

Commentary

Artificial Intelligence in Pediatric Obesity: Toward Precision Prediction and Personalized Management

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Description

Pediatric obesity represents one of the most challenging manifestations of the global metabolic disease burden. Its multifactorial etiology reflects the interplay between genetic and epigenetic susceptibility, dietary and behavioral patterns, environmental exposures, psychosocial determinants, and socioeconomic conditions. Childhood obesity is increasingly associated with early metabolic complications, including prediabetes, type 2 diabetes mellitus (T2DM), metabolic dysfunction-associated steatotic liver disease (MASLD), and cardiovascular disease [1]. This complexity creates substantial challenges for prevention and management. Artificial intelligence (AI), including machine learning (ML) and deep learning (DL), is emerging as a potentially transformative tool, with applications ranging from risk prediction and early diagnosis to treatment personalization and longitudinal monitoring [2].

A major strength of AI is its ability to integrate heterogeneous, high-dimensional data, supporting the concept of "deep phenotyping," which encompasses genetic and epigenetic characteristics, the exposome, metabolic and inflammatory status, diet, physical activity, sleep, psychological factors, and socioeconomic determinants. By combining these domains, AI-based models may generate individualized risk profiles and identify children susceptible to obesity or its complications before overt disease develops. Multi-omics approaches integrating genomic variants, DNA methylation, transcriptomics, metabolites, and gut microbiota may further refine risk stratification and provide a biological basis for precision prevention [3].

AI can also characterize environmental determinants of obesity. Computer vision and geospatial analyses can quantify features of the built environment, such as access to green spaces and recreational facilities, bicycle infrastructure, and fast-food outlet density. These approaches may help identify obesogenic environments and support geographically targeted public health interventions, highlighting the potential of AI for both personalized care and population-level prevention [2].

Among obesity-related complications, T2DM is an important target for predictive modeling. ML approaches, including support vector machines (SVMs), random forests, decision trees, artificial neural networks, and k-nearest neighbors, can identify combinations of clinical, biochemical, behavioral, and psychological characteristics associated with diabetes risk. However, pediatric evidence remains limited. One study comparing eight ML models in children with obesity identified SVM as the most effective for predicting T2DM onset, using BMI, creatinine, prealbumin, thyroid parameters, glycated hemoglobin, and post-load glucose concentrations [4]. Although promising, these findings should be interpreted cautiously because the literature is largely based on adults. Extrapolation to children is problematic given differences in metabolic phenotypes, developmental trajectories, pubertal status, and disease progression.

Beyond prediction, AI is increasingly being investigated for precision nutrition, aiming to tailor dietary interventions according to individual metabolic responses. By integrating anthropometric and biochemical characteristics with dietary intake, physical activity, and gut microbiota data, AI models may predict interindividual differences in postprandial glycemic responses. Adult studies suggest that algorithm-guided dietary interventions can improve glucose control and modify the gut microbiome. Whether similar benefits can be achieved in children remains uncertain, but this approach is particularly relevant to pediatric obesity, where adherence to lifestyle interventions and treatment response are highly heterogeneous.

MASLD represents another important application of AI, particularly given the limitations of current diagnostic approaches in children. Liver biopsy remains the reference standard for histological assessment but is invasive and unsuitable for widespread screening. ML models have

therefore been explored to identify children at increased risk of steatosis and disease progression using anthropometric, biochemical, dietary, inflammatory, and metabolic variables. DL techniques can additionally detect or quantify hepatic steatosis and fibrosis from ultrasound, computed tomography, elastography, and histological images. These approaches could ultimately support non-invasive risk stratification and reduce reliance on invasive diagnostic procedures.

The integration of multi-omics data may further improve understanding of MASLD pathogenesis. Transcriptomic, metabolomic, lipidomic, proteomic, and microbiome studies have identified candidate biomarkers and pathways associated with hepatic steatosis and inflammation. In children with obesity, circulating proteins, metabolite signatures, and ML-based microbiome analyses have shown potential diagnostic value and identified microbial patterns associated with MASLD progression. These findings also highlight the potential role of the gut–liver and gut–brain axes, although microbial signatures should not be interpreted as evidence of causality given the influence of age, diet, geography, medications, and lifestyle.

A further development is the integration of AI into digital health technologies, including mobile applications, wearable sensors, digital coaches, exergames, Internet of Things platforms, digital therapeutics, and large language models. These tools may enable continuous monitoring of physical activity, diet, sleep, and other lifestyle factors, while providing personalized feedback and supporting remote interaction with healthcare professionals. AI may also assist therapeutic decision-making, including prediction of pharmacological response and individualized insulin management. However, their effectiveness depends on user engagement, digital literacy, data quality, and algorithm reliability. AI should therefore currently be considered an adjunct to, rather than a substitute for, multidisciplinary care.

The main barrier to clinical translation is not the lack of promising algorithms, but the limited quality and generalizability of the supporting evidence. Pediatric datasets are often smaller and derived from single institutions or geographically restricted populations, potentially limiting model performance across different healthcare systems and patient groups. Dataset shift is particularly relevant in pediatric obesity, where disease trajectories vary according to age, sex, pubertal development, ethnicity, socioeconomic status, and environmental context. Under-representation of disadvantaged populations may further contribute to algorithmic bias and health inequalities.

Ethical considerations are equally important. AI-based pediatric interventions may require prolonged collection of sensitive clinical, behavioral, and potentially genomic data. Robust governance, parental informed consent, developmentally appropriate child assent, and compliance with privacy regulations are therefore essential. Moreover, rapid physiological and behavioral changes during childhood and adolescence may require periodic model recalibration and revalidation.

Conclusion

Overall, AI has the potential to shift pediatric obesity management toward individualized prediction and intervention by integrating multiple dimensions of the patient's phenotype. Its greatest value may lie in supporting earlier diagnosis, improved risk stratification, and more targeted interventions rather than replacing established clinical approaches. However, predictive accuracy alone is insufficient to justify clinical implementation. Large and representative pediatric cohorts, external validation, transparent reporting, subgroup-specific performance assessment, and rigorous evaluation of clinical utility are essential for responsible translation. The future role of AI will ultimately depend on demonstrating improved clinical outcomes while ensuring that these systems remain safe, equitable, interpretable, and accessible [2].

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