

# A Comprehensive Review on Management of Insulin Resistance Disorder by Innovative Technologies and Advancement of Precision Medicinal Therapies

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## ABSTRACT

The increasing prevalence of insulin resistance disorders, including type 2 diabetes and metabolic syndrome, underscores the urgent need for advanced diagnostic and therapeutic strategies. This review aims to explore the role of innovative precision medicine in revolutionizing the assessment and management of insulin resistance disorders. By integrating genetic, epigenetic and environmental data, precision medicine provides a more nuanced understanding of disease mechanisms and enables personalized treatment approaches. This review mainly highlights recent advancements in biomarker identification, novel therapeutic targets and individualized treatment regimens driven by precision medicine. We emphasize the importance of emerging technologies like genomics, metabolomics and digital health tools in enhancing diagnostic accuracy and therapeutic efficacy. The integration of these innovations promises to improve patient outcomes and offers a new paradigm in the management of insulin resistance disorders. By addressing the heterogeneous nature of insulin resistance disorders, precision medicine offers a promising avenue for more effective and efficient healthcare solutions. Despite the potential, challenges remain, including ethical considerations, high costs and the need for specialized training. The successful integration of precision medicine into routine clinical practice requires standardized protocols and improved infrastructure. Future research should address these challenges and focus on translating technological and scientific advancements into practical, equitable healthcare solutions. In conclusion, precision medicine offers a transformative approach to managing insulin resistance, with the potential to improve patient outcomes and advance our understanding of metabolic disorders.

**Keywords:** Genomic Biomarkers, Healthcare Integration, Insulin Resistance, Metabolic Disorders, Targeted Therapies.

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## INTRODUCTION

Type 2 Diabetes Mellitus (T2DM) and metabolic syndrome are two examples of insulin resistance disorders that have spread like wildfire around the world, posing serious health and economic hazards.<sup>1</sup> These conditions are characterized by impaired insulin action, leading to hyperglycemia and a range of metabolic complications.<sup>2</sup> The traditional approaches to diagnosing and

managing insulin resistance disorders have often been limited by their one-size-fits-all nature, failing to address the underlying heterogeneity of these conditions.<sup>3</sup> Recent advancements in the field of precision medicine offer new avenues for tackling the complexities of insulin resistance disorders. Precision medicine aims to customize treatment according to each person's unique genetic, environmental and lifestyle variations, thus providing more targeted and effective interventions.<sup>4,5</sup> Innovative diagnostic tools and therapeutic strategies are being developed to enhance the precision and efficacy of managing insulin resistance disorders.<sup>6,7</sup> This review aims to provide a comprehensive overview of the recent advancements in precision medicine and innovative technologies for managing insulin resistance disorders.<sup>8</sup>



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Additionally, we will address the promise of future advances in technology to revolutionize the detection and treatment of insulin resistance and ultimately enhance the outcomes for patients.<sup>9</sup> By addressing the diverse and multifaceted nature of these disorders, precision medicine holds promise for more effective and efficient healthcare solutions.<sup>10</sup>

### Limitations of traditional diagnostic and therapeutic approaches

Traditional diagnostic and therapeutic approaches, while foundational in medical practice, come with certain limitations that can hinder their effectiveness in addressing complex health conditions.<sup>11</sup> Diagnostic methods such as physical examinations, imaging and standard laboratory tests often rely on observable symptoms and standard biomarkers, which may not capture the underlying pathophysiology of a disease in its early stages.<sup>12</sup> This can lead to delayed diagnoses or misdiagnoses, particularly in conditions that present with non-specific or overlapping symptoms.<sup>13,14</sup> As a result, some patients may experience suboptimal outcomes or adverse effects, highlighting the need for more personalized and targeted interventions.<sup>15,16</sup> This kind of approach is especially important for controlling insulin resistance, which is a major risk factor for developing type 2 diabetes and other chronic metabolic conditions.<sup>17</sup> Traditional treatments for insulin resistance often involve generalized recommendations for diet, exercise and medication.<sup>18</sup>

## EPIDEMIOLOGY

### Global Scenario of Insulin Resistance Among Patients

A serious global health concern is insulin resistance, which occurs when the body's cells do not react to insulin as intended.<sup>19</sup> This disorder is closely linked to a condition called metabolic syndrome, characterized by obesity, elevated blood pressure and high cholesterol levels.<sup>20,21</sup> Urbanization, particularly in cities where sedentary lifestyles and high-calorie diets are more common, has further exacerbated this issue.<sup>22</sup> Insulin resistance is a global problem, affecting both developed and developing countries.<sup>23</sup> This rise in insulin resistance is also fueling the global diabetes crisis.<sup>24</sup> The International Diabetes Federation predicts that by 2045, over 783 million adults will have diabetes, with most cases stemming from insulin resistance.<sup>25,26</sup> Genetic factors are also recognized as playing a crucial role in the development of insulin resistance, with some populations being more genetically predisposed to the condition.<sup>27</sup> The field of precision medicine, which tries to customize treatments based on unique genetic profiles and other personal aspects, is growing in prominence as a result of the approach as shown in Figure 1.<sup>28</sup>

## Prevalence

The prevalence of insulin resistance has seen a significant increase globally, reflecting broader trends in rising obesity rates and changing lifestyles.<sup>30</sup> Insulin resistance is a common condition that affects a substantial portion of the population, with estimates suggesting that approximately 30-40% of adults in developed countries exhibit some degree of insulin resistance.<sup>31</sup> This prevalence is similarly high in many developing nations as well, where rapid urbanization and dietary shifts towards processed high-calorie foods contribute to increasing rates of metabolic disorders.<sup>32,33</sup> Globally, the World Health Organization highlights that insulin resistance is a significant health issue, particularly in regions experiencing economic development and lifestyle transitions, such as parts of Asia, the Middle East and Africa.<sup>34</sup> The rising prevalence is also influenced by an aging population, sedentary lifestyles and dietary patterns rich in refined carbohydrates and fats.<sup>35</sup> Additionally, genetic predispositions and socio-economic factors further contribute to the high rates of insulin resistance across different populations.<sup>36</sup>

## PATHOPHYSIOLOGY OF INSULIN RESISTANCE

The hormone insulin, which is essential for controlling blood glucose levels, causes the body's cells to become less sensitive, leading to the development of insulin resistance.<sup>37</sup> Insulin helps cells, especially those in muscle, liver and adipose tissues, absorb glucose during regular digestion so that it can be used as fuel or preserved for later.<sup>38</sup> However, with insulin resistance, these kinds of cells fail to react appropriately to insulin, resulting in diminished glucose uptake and higher blood sugar levels.<sup>39</sup> One key factor is the excess accumulation of fatty acids and inflammatory markers in tissues, particularly in the liver and muscles.<sup>40</sup> This can interfere with the insulin signaling pathway, impairing the ability of Insulin Receptors (INSR) on cell surfaces to effectively bind and activate insulin.<sup>41</sup> When adipose tissue swells, cytokines associated with inflammation are released, which may interfere with the way insulin functions normally.<sup>42,43</sup> Moreover, genetic predisposition and lifestyle factors such as poor diet, lack of physical activity and stress can exacerbate insulin resistance.<sup>44,45</sup>

### Mechanisms underlying insulin resistance

Chronic inflammation plays a significant role in this disruption. IL-6 and TNF-alpha are cytokines that trigger inflammation released from enlarged adipose tissue in obese people. These cytokines disrupt the insulin signaling pathway by preventing important signaling proteins including INSR Substrate (IRS) proteins from functioning.<sup>46</sup> This inhibition reduces the effectiveness of insulin in promoting glucose uptake by cells, leading to elevated blood sugar levels.<sup>47</sup> Oxidative stress refers to the state of being unbalanced between the body's capacity to neutralize Reactive Oxygen Species (ROS) and the amount of ROS that is produced.<sup>48</sup> This oxidative damage is particularly

detrimental to insulin-sensitive tissues like the liver, muscles and adipose tissue.<sup>49</sup> Additionally, an excess of free fatty acids in the bloodstream, often due to a high-fat diet or obesity, can lead to the accumulation of lipid intermediates within cells shown in Figure 2.<sup>50</sup> These intermediates, such as Diacylglycerol (DAG), can activate certain kinases that inhibit insulin signaling, further contributing to insulin resistance shown in the image of the graphical abstract.<sup>51</sup>

### Genetic Factors

Genetic predisposition plays a significant role in insulin resistance. Specific genetic variants can affect INSR function, glucose metabolism and fat storage.<sup>52</sup> Research has identified several genes associated with insulin resistance and metabolic syndrome, such as those involved in the insulin signaling pathway and glucose homeostasis. For instance, variations in genes like PPARG and TCF7L2 have been linked to an increased risk of insulin resistance and type 2 diabetes. Understanding these genetic predispositions can help identify individuals at higher risk and tailor preventive and therapeutic strategies.<sup>53</sup>

### Epigenetic Factors

Epigenetics involves changes in gene expression that do not alter the DNA sequence itself but are influenced by environmental and lifestyle factors.<sup>54</sup> Epigenetic modifications, such as DNA methylation and histone modification, can affect how genes related to insulin sensitivity are expressed.<sup>55</sup> These changes can be triggered by various factors, including diet, stress and exposure to toxins.<sup>56</sup>

### Environmental Factors

Environmental influences are crucial in the development of insulin resistance. Lifestyle factors, including diet, physical

activity and body weight, significantly impact insulin sensitivity.<sup>57</sup> High-calorie diets rich in refined carbohydrates and unhealthy fats contribute to obesity and insulin resistance.<sup>58</sup> Sedentary behavior and lack of physical activity exacerbate these effects by impairing glucose metabolism and promoting fat accumulation.<sup>59</sup>

### Heterogeneity of Insulin Resistance Disorders

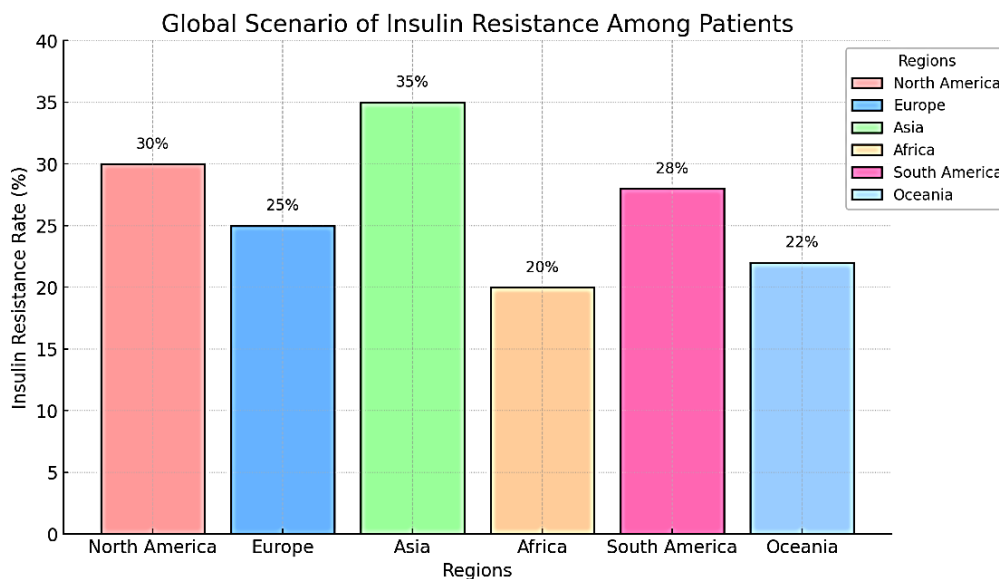
Insulin resistance disorders exhibit considerable heterogeneity, reflecting a wide range of clinical presentations and underlying mechanisms.<sup>60</sup> This variability arises from differences in genetic backgrounds, lifestyle factors and the interplay of various metabolic pathways.<sup>61</sup>

### Genetic Heterogeneity

Genetic factors contribute significantly to the diverse manifestations of insulin resistance.<sup>62</sup> Variations in genes related to insulin signaling, glucose metabolism and adipose tissue function can lead to different degrees and types of insulin resistance. For example, mutations in genes like INSR and PPARG (Peroxisome Proliferator-Activated Receptor Gamma) can result in distinct forms of insulin resistance, affecting how individuals respond to insulin and other treatments.<sup>63</sup>

### Metabolic Variability

Insulin resistance can affect various metabolic pathways differently, leading to distinct clinical presentations. Some individuals may experience insulin resistance primarily in the liver, resulting in elevated fasting glucose levels and an increased risk of type 2 diabetes.<sup>64</sup> Others may have insulin resistance predominantly in muscle tissue, which can manifest as impaired glucose uptake and reduced exercise tolerance.<sup>65</sup> The impact on fat tissue can also vary, with some individuals showing increased fat accumulation and others experiencing dysfunctional fat metabolism.<sup>66</sup>



**Figure 1:** Bar diagram shows the global Scenario of Insulin Resistance Among Patients.<sup>29</sup>

## Lifestyle and Environmental Influences

Environmental factors, such as diet, physical activity and stress, further contribute to the heterogeneity of insulin resistance disorders.<sup>67</sup> Variations in dietary habits, such as high-fat or high-sugar diets and differences in levels of physical activity can influence the severity and presentation of insulin resistance.<sup>68</sup> Additionally, chronic stress and exposure to environmental pollutants can exacerbate metabolic dysfunction in some individuals, leading to varied clinical outcomes.<sup>69</sup>

## INNOVATIVE DIAGNOSTIC TOOLS

Innovative diagnostic tools are revolutionizing the way insulin resistance and related metabolic disorders are identified and managed.<sup>71</sup> Advances in technology have introduced a range of sophisticated tools that offer more precise and timely diagnoses compared to traditional methods.<sup>72,73</sup> Additionally, advanced imaging techniques, such as Magnetic Resonance Spectroscopy (MRS), enable non-invasive assessment of liver fat content, which is crucial for evaluating hepatic insulin resistance.<sup>74</sup>

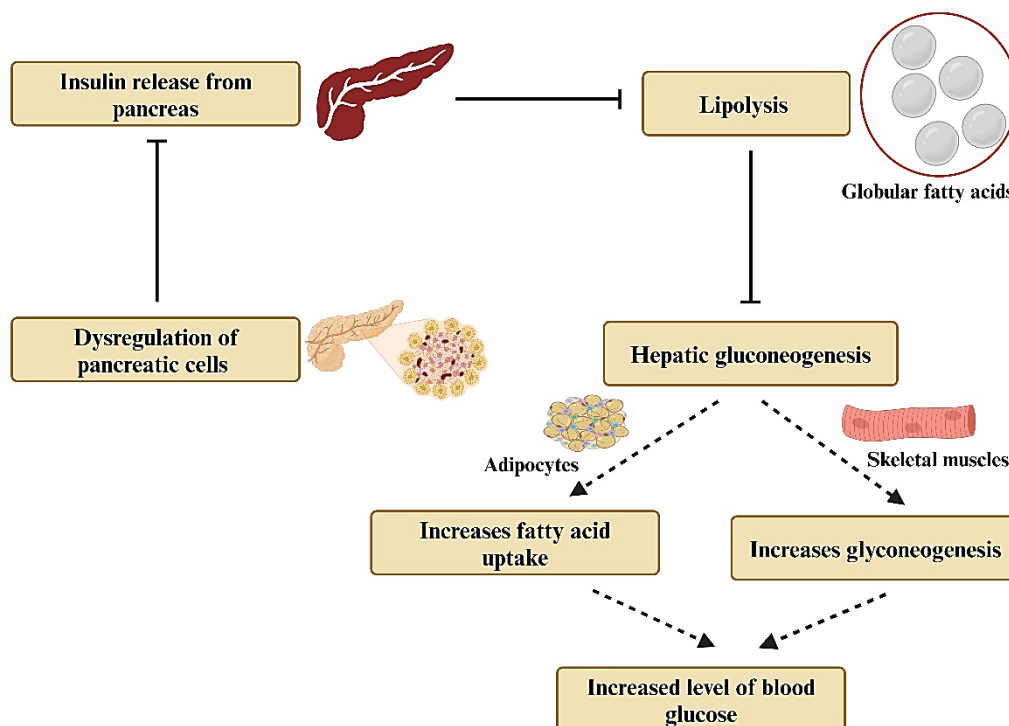
## Biomarker identification and validation

Biomarker identification and validation are crucial processes in advancing the diagnosis and treatment of insulin resistance and related metabolic disorders as shown in Table 1.<sup>75</sup> Biomarkers are measurable indicators of biological processes or conditions and their identification involves discovering substances or characteristics that are associated with the onset or progression of a disease.<sup>76</sup> For insulin resistance, biomarkers might include

specific proteins, lipids, or metabolites found in blood or other bodily fluids that reflect changes in insulin sensitivity or glucose metabolism.<sup>77</sup> The validation of these biomarkers is essential to ensure their reliability and clinical utility.<sup>78</sup> The ability to discover putative biomarkers for insulin resistance has been greatly improved by recent developments in omics technology, including genomics, proteomics and the study of metabolism.<sup>79</sup> These technologies enable comprehensive analyses of genetic variations, protein expressions and metabolic profiles, leading to the discovery of novel biomarkers that may offer new insights into the mechanisms underlying insulin resistance.<sup>80</sup>

## Genomic biomarkers for early detection

Genomic biomarkers are increasingly recognized for their potential in the early detection of insulin resistance and related metabolic disorders.<sup>86</sup> These biomarkers involve specific genetic variations or mutations that are associated with an increased risk of developing insulin resistance.<sup>87</sup> Advancements in genomic technologies, such as high-throughput sequencing and genotyping, have made it possible to discover and validate genomic biomarkers with greater precision. For example, variations in genes like TCF7L2 and PPARG have been linked to insulin resistance, providing valuable insights into an individual's risk profile.<sup>88</sup> The integration of genomic data with other omics approaches, such as transcriptomics and proteomics, enhances the ability to identify biomarkers that reflect not only genetic predispositions but also changes in gene expression and protein function.<sup>89,90</sup>



**Figure 2:** Graphical Illustration showed a Pathogenesis of Insulin Resistance.<sup>70</sup>

**Table 1: Biomarker Identification and Validation in the Treatment of Insulin Resistance.**

Sl. No.	Biomarker Type	Examples	Mechanism/Role in Insulin Resistance	Validation Techniques	References
1	Genetic Biomarkers	SNPs in IRS1, PPARG	Genetic variants associated with insulin signaling pathways influence insulin sensitivity.	Genome-Wide Association Studies, Next-Generation Sequencing.	81
2	Protein Biomarkers	Adiponectin, C-reactive protein	Proteins involved in inflammation and metabolism correlated with insulin resistance severity.	ELISA, Mass Spectrometry, Western Blot.	82
3	Metabolic Biomarkers	Glucose, Free fatty acids	Elevated levels indicate metabolic dysregulation linked to insulin resistance.	Metabolomics, High-Performance Liquid Chromatography.	83
4	Inflammatory Biomarkers	IL-6, TNF-alpha	Inflammatory cytokines that impair insulin signaling pathways in target tissues.	ELISA, Flow Cytometry.	84
5	MicroRNA Biomarkers	miR-122, miR-192	MicroRNAs that regulate gene expression related to insulin resistance and glucose metabolism.	Quantitative PCR (qPCR), Microarray Analysis.	85

### Epigenomic and metabolomic biomarkers

Epigenomic and metabolomic biomarkers are emerging as powerful tools for understanding and detecting insulin resistance. Epigenomic biomarkers involve modifications to the genome that affect gene expression without altering the DNA sequence itself.<sup>91</sup> These modifications, such as DNA methylation and histone modifications, can influence how genes related to insulin signaling and glucose metabolism are expressed.<sup>92</sup> By profiling metabolites in blood, urine, or other bodily fluids, researchers can identify patterns and biomarkers associated with altered glucose metabolism and insulin action.<sup>93</sup>

### Role of digital health tools (wearable devices, mobile apps) in continuous monitoring

Digital health tools, including wearable devices and mobile apps, play a transformative role in the continuous monitoring of health conditions such as insulin resistance. Wearable devices, such as smartwatches and fitness trackers, offer real-time tracking of various physiological metrics, including physical activity, heart rate and sleep patterns.<sup>94</sup> These devices enable individuals to monitor their daily behaviors and physiological responses, providing valuable insights into factors that influence insulin sensitivity and overall metabolic health.<sup>95</sup> Some apps are integrated with Continuous Glucose Monitors (CGMs), allowing for seamless tracking of glucose levels throughout the day and facilitating immediate adjustments to lifestyle or medication based on real-time data.<sup>96,97</sup> By providing a comprehensive view of daily habits and metabolic responses, digital health tools contribute significantly to personalized and effective management strategies for insulin resistance and related metabolic conditions.<sup>98</sup>

### NOVEL THERAPEUTIC TARGETS ON INSULIN-RESISTANT

Precision medicine is revolutionizing the identification of new therapeutic targets by tailoring treatment strategies to an individual's unique genetic, molecular and environmental profile. This approach enables a more precise understanding of the underlying mechanisms driving diseases like insulin resistance and metabolic disorders.<sup>99</sup> Targeted therapies informed by genetic and epigenetic data represent a significant advancement in personalized medicine, offering more precise and effective treatment options for conditions such as insulin resistance and metabolic disorders.<sup>100</sup> Personalized treatment regimens are tailored strategies designed to address the unique characteristics and needs of individual patients, based on comprehensive assessments of their genetic, environmental and lifestyle factors. This approach moves beyond one-size-fits-all treatments by integrating detailed patient data, including genetic profiles, metabolic markers and lifestyle habits, to develop customized therapeutic plans.<sup>101</sup> The personalized regimens may involve specific dietary recommendations, targeted physical activity plans and medications selected based on genetic predispositions and biomarkers.<sup>102</sup> This approach involves using multiple therapeutic agents or strategies simultaneously to target different pathways or mechanisms involved in the disease.<sup>103</sup> The rationale behind combination therapies is that by addressing multiple facets of a condition, they can achieve a synergistic effect, improving overall efficacy and potentially overcoming limitations associated with single-agent treatments.<sup>104</sup> The mechanisms underlying T2DM and treatment options for insulin resistance shown in Figure 3. Diagram illustrating the mechanisms underlying Type 2 Diabetes Mellitus (T2DM) and treatment options for insulin resistance.<sup>105</sup>

## EMERGING TECHNOLOGIES IN THE MANAGEMENT OF INSULIN RESISTANCE

Emerging technologies are significantly advancing the management of chronic situations, including insulin resistance and metabolic disorders. Innovations such as Artificial Intelligence (AI) and machine learning are transforming how data is analyzed and utilized, enabling more accurate predictions and adapted treatment plans. AI algorithms can analyze vast quantities of patient data, including genetic, clinical and lifestyle information, to identify patterns and predict disease progression, chief to more effective and timely interventions. Some of the specific points are given below in detail and shown in Figure 4.<sup>106</sup>

### Genomics and Personalized Medicine

Genomics has become a cornerstone of personalized medicine, allowing for tailored healthcare approaches based on an individual's genetic profile. By analyzing an individual's genome, healthcare providers can identify genetic variations that predispose them to certain diseases, including insulin resistance and metabolic disorders.<sup>107</sup> This genetic information enables the development of personalized treatment plans that address specific genetic factors, optimizing therapeutic efficacy and minimizing adverse effects. Personalized medicine also facilitates the selection of targeted therapies that align with the unique genetic makeup of each patient, leading to more precise and effective interventions.<sup>108</sup>

### Role of Big Data and Artificial Intelligence in Precision Medicine

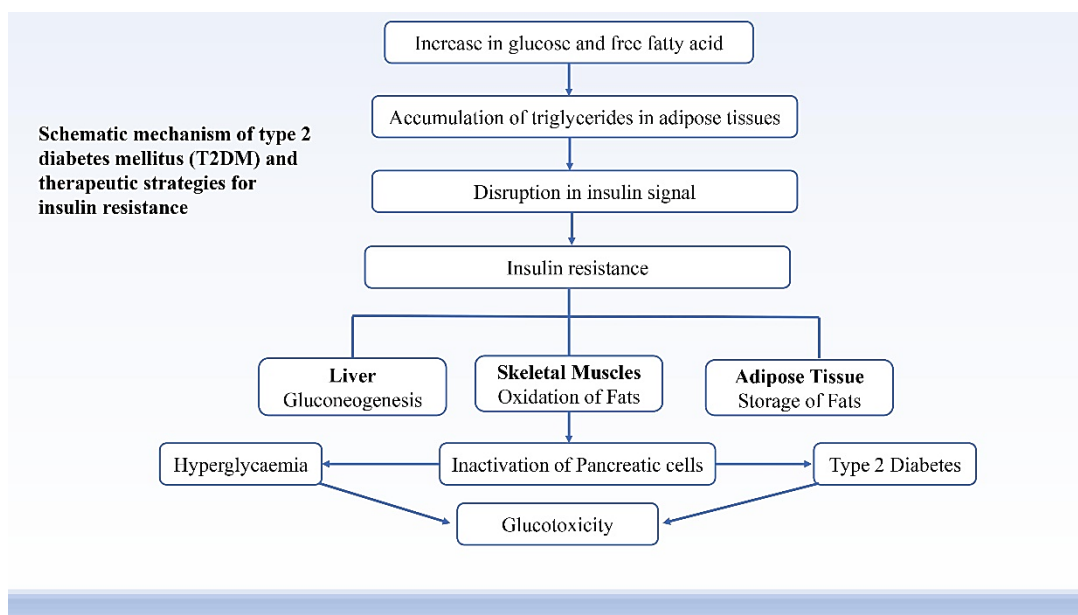
By facilitating the analysis and interpretation of intricate health data, big data and AI are transforming precision medicine. AI algorithms can analyze enormous volumes of data from many sources, such as genetic data, electronic health records and lifestyle factors, to find patterns and insights that guide individualized treatment plans.<sup>109</sup> This combination of big data and AI improves diagnostic accuracy, predicts disease risk and personalizes treatment plans, leading to more effective and individualized healthcare.<sup>110</sup>

### Advances in Drug Development and Delivery Systems

Advances in drug development and delivery systems are significantly improving the management of complex conditions. Innovative approaches, such as targeted drug delivery and nanotechnology, enable more precise and controlled release of medications, enhancing their efficacy and reducing side effects.<sup>111</sup> Additionally, advancements in drug discovery, such as high-throughput screening and computational drug design, accelerate the identification of novel compounds and therapeutic targets, leading to the development of more effective and specific treatments shown in Table 2.<sup>112</sup>

### Telemedicine and Its Impact on Patient Management

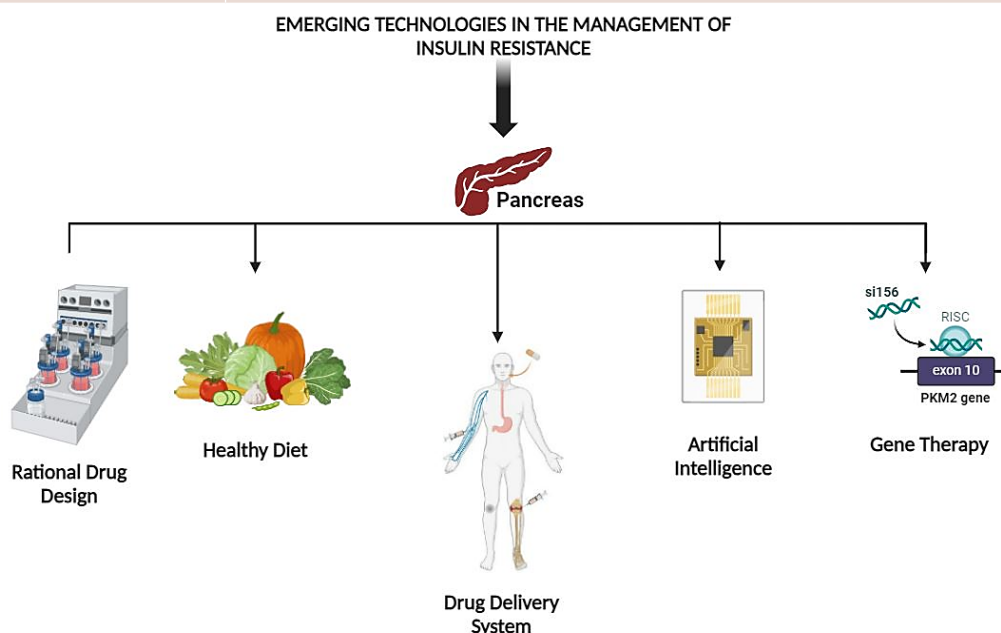
Telemedicine has transformed patient management by providing convenient and accessible healthcare solutions through digital platforms. It enables remote consultations, allowing patients to receive care from healthcare providers without the need for in-person visits. This approach improves access to care, especially



**Figure 3:** Diagram illustrating the mechanisms underlying Type 2 Diabetes Mellitus (T2DM) and treatment options for insulin resistance.

**Table 2: Various developments in drug discovery with their cellular mechanisms of action.**

Sl.No.	Technology/ Advancement	Mechanism on Cells	References
1	Rational Drug Design	Drugs are designed to specifically bind to target proteins or receptors on cells, inhibiting or activating specific pathways.	113
2	Biologics and Biosimilars	Biologics, such as monoclonal antibodies, bind to specific antigens on cell surfaces, marking them for immune destruction or blocking signaling pathways.	114
3	Artificial Intelligence in Drug Discovery	AI models predict molecular interactions and optimize compounds that specifically target cellular proteins, improving efficacy and reducing off-target effects.	115
4	Gene Therapy	Introduction of genetic material into cells to replace faulty genes or to introduce new genes that can help fight disease at the cellular level.	116
5	CRISPR-Cas9	A method for editing the genome that makes it possible to precisely alter DNA inside cells, correcting mutations in genes.	117

**Figure 4:** Novel therapeutic approaches to maintain the insulin resistant disorder.

for individuals in remote or underserved areas and facilitates ongoing monitoring and follow-up.<sup>118</sup> The impact of telemedicine extends to enhancing patient engagement, reducing healthcare costs and improving overall management of chronic conditions by providing more flexible and accessible healthcare options.<sup>119</sup>

## FUTURE DIRECTIONS AND CHALLENGES

The future of precision medicine in managing insulin resistance is poised for significant advancements, driven by continuous innovations in technology and research. One of the key directions includes the further refinement of multi-omics approaches, which integrate data from genomics, proteomics and metabolomics to offer a more comprehensive understanding of individual variations in insulin resistance.<sup>120</sup> However, these advancements also come with challenges. Ethical, legal and social implications,

such as the protection of genetic data and equitable access to new technologies, need to be addressed to ensure fair and responsible use of precision medicine.<sup>121</sup>

## Future Advancements in Precision Medicine

The future of precision medicine in managing insulin resistance promises several exciting advancements. Emerging technologies, such as advanced genomics and proteomics, are likely to further refine our understanding of the genetic and molecular underpinnings of insulin resistance. Innovations in multi-omics approaches, which integrate genomics, transcriptomics and metabolomics, will enable more comprehensive profiling of individual patients and enhance the ability to identify personalized therapeutic targets. The potential use of gene editing technologies, such as Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR), could also play a role in

correcting genetic predispositions to insulin resistance, paving the way for novel preventive and therapeutic strategies.<sup>122,123</sup>

### Barriers to Widespread Adoption and Strategies

Several barriers hinder the widespread adoption of precision medicine, including high costs, limited access to advanced technologies and the need for specialized training among healthcare providers.<sup>124</sup>

### Integration of Precision Medicine into Routine Clinical Practice

There are numerous significant obstacles to incorporating precision medicine into standard clinical practice. These include developing standardized protocols for data collection and analysis, ensuring interoperability between different healthcare systems and aligning precision medicine approaches with existing treatment guidelines.<sup>125</sup> Facilitating collaboration among academics, physicians and policymakers can also help translate study findings into practical uses.<sup>126</sup>

### CONCLUSION

In Conclusion, the journey through precision medicine in managing insulin resistance unveils a landscape brimming with potential and innovation. The key findings underscore the transformative impact of genomic and epigenomic insights, which are paving the way for more precise diagnoses and personalized treatment strategies. Advances in wearable technology and data analytics are revolutionizing how we monitor and manage metabolic health, while breakthroughs in drug development and delivery systems promise more effective and targeted therapies. Looking ahead, the implications for both research and clinical practice are profound. Future research must continue to explore the integration of multi-omics data and address the ethical, legal and social challenges associated with precision medicine. Clinically, embedding these innovations into routine care will require developing robust protocols and fostering collaboration among healthcare professionals to confirm that these advancements are accessible and beneficial to specific patients. Furthermore, precision medicine holds extraordinary promise for transforming the management of insulin resistance. By exploiting the potential of customized data and modern technologies, we are on the cusp of a new era in healthcare that offers more tailored, effective and equitable treatment options. As this paper navigates the challenges and embraces the opportunities ahead, precision medicine stands poised to redefine our approach to metabolic disorders and improve patient outcomes on a global scale.

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### CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

### ABBREVIATIONS

**AI:** Artificial intelligence; **CGM:** Continuous glucose monitors; **CRISPR:** Clustered regularly interspaced short palindromic repeats; **DAG:** Diacylglycerol; **DM:** Diabetes mellitus; **DNA:** Deoxyribonucleic acid; **ELISA:** Enzyme-linked immunosorbent assay; **INSR:** Insulin receptors; **IRS:** Insulin receptor substrate; **MRS:** Magnetic resonance spectroscopy; **PCR:** Polymerase chain reaction; **PPARG:** Peroxisome proliferator-activated receptor gamma; **RNA:** Ribonucleic acid; **ROS:** Reactive oxygen species; **T2DM:** Type 2 diabetes mellitus; **TCF:** Transcription factors; **TNF:** Tumour necrosis factor.

### SUMMARY

This review mainly highlights recent advancements in biomarker identification, novel therapeutic targets and individualized treatment regimens driven by precision medicine. We emphasize the importance of emerging technologies like genomics, metabolomics and digital health tools in enhancing diagnostic accuracy and therapeutic efficacy. The key findings underscore the transformative impact of genomic and epigenomic insights, which are paving the way for more precise diagnoses and personalized treatment strategies. Future research must continue to explore the integration of multi-omics data and address the ethical, legal and social challenges associated with precision medicine.

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