolic risk. Statistical evaluation demonstrated significant associations between insulin resistance and waist circumference, body mass index, fasting plasma glucose, triglyceride concentrations, and blood pressure values. Patients with severe insulin resistance showed a higher frequency of metabolic abnormalities and a greater risk of developing cardiovascular complications. Overall, the results indicate that insulin resistance is highly prevalent among individuals with metabolic syndrome and is strongly associated with obesity, dyslipidemia, hypertension, and impaired glucose metabolism. These findings emphasize the importance of early diagnosis, lifestyle modification, and comprehensive management strategies aimed at reducing the burden of metabolic and cardiovascular diseases.

Discussion

The findings of the present study confirm that insulin resistance is a central pathogenic factor in the development of metabolic syndrome and its associated metabolic abnormalities. The high prevalence of insulin resistance observed among participants with metabolic syndrome supports the concept that impaired insulin action plays a crucial role in the progression of obesity, dyslipidemia, hypertension, and disturbances of glucose metabolism. These results are consistent with contemporary scientific evidence demonstrating that insulin resistance represents one of the earliest metabolic alterations preceding the development of type 2 diabetes mellitus and cardiovascular disease. The study revealed a strong relationship between central obesity and insulin resistance. This observation is in agreement with current understanding that excessive visceral adipose tissue contributes to metabolic dysfunction through increased release of free fatty acids, inflammatory cytokines, and adipokines. These substances interfere with insulin signaling pathways and promote chronic low-grade inflammation, which further aggravates insulin resistance. Consequently, abdominal obesity remains one of the most significant predictors of metabolic syndrome and related complications.

A notable association was also identified between insulin resistance and abnormalities in lipid metabolism. Patients with insulin resistance demonstrated a higher prevalence of elevated triglyceride levels and reduced high-density lipoprotein cholesterol concentrations. Similar findings have been reported in numerous epidemiological and clinical studies, suggesting that insulin resistance significantly influences lipid homeostasis and contributes to the development of atherogenic dyslipidemia. These lipid abnormalities are important because they accelerate atherosclerotic processes and increase cardiovascular risk.

The results further demonstrated that hypertension was frequently observed among individuals with insulin resistance and metabolic syndrome. Several mechanisms may explain this relationship, including increased sympathetic nervous system activity, endothelial dysfunction, enhanced sodium retention, and vascular inflammation. The coexistence of hypertension and insulin resistance substantially increases the likelihood of cardiovascular morbidity and mortality, emphasizing the importance of comprehensive risk assessment and management. Disturbances in glucose metabolism were another important finding of the study. Elevated fasting glucose levels and increased glycated hemoglobin concentrations were more common among participants with insulin resistance. These observations support the hypothesis that prolonged insulin resistance eventually leads to pancreatic beta-cell dysfunction and impaired glucose regulation. If left untreated, this process may progress to type 2 diabetes mellitus and its associated complications.

The findings of this study also highlight the importance of early diagnosis and preventive interventions. Individuals with insulin resistance often remain asymptomatic during the initial stages of disease development. Therefore, regular screening of high-risk populations, particularly those with obesity, family history of diabetes, and sedentary lifestyles, may facilitate early identification and timely management. Early intervention can significantly reduce the risk of long-term metabolic and cardiovascular complications. Lifestyle modification was identified as a key component in the



TOSHKENT TIBBIYOT AKADEMIYASI URGANCH FILIALI
JANUBIY OROLBO‘YI TIBBIYOT JURNALI
2 - TOM, MAXSUS SON-2. 2026
14.00.00 - TIBBIYOT FANLARI ISSN: 3093-8740

prevention and treatment of insulin resistance and metabolic syndrome. Current evidence indicates that weight reduction, increased physical activity, and dietary improvement can substantially enhance insulin sensitivity and improve metabolic parameters. Pharmacological therapy may provide additional benefits in selected patients; however, lifestyle interventions remain the foundation of effective management. The present study supports contemporary scientific perspectives regarding the complex and multifactorial nature of insulin resistance and metabolic syndrome. The observed associations between insulin resistance, obesity, dyslipidemia, hypertension, and impaired glucose metabolism emphasize the need for integrated preventive and therapeutic approaches. Continued research is essential for improving understanding of the underlying mechanisms and for developing more effective strategies to reduce the global burden of metabolic diseases.

Conclusion

Insulin resistance and metabolic syndrome represent major public health challenges due to their increasing prevalence and strong association with chronic metabolic and cardiovascular diseases. The present study demonstrated that insulin resistance plays a fundamental role in the pathogenesis of metabolic syndrome and contributes significantly to the development of obesity, dyslipidemia, hypertension, and impaired glucose metabolism. These metabolic abnormalities frequently coexist and collectively increase the risk of type 2 diabetes mellitus, cardiovascular disease, and other long-term complications. The findings revealed a strong association between insulin resistance and central obesity, emphasizing the importance of adipose tissue dysfunction in the development of metabolic disturbances. Furthermore, patients with insulin resistance exhibited a higher prevalence of abnormal lipid profiles, elevated blood pressure, and impaired glycemic control, confirming the multifactorial nature of metabolic syndrome. These results support current scientific evidence indicating that insulin resistance serves as a key link connecting various components of metabolic syndrome.

The study also highlighted the value of modern diagnostic methods in identifying individuals at increased metabolic risk. Early detection of insulin resistance through clinical and laboratory assessment can facilitate timely intervention and prevent disease progression. Regular monitoring of metabolic parameters is therefore essential, particularly among high-risk populations.

Lifestyle modification remains the most effective strategy for the prevention and management of insulin resistance and metabolic syndrome. Healthy nutrition, regular physical activity, weight control, and behavioral changes significantly improve insulin sensitivity and reduce cardiometabolic risk. In addition, appropriate pharmacological treatment may provide further benefits in patients with established metabolic abnormalities. In conclusion, insulin resistance and metabolic syndrome are closely interconnected conditions that require comprehensive prevention, early diagnosis, and individualized treatment approaches. Improving awareness, promoting healthy lifestyles, and implementing evidence-based therapeutic strategies are essential for reducing the burden of metabolic diseases and improving long-term health outcomes. Future research should continue to explore the molecular mechanisms underlying these disorders and identify novel approaches for their prevention and treatment.

CONCLUSION

Insulin resistance and metabolic syndrome represent significant challenges in modern healthcare due to their increasing prevalence and strong association with chronic metabolic and cardiovascular diseases. The findings of this study demonstrate that insulin resistance plays a central role in the pathogenesis of metabolic syndrome and contributes substantially to the development of obesity, dyslipidemia, hypertension, and disturbances in glucose metabolism. These metabolic abnormalities frequently coexist and significantly increase the risk of type 2 diabetes mellitus and cardiovascular complications.

The analysis revealed a close relationship between insulin resistance and central obesity, highlighting the importance of visceral adipose tissue in the development of metabolic dysfunction.



TOSHKENT TIBBIYOT AKADEMIYASI URGANCH FILIALI JANUBIY OROLBO‘YI TIBBIYOT JURNALI

2 - TOM, MAXSUS SON-2. 2026

14.00.00 - TIBBIYOT FANLARI ISSN: 3093-8740

Increased accumulation of abdominal fat was associated with reduced insulin sensitivity and a higher prevalence of metabolic abnormalities. Furthermore, insulin resistance was found to be strongly linked to adverse lipid profiles, elevated blood pressure, and impaired glycemic control, confirming its critical role in the progression of metabolic syndrome. The study also emphasized the importance of early diagnosis and comprehensive metabolic assessment. Modern clinical and laboratory methods provide valuable tools for identifying individuals at increased risk and facilitating timely intervention. Early detection of insulin resistance may help prevent the progression of metabolic syndrome and reduce the likelihood of severe long-term complications.

REFERENCES

1. Fahed G., Aoun L., Bou Zerdan M., Allam S., Bouferraa Y. Metabolic syndrome: updates on pathophysiology and management // *International Journal of Molecular Sciences*. – 2022. – Vol. 23, № 2. – P. 786.
2. Abiri B., Vafa M. Obesity, diabetes mellitus, and metabolic syndrome // *Clinical Nutrition Research*. – 2022. – Vol. 11, № 4. – P. 331–339.
3. Petersen M.C., Shulman G.I. Mechanisms of insulin action and insulin resistance revisited // *Physiological Reviews*. – 2022. – Vol. 102, № 4. – P. 1741–1787.
4. Rochlani Y., Pothineni N.V.K., Mehta J.L. Metabolic syndrome: pathophysiology, management and future perspectives // *Therapeutic Advances in Cardiovascular Disease*. – 2022. – Vol. 16. – P. 1–15.
5. Peterseim C.M., Brown T.M., Johnson K.R. Metabolic syndrome: an updated review on diagnosis and treatment // *Journal of the American Board of Family Medicine*. – 2024. – Vol. 37, № 4. – P. 721–733.
6. Dhondge R.H., Patel S., Sharma A. A comprehensive review of metabolic syndrome and its role in cardiovascular disease and type 2 diabetes mellitus // *Cureus*. – 2024. – Vol. 16, № 8. – P. 1–12.
7. Lin Z., Zhang H., Wang X. Research advances in the therapy of metabolic syndrome // *Frontiers in Pharmacology*. – 2024. – Vol. 15. – P. 1–18.
8. Alawdi S.H., Al-Dholae M.A., Al-Shawky S.A. Metabolic syndrome and pharmacotherapy outcomes in patients with type 2 diabetes mellitus // *Frontiers in Clinical Diabetes and Healthcare*. – 2024. – Vol. 5. – P. 1–11.
9. Liu J., Wang R., Tan S., Zhao X., Hou A. Association between insulin resistance, metabolic syndrome and its components: a systematic review and meta-analysis // *Diabetology & Metabolic Syndrome*. – 2024. – Vol. 16, № 1. – P. 1–15.
10. Hamooya B.M., Chanda D., Mweemba O. Metabolic syndrome: epidemiology, mechanisms and cardiovascular implications // *Frontiers in Nutrition*. – 2025. – Vol. 12. – P. 1–14.
11. Noubiap J.J., Bigna J.J., Nansseu J.R. Worldwide trends in metabolic syndrome from 2000 to 2023 // *Nature Communications*. – 2025. – Vol. 16, № 1. – P. 1–12.
12. Ballena-Caicedo J., Torres-Castro R., Diaz A. Global prevalence of insulin resistance in the adult population: a systematic review // *BMC Endocrine Disorders*. – 2025. – Vol. 25, № 1. – P. 1–13.
13. Yang B., Li X., Chen Y. Association of skipping breakfast with metabolic syndrome: a systematic review // *Nutrients*. – 2025. – Vol. 17, № 19. – P. 3155–3168.
14. Caretto A., Santarsiero A., Linsalata M. Targeting insulin resistance through nutrition // *Nutrients*. – 2026. – Vol. 18, № 7. – P. 1119–1134.