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ARTIFICIAL INTELLIGENCE AND PRECISION MEDICINE IN OBESITY MANAGEMENT: CURRENT APPLICATIONS, CHALLENGES, AND FUTURE DIRECTIONS

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ABSTRACT

Obesity is a complex, chronic, and heterogeneous disease that affects more than one billion people worldwide and represents one of the greatest public health challenges of the twenty-first century. Despite significant advances in pharmacotherapy, including glucagon-like peptide-1 receptor agonists (GLP-1 RAs) and dual incretin-based therapies, considerable interindividual variability in treatment response remains a major obstacle to effective obesity management. The emergence of precision medicine and artificial intelligence (AI) has created new opportunities to address this challenge by enabling individualized risk assessment, phenotype-based treatment selection, and prediction of therapeutic outcomes. Recent developments in genomics, machine learning, digital health technologies, and large-scale healthcare datasets have facilitated the transition from a one-size-fits-all approach toward personalized obesity care. AI-based models can integrate genetic, metabolic, behavioral, and clinical data to identify obesity subtypes, predict responses to pharmacological interventions, and support clinical decision-making. Furthermore, digital phenotyping and wearable technologies provide continuous monitoring of lifestyle behaviors and physiological parameters, allowing dynamic adaptation of treatment strategies. This review examines the current role of AI and precision medicine in obesity management, focusing on obesity phenotyping, genomic risk stratification, predictive analytics, digital health interventions, and AI-assisted pharmacotherapy selection. Additionally, ethical, regulatory, and implementation challenges are discussed. The integration of artificial intelligence with precision medicine has the potential to transform obesity treatment by improving therapeutic effectiveness, reducing healthcare costs, and advancing individualized patient care.

KEYWORDS

Obesity, Artificial Intelligence, Precision Medicine, Machine Learning, Digital Health, Pharmacotherapy

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1. Introduction

Obesity has emerged as one of the most significant global health challenges, affecting over one billion individuals worldwide and contributing substantially to morbidity, mortality, and healthcare expenditures. Traditionally regarded as a consequence of excessive caloric intake and insufficient physical activity, obesity is now recognized as a multifactorial chronic disease resulting from complex interactions among genetic, neurobiological, environmental, behavioral, and socioeconomic factors (Blüher, 2019; Bray et al., 2017).

Although recent therapeutic advances, particularly incretin-based pharmacotherapies such as semaglutide and tirzepatide, have significantly improved weight-loss outcomes, considerable variability in treatment response remains evident. While some individuals achieve substantial and sustained weight reduction, others experience limited clinical benefit despite similar treatment regimens (Wilding et al., 2021; Jastreboff et al., 2022). This variability highlights the limitations of conventional obesity management strategies and underscores the need for more personalized therapeutic approaches.

Precision medicine has emerged as a promising framework for addressing the heterogeneity of obesity. Rather than treating obesity as a uniform condition, precision medicine seeks to identify distinct biological and behavioral phenotypes that influence disease development and treatment response. Advances in genomics have revealed numerous genetic variants associated with obesity susceptibility, ranging from rare monogenic disorders involving the melanocortin pathway to complex polygenic risk profiles that influence body weight regulation throughout life (Loos & Yeo, 2022; Khera et al., 2018).

Simultaneously, artificial intelligence (AI) has rapidly transformed multiple areas of healthcare by enabling the analysis of large and complex datasets that exceed traditional analytical capabilities. Machine learning algorithms can identify patterns within genomic, clinical, behavioral, and environmental data, supporting disease prediction, patient stratification, and personalized treatment recommendations (Beam & Kohane, 2018; Topol, 2019). In obesity care, AI-based approaches have demonstrated potential in predicting

treatment response, identifying high-risk individuals, optimizing pharmacotherapy selection, and supporting long-term weight management strategies (Choong et al., 2024; Patel et al., 2021).

The integration of artificial intelligence with precision medicine represents a paradigm shift in obesity management. By combining genomic information, metabolic profiling, behavioral data, and real-world patient monitoring, clinicians may increasingly tailor interventions to individual patient characteristics. Such an approach could improve treatment efficacy, minimize adverse effects, and enhance long-term adherence to therapy.

This review aims to provide a comprehensive overview of current applications of artificial intelligence and precision medicine in obesity management. Particular attention is given to obesity phenotyping, genomic risk assessment, predictive analytics, digital health technologies, AI-assisted pharmacotherapy selection, and future directions for personalized obesity care.

2. Methodology

This review was conducted to examine the current role of artificial intelligence and precision medicine in obesity management, with particular emphasis on obesity phenotyping, genomics, digital health technologies, predictive analytics, and personalized pharmacotherapy.

A narrative literature review approach was adopted. Relevant publications were identified through searches of PubMed, Scopus, Web of Science, and Google Scholar databases. The search strategy included combinations of the following keywords: “obesity,” “precision medicine,” “artificial intelligence,” “machine learning,” “digital health,” “genomics,” “polygenic risk scores,” “pharmacotherapy,” “semaglutide,” “tirzepatide,” and “setmelanotide.”

Priority was given to peer-reviewed articles published between 2015 and 2025, although seminal earlier studies were included when necessary to provide historical context or explain fundamental biological mechanisms. Eligible sources included original research articles, randomized controlled trials, systematic reviews, meta-analyses, clinical guidelines, and high-impact review articles.

Publications were selected based on their relevance to the objectives of the review. Particular attention was paid to studies examining the application of artificial intelligence in obesity care, advances in precision medicine, obesity phenotyping, genomics-guided treatment approaches, and emerging pharmacological therapies. Articles not directly related to obesity management or lacking sufficient methodological rigor were excluded.

The collected evidence was synthesized narratively to provide a comprehensive overview of current developments, clinical applications, challenges, and future directions in AI-assisted precision obesity medicine.

Table 1. Literature Search Strategy

Component	Description
Review design	Narrative literature review
Objective	To evaluate current applications of artificial intelligence and precision medicine in obesity management, with emphasis on obesity phenotyping, genomics, digital health technologies, predictive analytics, and personalized pharmacotherapy
Databases searched	PubMed, Scopus, Web of Science, Google Scholar
Search period	January 2015 – June 2026
Key search terms	“obesity”, “artificial intelligence”, “machine learning”, “precision medicine”, “genomics”, “polygenic risk scores”, “digital health”, “pharmacotherapy”, “semaglutide”, “tirzepatide”, “setmelanotide”
Types of evidence included	Original research articles, randomized controlled trials, systematic reviews, meta-analyses, clinical guidelines, and high-impact review articles
Inclusion criteria	Peer-reviewed publications in English addressing obesity pathophysiology, obesity phenotyping, precision medicine, artificial intelligence, digital health technologies, or obesity pharmacotherapy
Exclusion criteria	Conference abstracts without full text, non-English publications, studies unrelated to obesity management, and articles lacking sufficient methodological quality
Data synthesis	Narrative synthesis of evidence focusing on clinical applications, challenges, and future directions of AI-assisted precision obesity medicine

Source: Authors' own elaboration. Literature was selected according to relevance to the objectives of the review and methodological quality of the identified studies.

3. Results

3.1 Biological Heterogeneity of Obesity

Obesity is no longer understood as a uniform disorder defined only by excess body weight. It is a chronic and heterogeneous disease in which genetic predisposition, neuroendocrine regulation, eating behavior, energy expenditure, metabolic status, and environmental factors interact over time. This heterogeneity explains why individuals with similar body mass index (BMI) may differ substantially in cardiometabolic risk, appetite regulation, treatment response, and long-term prognosis (Blüher, 2019; Loos & Yeo, 2022).

A clinically useful way to approach this heterogeneity is through obesity phenotyping. Several phenotypes have been proposed, including impaired satiation, impaired satiety, hedonic or reward-driven eating, and reduced resting energy expenditure. Patients with impaired satiation often require larger food volumes before meal termination, whereas impaired satiety is characterized by persistent hunger or shortened intervals between meals. Hedonic eating is more closely related to reward pathways and emotional eating patterns, while reduced energy expenditure reflects differences in basal metabolic rate, adaptive thermogenesis, or body composition (Acosta et al., 2021). Hedonic eating has also been linked to alterations in dopaminergic reward pathways (Volkow et al., 2013; Wang et al., 2001).

These phenotypes are not mutually exclusive, and many patients present with overlapping mechanisms. Nevertheless, phenotype-based assessment has practical value because it moves obesity management beyond a one-size-fits-all model. For example, patients with prominent appetite dysregulation may benefit from incretin-based therapies, whereas individuals with reward-driven eating may require additional behavioral or pharmacological strategies targeting food cravings and emotional eating. Recognition of these differences provides the biological rationale for precision obesity medicine and for the use of artificial intelligence to support patient stratification.

Table 2. Major Obesity Phenotypes and Their Clinical Characteristics

Phenotype	Dominant Mechanism	Clinical Characteristics	Potential Therapeutic Implications
Impaired satiation	Delayed meal termination	Large meal size, difficulty achieving fullness	GLP-1 receptor agonists, dual incretin therapies
Impaired satiety	Persistent hunger between meals	Frequent eating episodes, increased appetite	Appetite-regulating pharmacotherapy, behavioral interventions
Hedonic eating	Dysregulation of reward pathways	Food cravings, emotional eating, compulsive eating patterns	Behavioral therapy, naltrexone/bupropion
Reduced energy expenditure	Low resting metabolic rate and adaptive thermogenesis	Weight gain despite moderate caloric intake	Combined lifestyle and pharmacological interventions
Monogenic obesity	Genetic defects affecting appetite regulation	Early-onset severe obesity, hyperphagia	Precision therapies (e.g., setmelanotide)

Source: Adapted from Acosta et al. (2021), Loos and Yeo (2022), and Clément et al. (2020).

3.2 Genomics and Precision Obesity Medicine

Genomic research has substantially improved understanding of obesity pathogenesis. Rare monogenic forms of obesity, particularly those involving the leptin-melanocortin pathway, demonstrate that specific genetic abnormalities can directly disrupt appetite regulation and energy homeostasis. Mutations affecting LEPR, POMC, PCSK1, and MC4R may lead to severe early-onset obesity, hyperphagia, and impaired central appetite control (Farooqi & O'Rahilly, 2006).

The development of setmelanotide, a melanocortin-4 receptor agonist, illustrates the clinical relevance of genotype-guided treatment. In selected patients with defects in the melanocortin pathway, targeted

pharmacotherapy can produce clinically meaningful weight loss and appetite reduction, representing one of the clearest examples of precision medicine in obesity care (Clément et al., 2020; Kühnen et al., 2016). Although such monogenic disorders are uncommon, they highlight the importance of identifying biological subgroups rather than treating obesity as a single entity.

Most obesity, however, is polygenic and results from the cumulative contribution of many variants with small individual effects. Polygenic risk scores may help identify individuals at increased lifetime risk and support earlier preventive strategies. Khera et al. (2018) showed that polygenic risk can meaningfully stratify susceptibility to common diseases, including obesity-related conditions. In clinical practice, genomic information is unlikely to be sufficient on its own; its greatest value will likely come from integration with metabolic markers, behavioral data, comorbidities, and treatment history.

3.3 Artificial Intelligence in Obesity Care

Artificial intelligence (AI) offers tools for analyzing the multidimensional data generated in modern obesity care. Electronic health records, laboratory results, genomic information, dietary data, wearable-device outputs, and medication histories can all contribute to individualized risk assessment and treatment planning. Machine-learning methods are particularly useful because they can identify complex and nonlinear relationships among variables that may not be captured by traditional statistical approaches (Beam & Kohane, 2018; Topol, 2019).

In obesity management, AI has several potential applications: predicting obesity risk, identifying clinically meaningful phenotypes, estimating treatment response, detecting risk of weight regain, and supporting clinical decision-making. Choong et al. (2024) demonstrated that machine-learning approaches can be applied to large administrative datasets to predict obesity risk. Although such models require careful validation before routine use, they illustrate how AI may help clinicians recognize high-risk patients earlier and prioritize preventive interventions.

Clinical decision support systems represent one of the most practical future applications of AI. A decision-support tool could combine age, BMI trajectory, comorbidities, medication history, eating behavior, metabolic biomarkers, and genetic data to suggest the most appropriate therapeutic strategy. Such systems should not replace clinical judgment, but they may help reduce trial-and-error prescribing, improve treatment efficiency, and support shared decision-making. Their usefulness will depend on transparency, external validation, and integration into routine clinical workflows.

Table 3. Current Applications of Artificial Intelligence in Obesity Management

AI Application	Data Sources	Clinical Utility	Potential Benefits
Obesity risk prediction	Electronic health records, demographics, laboratory data	Identification of high-risk individuals	Earlier prevention and intervention
Obesity phenotyping	Clinical, behavioral, metabolic, and genomic data	Patient stratification	More personalized treatment selection
Treatment-response prediction	Clinical and pharmacological datasets	Prediction of response to anti-obesity therapies	Reduced trial-and-error prescribing
Clinical decision support systems	Integrated multimodal datasets	Personalized therapeutic recommendations	Improved clinical decision-making
Digital phenotyping	Smartphones, wearables, activity trackers	Continuous monitoring of patient behavior	Early identification of treatment failure
Drug discovery and development	Genomic and molecular datasets	Identification of therapeutic targets	Accelerated drug development
Real-world evidence analysis	Claims databases and electronic health records	Post-marketing surveillance	Improved safety and effectiveness monitoring

Source: Adapted from Beam and Kohane (2018), Topol (2019), Choong et al. (2024), and Patel et al. (2021).

3.4 Digital Phenotyping and Continuous Monitoring

Digital phenotyping extends precision medicine from episodic clinical assessment to continuous real-world monitoring. Smartphones, wearable devices, smart scales, mobile applications, and continuous glucose monitoring systems can collect longitudinal information on physical activity, sleep, dietary behavior, sedentary time, heart rate, and glycemic responses. These data may provide a more accurate picture of daily behavior than self-report alone, which is often limited by recall bias and incomplete reporting (Patel et al., 2021).

Wearable devices and mobile health applications can improve patient engagement by providing feedback between clinical visits. They may also help clinicians identify early warning signs of treatment failure, such as declining physical activity, worsening sleep patterns, or weight regain. When combined with AI-based analytics, digital phenotyping may support adaptive treatment strategies in which interventions are modified according to real-time behavioral and physiological data.

Continuous glucose monitoring is also relevant to precision obesity care, particularly in patients with insulin resistance, prediabetes, or type 2 diabetes. Interindividual variability in postprandial glucose responses suggests that personalized nutrition strategies may be more effective than general dietary recommendations for selected patients. However, digital health tools also raise concerns regarding data accuracy, patient burden, privacy, interoperability, and unequal access. Their role should therefore be understood as supportive rather than as a replacement for clinician-led care.

3.5 AI-Guided Pharmacotherapy Selection and Personalized Treatment Strategies

The rapid expansion of anti-obesity pharmacotherapy has made treatment selection increasingly complex. Semaglutide and tirzepatide have demonstrated substantial average weight-loss efficacy in clinical trials, but individual responses vary considerably (Wilding et al., 2021; Jastreboff et al., 2022). Some patients achieve large and sustained reductions in body weight, whereas others have modest responses, adverse effects, or difficulty maintaining treatment adherence. This variability creates a strong rationale for predictive tools that can guide therapy selection.

AI-guided pharmacotherapy aims to match treatment to patient characteristics. A model could estimate the probability of response to GLP-1 receptor agonists, dual incretin therapy, naltrexone/bupropion, or lifestyle intervention by integrating phenotype, comorbidities, prior weight-loss history, behavioral patterns, and metabolic profile. For example, patients with impaired satiation may be particularly suitable candidates for incretin-based therapies, whereas patients with prominent hedonic eating may require additional behavioral support or therapies affecting reward-related pathways (Acosta et al., 2021).

Genomics and pharmacogenomics may further refine treatment selection. Monogenic obesity already provides a clear example of genotype-guided therapy through setmelanotide in selected melanocortin-pathway disorders (Clément et al., 2020; Kühnen et al., 2016). For common obesity, the role of pharmacogenomics remains less established, but integration of polygenic risk, metabolic biomarkers, and digital monitoring may eventually support more precise treatment pathways. Emerging therapies such as retatrutide may further expand opportunities for precision obesity treatment (Jastreboff et al., 2023). The main challenge is prospective validation: prediction models must demonstrate clinical benefit, safety, fairness, and cost-effectiveness before they can be widely implemented.

3.6 Artificial Intelligence in Drug Discovery and Clinical Trial Optimization

AI is also increasingly relevant to obesity drug development. Machine-learning methods can support target identification, compound screening, drug repurposing, and prediction of pharmacokinetic or toxicity profiles. In a disease involving complex pathways of appetite regulation, reward processing, gut-brain signaling, adipose tissue function, and energy expenditure, computational tools may help identify therapeutic targets that would be difficult to detect using conventional methods alone (Topol, 2019).

AI may also improve clinical trial design. Obesity trials often include heterogeneous populations, which can obscure treatment effects and increase sample-size requirements. Predictive models may help identify patient subgroups more likely to respond to a specific therapy, improve participant recruitment, and support stratified trial designs. Digital health technologies can additionally provide remote monitoring of adherence, physical activity, sleep, and other outcomes, reducing participant burden while increasing the richness of collected data.

Real-world evidence will become increasingly important as highly effective anti-obesity therapies enter routine practice. Electronic health records, claims databases, and digital health platforms can help evaluate long-term effectiveness, persistence, safety, and patterns of medication use outside controlled trial settings. AI-based analysis of these data may support post-marketing surveillance and identify patient groups that benefit most from specific treatments. Together, these applications may accelerate therapeutic innovation while supporting more personalized and efficient obesity care.

4. Discussion

4.1 Ethical, Regulatory, and Social Challenges

The findings presented in this review demonstrate that obesity is a heterogeneous chronic disease requiring increasingly individualized management strategies. Evidence from genomics, phenotyping studies, digital health technologies, and artificial intelligence applications consistently supports a transition away from conventional one-size-fits-all treatment models. The integration of biological, behavioral, and environmental data enables more precise patient stratification and may improve treatment selection, prediction of therapeutic response, and long-term outcomes.

Particularly promising developments include AI-assisted obesity phenotyping, predictive models for pharmacotherapy response, digital phenotyping through wearable technologies, and precision medicine approaches based on genomic risk assessment. Together, these innovations have the potential to improve clinical effectiveness while reducing unnecessary treatment exposure and healthcare costs. However, successful implementation will depend on addressing important ethical, regulatory, and practical challenges.

At the same time, the available evidence should be interpreted with caution. Many AI-based prediction models in obesity care have been developed using retrospective or population-specific datasets, and relatively few have undergone prospective validation in routine clinical settings. As a result, their clinical utility, generalizability, and impact on patient outcomes remain incompletely established. Future implementation should therefore prioritize externally validated models, transparent reporting standards, clinician oversight, and evaluation across diverse patient populations.

Despite its considerable potential, the implementation of artificial intelligence in obesity management raises important ethical, regulatory, and social concerns. AI systems rely heavily on large datasets that often contain sensitive health information, including genetic, behavioral, and lifestyle data. Ensuring privacy, data security, and informed consent therefore remains a critical challenge.

Algorithmic bias represents another major concern. Many machine learning models are developed using datasets derived predominantly from specific geographic regions or demographic groups. Consequently, AI-based recommendations may perform less accurately in underrepresented populations, potentially exacerbating existing healthcare inequalities. Addressing these biases will require the development of more diverse datasets and continuous evaluation of algorithm performance across different populations.

Transparency and explainability are also important considerations. Many advanced machine learning models operate as “black boxes,” making it difficult for clinicians and patients to understand how recommendations are generated. Improving model interpretability may enhance trust, facilitate clinical adoption, and support ethical decision-making.

From a regulatory perspective, healthcare systems must establish clear frameworks governing the development, validation, and implementation of AI-based clinical tools. Regulatory agencies increasingly recognize the need for standards addressing algorithm safety, performance monitoring, and accountability. Such frameworks will be essential for ensuring that AI technologies improve patient care while minimizing potential risks.

Finally, the increasing reliance on digital technologies raises concerns regarding equitable access to healthcare. Precision medicine approaches frequently depend on genomic testing, wearable devices, and digital monitoring systems that may not be equally accessible across all socioeconomic groups. Future implementation strategies should therefore prioritize both innovation and accessibility.

4.2 Future Directions

The future of obesity management will likely involve increasing integration of artificial intelligence, genomics, digital health technologies, and advanced pharmacotherapy. Rather than relying on isolated clinical variables, future decision-support systems may incorporate multimodal datasets including genetic information, metabolic biomarkers, behavioral profiles, wearable-device outputs, and environmental exposures.

One particularly promising concept is the development of digital twins—virtual patient models that simulate disease progression and treatment responses. Such systems could allow clinicians to evaluate multiple therapeutic strategies before initiating treatment, thereby improving precision and reducing unnecessary interventions.

Continued advances in multi-omics technologies, machine learning, and real-world data analysis may further enhance obesity phenotyping and facilitate increasingly individualized treatment approaches. As

evidence accumulates, obesity care may gradually transition from population-based treatment algorithms toward highly personalized therapeutic pathways.

Future research should prioritize prospective validation of AI-based prediction models, assessment of long-term clinical outcomes, and evaluation of implementation strategies in real-world healthcare settings. Collaboration among clinicians, data scientists, regulators, and patients will be essential for realizing the full potential of precision obesity medicine.

5. Conclusions

Obesity is a heterogeneous chronic disease that requires increasingly individualized management strategies. Advances in genomics, artificial intelligence, and digital health technologies have created new opportunities to move beyond traditional one-size-fits-all treatment approaches. Precision medicine frameworks allow the identification of biologically distinct obesity phenotypes, while AI-based systems facilitate risk prediction, treatment selection, and continuous patient monitoring.

Current evidence suggests that the integration of artificial intelligence with precision medicine may substantially improve obesity prevention and treatment. Applications ranging from phenotype-guided pharmacotherapy and genomic risk assessment to digital phenotyping and clinical decision support systems demonstrate the transformative potential of these technologies.

Although important ethical, regulatory, and implementation challenges remain, the convergence of artificial intelligence, precision medicine, and modern obesity pharmacotherapy represents a major step toward more effective, personalized, and sustainable obesity care. Continued interdisciplinary research will be critical for translating these innovations into routine clinical practice and improving outcomes for patients worldwide.

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Author Contributions (CRediT):

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Hubert Łagosz: Literature Review, Data Interpretation, Writing – Review & Editing.

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All authors contributed to the manuscript, reviewed the final version, and approved it for publication.

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