Review Article

Applications of artificial intelligence in the management of childhood obesity

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Abstract

Background: Childhood obesity has emerged as a significant public health challenge, with long-term implications that often extend into adulthood, increasing the susceptibility to chronic health conditions. **Objective:** The objective of this review is to elucidate the applications of artificial intelligence (AI) in the prevention and treatment of pediatric obesity, emphasizing its potential to complement and enhance traditional management methods. **Methods:** We undertook a comprehensive examination of existing literature to understand the integration of machine learning and other AI techniques in childhood obesity management strategies. **Results:** The findings from numerous studies suggest a strong endorsement for AI's role in addressing childhood obesity. Particularly, machine learning techniques have shown considerable efficacy in augmenting current therapeutic and preventive approaches. **Conclusion:** The intersection of AI with conventional obesity management practices presents a novel and promising approach to fortify interventions targeting pediatric obesity. This review accentuates the transformative capacity of AI, thereby advocating for continued research and innovation in this rapidly evolving domain.

Keywords: Artificial intelligence, childhood obesity, exergaming, intervention, machine learning

Introduction

Childhood obesity is a complex, multifactorial syndrome influenced by biological, genetic, socioeconomic, and environmental factors, often associated with more than one of these.[1] It is a significant health concern as it can lead to adult obesity, thereby increasing the risk for numerous medical disorders, including diabetes mellitus, hypertension, cardiovascular disorders, cancer, and depression.[2] Therefore, early detection, prevention, and long-term management strategies are crucial to mitigate the healthcare burden of childhood obesity.

The rapid urbanization, globalization, and technological advancements of the modern era have significantly transformed lifestyle habits, impacting pediatric nutritional status and development.[3] These changes have led to decreased physical activity and increased sedentary habits, often coupled with a high caloric intake of unhealthy food items rather than fruits and green leafy vegetables, particularly in developing countries.

Traditional interventions for weight management may not be feasible or accessible to all due to commuting inconveniences, lack of facilities, and economic constraints. Moreover, surgical weight reduction procedures often offer only temporary solutions and may lead to significant weight gain over time.[4] Existing research studies for evaluating obesity risk have primarily relied on logistic regression modeling techniques, which have several limitations, such as the use of a limited number of predictors and linearity assumptions.[5] This necessitates the exploration of nonlinear interactions via artificial intelligence (AI).

AI techniques simulate human intelligence processes through computers and other machines. These techniques work in

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conjunction with data inputs, utilizing the data for pattern analysis and correlations, making predictions, and identifying causative factors. This is achieved by establishing associations between essential data points, eliminating the need for prior interpretations or assumptions required for traditional data handling models.[6] Innovative AI-based digital technologies can provide at-home wearable solutions to obtain, track, and analyze data, as well as offer management advice based on algorithms and neural networks.[7]

Importantly, AI-based techniques can predict the development of childhood obesity as early as two years of age, thereby facilitating early identification, prevention, and addressing obesity in children.[8] Moreover, the technological components of AI-based methods and devices can keep the pediatric population engaged and motivated while enjoying their home comfort. AI-based machine learning (ML) models produce more precise obesity predictions than statistical modeling[9] and identify variables that influence obesity risks ranging from a child's pocket money and mobile phone usage to the style of feeding and childhood attitudes toward food items provided by caregivers, to their sleep quality and academic performance.[9]

AI models have enhanced user capacity to self-track and implement predictions for devising tailored goals and strategies, by the use of real-time data analytical systems for driving health interventions. Positive test reports have been documented after engaging AI-based behavioral coaches via chatbots, showing that conversational models can be integrated into a child's weight management regime and deliver timely reminders or nudges to make children vigilant for their health and encourage health discipline.[10] AI-based recipe recommendations have been developed incorporating food constraints, dietary preferences, and metabolic requirements to deliver personalized weight management plans. This review addresses the role of AI in the prediction, identification, and management of childhood obesity, which could guide family physicians, pediatricians, and public health officials to further inform and guide in the development of policies to improve overall global childhood healthcare. Primary care physicians and family practitioners play a pivotal role in the early detection and management of childhood obesity. With the advent of AI tools, these healthcare professionals can leverage technology to predict obesity risk, monitor progress, and guide interventions, thereby playing a crucial role in mitigating the childhood obesity epidemic.

Materials and Methods

A thorough search for eligible articles pertaining to the use of AI in various aspects of childhood obesity (diagnosis, treatment, management, and patient interactive interface) was made. PubMed, Google Scholar, Scopus, and Embase were searched for articles mentioning the application of AI in the management of childhood obesity. The different search terms used for the identification of articles in all the databases were as follows: 'childhood,' 'obesity,' 'Artificial intelligence,' 'management,' 'diagnosis,' 'treatment,' and 'screening.' These terms formed the basis for the selection of articles for inclusion in our narrative review.

The articles were shortlisted, and their full text was obtained, following which the entire article was scrutinized for assessment of the required data. The entire selection process enabled us to select articles that mentioned the use of AI for managing childhood obesity, either in its diagnosis or treatment or both. Two independent reviewers assessed the eligibility of all the selected articles, and the dilemma of whether to include a particular article for inclusion in the review was arbitrated by an independent reviewer, and the necessary decision was made whether to include that particular article or not.

Finally, the data were organized, and the resulting information was grouped under different subheadings (mobile applications and software) pertaining to the role of AI in screening, diagnosis, treatment, and overall management of childhood obesity.

Results

ML has been widely utilized to evaluate pediatric obesity, both for identifying various intervention goals and for predicting future weight outcomes. Alternative classification systems for adult and early childhood obesity have been proposed by numerous studies. Based on survey data on factors including age, parental obesity, and activity level, linear regression and ML approaches (Bayesian networks and classification and regression trees models) are used to categorize adults over 18 as having or not having obesity. To control pediatric illness and provide preventive treatment, the CHICA System (Child Health Improvement through Computer Automation) integrates an electronic medical record with a computerized decision-support system.[11] CHICA integrates into the high-volume workflow of the pediatric practices at the Indian University School of Medicine by implementing age-appropriate patient screening via a tablet in the waiting room and combining this information with electronic medical record data to produce patient-specific recommendations and reminders for the doctor.

CHICA collects a wide range of clinical data from patients and professionals. It contains data for quality measures that go far beyond the Healthcare Effectiveness Data Information Set since it adheres to the evidence-based recommendations of the American Academy of Pediatrics and the United States Preventative Services Task Force (HEDIS). To utilize the extensive data, it has gathered by working closely with payors and healthcare organizations, to streamline the reporting of meaningful use and quality measures for hospitals that utilize CHICA, and for other purposes. Prior to choosing the 20 questions to ask patients when they register at the clinic, CHICA first analyses their medical information. The patient or proxy is given an electronic tablet with these questions displayed on it, and they can respond to them while they wait. This state-of-the-art decision-support system may link to any electronic health record to collect outcomes, risks, and concerns expressed by patients and send them as alerts and reminders to clinicians. Since 2004, the system has provided care to more than 47,000 patients, and it has been the subject of numerous awards from the National Institutes of Health, the Agency for Healthcare Research and Quality, the Centers for Disease Control, and foundations. These awards have enabled the publication of more than 30 peer-reviewed articles.

A total of 167 characteristics from the first 2 years of life were used by Dugan *et al.*[8] to assess several ML algorithms (decision trees, random forest, and Bayesian networks) using longitudinal data from CHICA. When predicting childhood obesity, they discovered that decision trees had the highest level of accuracy. In contrast to earlier models that, for instance, predicted obesity by applying more expensive and less available genetic data, several models have been developed for the detection of juvenile obesity that make use of routinely collected Electronic Health Records (EHR) data.[2]

Digitalization and improvements in mobile technology have had a significant impact on communications, creating new potential to enhance the provision of healthcare services. Mobile phone technology, for instance, has been effectively integrated into treatments to encourage a nutritious diet, exercise, and weight loss.[12] Two advantages of employing mobile phone-based (mHealth) interventions over more conventional face-to-face interventions are the flexibility of delivery and the lack of clinic attendance (or the frequency of visits can be decreased).

MINISTOP application

A unique trial focused on preventing obesity in young children, known as the MINISTOP (Mobile-based Intervention Intended to Stop Obesity in Pre-schoolers) 1.0 trial, was carried out from 2013 to 2015 using a sample of Swedish children selected from the general population.[13] The MINISTOP 1.0 smartphone app, which had an elevated participation and usage rate among the parents, was used in the experiment. In terms of fat mass index, the efficacy analysis found no changes between the groups, but children in the app group had a higher likelihood of modifying a composite score for six food and activity-related behaviors. It is promising that children with higher fat mass indices had a bigger benefit from the intervention on their eating and activity patterns ($P = 0.019$), as these youngsters were in need of it. The MINISTOP application interface was particularly useful in displaying this discovery since it could spot changes in the condition of childhood obesity.[14] The MINISTOP 1.0 app, which was given to the families by the researchers, is not practical in everyday situations. Thus, the MINISTOP app will thus be assessed in a primary child healthcare setting to look at its usability and deployment. The MINISTOP 1.0 software has been translated and customized for priority populations, such as immigrant children (25% of all Swedish children), who are less likely to participate in population-based health interventions, to maximize accessibility.[13] Additionally, the MINISTOP 1.0 software has been altered in response to user comments and demands, such as those from parents and healthcare professionals. The effectiveness and application of this updated program, known as MINISTOP 2.0, will be assessed in practical settings, such as normal pediatric medical care. Swedish primary child health care has been closely involved in the development of this study, which is referred to as the MINISTOP 2.0 experiment. The interface of the MINISTOP mobile application is shown in Figure 1.

Over the past several years, several technology-based health management products and services that focus on controlling obesity have emerged. The majority of these have been offered as web- and mobile-based solutions. By using these tools, the user can input basic details about the meals consumed or planned, and the system will estimate how many calories are still needed to complete the day's activities—use of Internet of Things technology to manage childhood obesity with a mobile-based health monitoring application. The management system provides capabilities that make it easier for parents and medical professionals to follow and monitor the user remotely. This is made more easily user-friendly by the availability of applications and interface which engages parents of children to make better use of the available technology.

Food prediction model

To satisfy the overall daily calorie and macronutrient requirements at any given moment, the food prediction model analyses data, makes decisions about prospective foods and meals, and ensures that they will not exceed the daily deficit. Additionally, the ideal solution must guarantee that the user's health is not jeopardized by unwise food decisions or bad eating practices. The registration data is used to extract a user's health status records, including information on their diabetes and cholesterol levels, which are then analyzed in the model to aid in prediction.

User application software design

The user application was developed as an interactive process that would ask users for information and then display the results. The application provides input for food-related data as well as

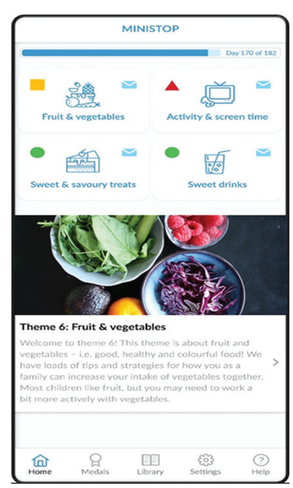

Figure 1: The MINISTOP mobile application interface[14]

interfaces for user registration, health-related data, authentication, and user input. With the current method, people may submit their top meals using a search interface. The alternatives for entering food accurately from sources such as barcode scanning, text receipt image processing, and food photography have all been created.[15]

Active video game interventions

Lindberg *et al*.[16] introduced the game Running Othello as part of the physical education curriculum in South Korean schools for the experimental group, while the control group used printed leaflets and the standard curriculum. The children in the experimental group showed more engagement and higher heart rates than those in the control group, indicating positive results. Argarini *et al*.[17] assessed the impact of moderate-intensity physical activity on children with BMIs in the 85th percentile in a separate study. Xbox 360 sports, dancing, and workout games were played over the course of 4 weeks. Between male and female participants, there was no difference in the BMI decrease and development of fundamental mobility abilities. Two groups of people participated in stationary cycling while playing the interactive video game "Game Bike" according to Adamo *et al*.[18] One group cycled while listening to music, and the other group played Game Bike while pedaling. The study tracked exercise frequency, calorie consumption, cardiovascular fitness, body composition, and heart disease risk in overweight or obese children. The group that received music-based instruction demonstrated better results and more effort than those that used the GameBike. There was no statistically significant difference in BMI between or among the groups.

Exergaming was conducted by Staiano *et al*.[19] utilizing four Xbox 360 and Kinect games at once, while the control group was asked to continue their usual level of physical activity. The intervention group, which displayed improved scores, greater physical activity, and improved cardiometabolic health, demonstrated statistically significant changes. The exercise game "MyPlatePick," created by Ruggiero *et al*.[20] to encourage movement and healthy behavioral changes by mixing nutrition instruction and exercise. There were noticeable improvements in eating habits and an increase in physical activity. Exergaming's impact on kids taking part in a program based on groups to manage weight has also been studied. When comparing the group that participated in the exergaming to the control group, which only took part in the program, an increase in physical activity was observed. The group who played active video games had lower BMI and weight. Another study looked at how dance-based exergaming affected females who were matched to a control group and engaged in their usual amount of physical activity. At the follow-up, similar results were seen in both groups; there were no statistically significant differences.

Web-based/mobile-based

Yang and colleagues[21] created a HAPPYME platform that utilizes mobile technology and encourages students to complete tasks related to physical activity and healthy eating habits. Their parents can track their performance after receiving input from the platform. Obese Go! is a mobile game-based application created by Curiel *et al*.,[22] which is an internet-based intervention that disseminates knowledge about a nutritious diet and active lifestyle. This intervention had no observable effects on BMI ratings. Another research offered an interactive software solution specific to Chinese food that enabled users to confirm the nutritional data about the meal they consumed. It had self-evaluation exercises to gauge one's capacity for problem-solving. A computerized clinician decision-support system was created by Fiechtner *et al*.[23] to track family behavior and discovered that residing within a 1-mile radius of a grocery store promotes healthier eating habits.

ML-based studies

Using structured and unstructured data from two sizable EHR, Lingren *et al*.[24] developed rule-based and ML-based algorithms to identify children at long-term risk of problems and those who had severe early childhood obesity. Overall, the rule-based algorithms outperformed the others. Using anthropometric data, Rios-Julian *et al*.[25] estimated the viability of creating an automated screening tool for identifying obesity. Dugan *et al*.[8] used ML to the gathered data to construct an algorithm that might predict childhood obesity in children older than 2 years old using data acquired before their second birthday. A highly accurate and sensitive model could be created utilizing data from the Child Health Improvement by Computer Automation system using six distinct ML-based techniques, including Random Tree, Random Forest, J48, ID3, Naive Bayes, and Bayes.

Discussion

The findings of this review have significant implications for primary care providers and family physicians. As the first point of contact for children and their families, these healthcare professionals are uniquely positioned to utilize AI tools in the management of childhood obesity. These tools can aid in early detection, provide personalized interventions, and monitor progress, thereby enhancing the quality of care provided.[26]

Advanced AI systems have demonstrated their utility in addressing, treating, and preventing obesity. Before implementing a new AI health system, it is necessary to go through a Verification Methods Spectrum. This spectrum is arranged by levels of complexity, beginning with the simplest and advancing to the most complex, and it includes the following steps: testing, real-time monitoring, statistical analysis, model evaluation, and mathematical proof.

To improve results for obese children who are having bariatric surgery, a decision-support system (DSS) using a Bayesian Network was validated to help patients with their nutritional diagnosis. The Roux-en-Y gastric bypass surgical procedure was used on the study participants. Scientific research and expert consultations on nutrition were performed to create the database for the DSS. The fact that some factors (iron deficiency, vitamin B12 deficiency, and thiamine deficiency) had a significant degree of disagreement among doctors was not discovered when the system generated the diagnostic. The study found that DSS is a reliable technique for helping medical professionals diagnoses nutrition issues in people after bariatric surgery.

The market for mobile applications, including several AI systems, has expanded significantly over the last five years, with 197 billion APPs downloaded in 2017.[27] Smartphones are interactive gadgets that are extensively used nowadays and can offer users new apps, including health-related ones that could be used to promote behavioral changes. Given the increasing prevalence of obesity, sedentary lifestyle, and related illnesses, researchers and industries in the field of information technology are giving significant attention to the development of wearable systems. One such system is mobile personal trainer, which appeared to encourage users to begin and maintain an exercise routine, which is regarded as a difficult activity.[28] The technology monitors the heart rate and velocity of the user, enabling precise navigation through the guidance of sports physiologists and certified fitness coaches. Real-time data provided by the user's sensors motivates a safety-guided activity with a simple and useful structure. The system will be updated, and the programmers want to enhance some capabilities to better cater to users' preferences and demands. There are numerous additional exercise-related apps that could support users with their habits, like Bunny Bolt, App-titude, and iDAT.[26] Technology developers must strike a balance between professional advice and medical proof to produce a successful app.

Robots, however, may be a viable platform to meet these specific demands because children have distinct care needs from senior individuals.[29] Illnesses like cancer and diabetes can interfere with a child's regular routine, impact their social requirements, and present several difficulties during treatment and lifestyle changes, all of which have an impact on the child's mental health.[30] Social robots may be useful in the management of chronic illnesses by providing a sense of warmth and company because they may give effective support through encouragement, teaching to maintain good behaviors, and entertainment essential to relieving stress. Therefore, it follows that robots might potentially have an equivalent effect on the treatment of obesity, aiding kids emotionally, motivating them, and ultimately influencing them to choose a healthier lifestyle. Robots have been shown to be helpful in the treatment of several diseases.[31] Robotics and AI might be used to develop user-cantered solutions using real-time treatment program customization, and ML can help filter datasets to find at-risk youngsters and generate predictions about their conditions.

The potential of AI in managing pediatric health conditions is increasingly being recognized. For instance, AI has been successfully applied in neonatology to evaluate the role of AI in neonatal diseases and define methodologies.[32] Similarly, AI has been used to predict malnutrition risk using m-health data, with Random Forest and Gradient Boosting identified as the best-performing classifiers.[33] This predictive capability of AI can be leveraged in the context of childhood obesity to predict obesity risk and manage it effectively. Furthermore, AI has been used to personalize digital health behavior change interventions, which could be beneficial in managing childhood obesity by personalizing interventions based on individual needs.[34,35] Lastly, the use of humanoid robots, such as Pepper, in improving adherence to treatment in children with asthma[36] suggests the potential of using similar approaches to improve adherence to obesity management interventions in children.

In summary, the integration of AI in pediatric healthcare holds significant promise for improving health outcomes. The current study's findings contribute to the growing body of evidence supporting the use of AI in managing childhood obesity. However, as with any emerging technology, it is crucial to approach its application with caution, ensuring ethical considerations and the unique needs of the pediatric population are adequately addressed. Future research should continue to explore and refine AI-based interventions, with a focus on personalization and user engagement, to maximize their effectiveness in combating childhood obesity. The potential of AI in transforming pediatric healthcare is vast, and the journey has only just begun.

Conclusion

In conclusion, the advent of AI in pediatric healthcare has ushered in a new era of precision medicine characterized by enhanced diagnostic accuracy, personalized treatment plans, and improved patient outcomes. The findings of this study underscore the transformative potential of AI in revolutionizing pediatric healthcare, particularly in the realms of disease diagnosis and treatment optimization. The integration of AI not only promises improved health outcomes for children but also serves as a valuable tool for primary healthcare providers and family medicine physicians, equipping them with precise, data-driven insights to inform their clinical decision-making and ultimately enhance the quality of care provided. As we continue to navigate this exciting frontier, it is imperative that we remain cognizant of the ethical considerations and challenges inherent in AI implementation and strive to ensure that its benefits are accessible to all.

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Conflicts of interest

There are no conflicts of interest.

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