

## A Review of Biomarker in Insulin Resistance through Metabolomic Perspective

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### Structured Abstract

**Background:** Insulin resistance (IR) is a critical metabolic condition that significantly contributes to the development of type 2 diabetes, cardiovascular diseases, and other related disorders. The asymptomatic progression of IR, often undetected until advanced stages, highlights the limitations of traditional biomarkers, which lack the sensitivity and specificity required for early diagnosis. In response, the field of metabolomics has emerged as a powerful tool for identifying novel biomarkers that reflect real-time physiological and pathological changes at the metabolic level. This review aims to comprehensively evaluate metabolomic biomarkers associated with insulin resistance, compare their diagnostic efficacy with conventional markers, and assess their roles in early detection, disease prognosis, and therapeutic advancement.

**Methods:** The methodology involved a critical analysis of current scientific literature, focusing on key metabolites—particularly amino acids (e.g., branched-chain amino acids, aromatic amino acids, kynurenine) and lipid-related compounds (e.g., diacylglycerols, ceramides, acylcarnitines)—as well as the analytical techniques used for their detection, including mass spectrometry (MS), nuclear magnetic resonance (NMR), and chromatography-based platforms and also about the current development of aptamer as therapeutic strategy for insulin resistance.

**Results:** The findings indicate that metabolomic biomarkers offer superior accuracy, specificity, and sensitivity compared to traditional biomarkers such as HOMA-IR and HbA1c. These metabolites are intricately linked to disruptions in metabolic pathways and demonstrate strong correlations with insulin resistance in both clinical and experimental studies. Moreover, metabolomic profiling enables early detection of metabolic alterations prior to the onset of overt hyperglycemia, allowing for timely intervention. Additionally, these biomarkers support the development of personalized treatment strategies by identifying targetable metabolic pathways. The function of Aptamer 1R-A62 that can give better benefit than natural insulin also highlighting the potential use of metabolites as therapeutic strategy for metabolic related disease.

**Conclusion:** In conclusion, metabolomic biomarkers represent a promising advancement in the early diagnosis and management of insulin resistance. Future research should focus on clinical validation, standardization of analytical protocols, and integration of metabolomics into routine diagnostic workflows to enhance preventive and therapeutic outcomes.

**Keywords:** Insulin Resistance, Metabolomic Biomarkers, Mass Spectrometry, Aptamer Therapeutic, Early Diagnosis

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