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The Application of Artificial Intelligence in Diabetes Management

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ABSTRACT

With the global prevalence of diabetes continuously rising, the management of diabetes has become a significant challenge in the field of public health. The application of Artificial Intelligence (AI) technologies in diabetes management, especially in personalized dietary interventions, has shown tremendous potential. This study conducts a systematic literature review to explore the various applications of AI in diabetes management, covering areas such as dietary intervention, personalized treatment, and complication prediction. The study finds that AI can effectively predict the risk of diabetes, optimize dietary plans, improve patient adherence, and reduce the incidence of diabetes-related complications. However, despite the significant progress made by AI technologies, challenges remain in terms of technological standardization, data privacy protection, and clinical translation. Future research should focus on the comprehensive application of AI in diabetes management, including combining exercise interventions, enhancing model accuracy, and expanding the diversity of datasets. Overall, the application of AI in personalized diabetes management holds great promise, but its clinical translation and long-term use still require further research and optimization.

KEYWORDS

Artificial Intelligence; Diabetes; Dietary Intervention; Personalized; Machine Learning; Deep Learning

1. INTRODUCTION

1.1. Background and Significance

In April 2025, the International Diabetes Federation (IDF) released the latest global diabetes map (11th edition), As shown in Figure 1, the number of adults with diabetes aged 20-79 worldwide reached 589 million in 2024, accounting for 11.1% of the total population in this age group. By 2050, the total number of diabetes patients is expected to rise to 853 million. In 2024, diabetes-related deaths exceeded 3.4 million, accounting for 9.3% of global mortality.

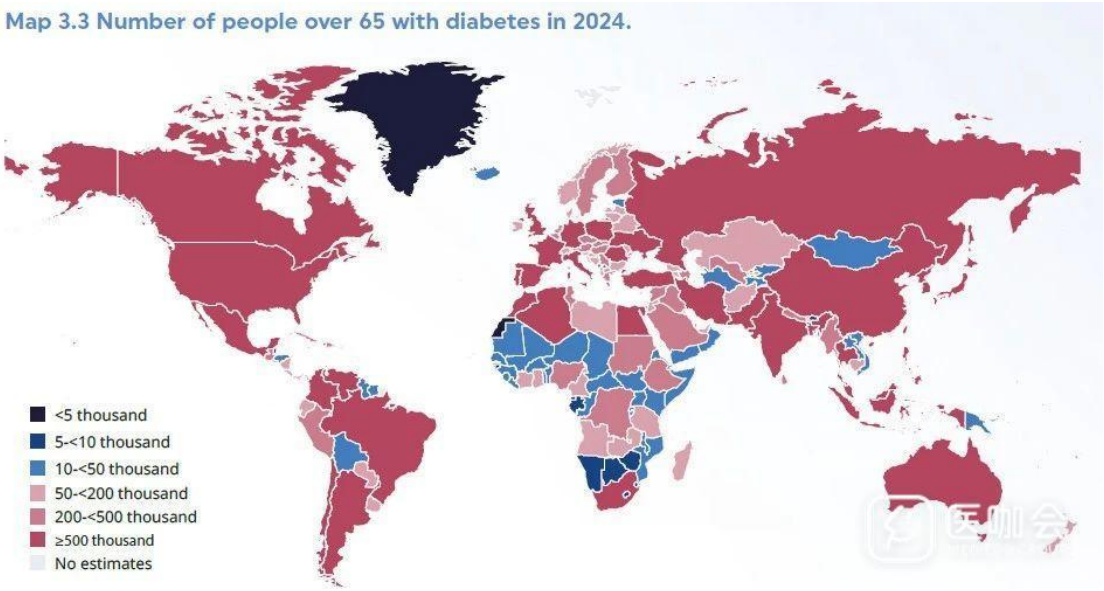

Figure 1. Global Diabetes Map

The application of artificial intelligence (AI) in healthcare has been primarily focused on precision screening, risk prediction, and personalized health management. By analyzing large-scale clinical data, AI can effectively predict the risk of diseases like diabetes, for instance, by using models like logistic regression and support vector machines to assess the likelihood of disease onset [1]. At the same time, AI shows significant potential in dietary monitoring, such as using food image recognition systems to estimate dietary calories and nutritional components, providing individuals with customized health management plans [2]. AI has vast potential in diabetes management, especially in predicting, diagnosing, and treating diabetes and its complications. By analyzing real-time data (such as continuous glucose monitoring, nutritional monitoring, and activity tracking), AI can help develop personalized treatment plans, improve prediction accuracy, and enhance patient outcomes. Furthermore, AI supports precision medicine by analyzing multi-dimensional data (including genetic, environmental, and behavioral factors), providing more effective management and treatment for diabetes patients. In the future, AI-based precision prediction and diagnosis will play an essential role in the field of diabetes [3].

1.2. Research Questions and Objectives

The research questions focus on comparing the effectiveness of different intervention strategies in terms of blood glucose control, adherence, and complication risk. Secondly, this study reviews the current research on AI dietary interventions for special populations and analyzes their applicability. Finally, this research will discuss future challenges, application values, and prospects related to "the application of AI in diabetes management." The objective of this study is to systematically review and analyze domestic and international research on AI-based personalized dietary interventions in diabetes, evaluating the effects and challenges of different technical approaches, and proposing future research and practical recommendations.

2. LITERATURE REVIEW

2.1. Current Status and Challenges in Diabetes Management

From September 2023 to September 2024, Ye Fang conducted a cross-sectional survey of 300 type 2 diabetes patients in Keqiao District, Shaoxing City, Zhejiang Province. The study found that community diabetes patients tend to be older, with lower educational levels and a lack of self-health management awareness. Additionally, many elderly patients experience significant fear of

hypoglycemia, especially those living alone, who face increased psychological burden due to a lack of timely care. These factors present significant challenges in diabetes management [4]. In the same year, the Taizhou Haiying District Community Health Service Center evaluated the status of 70 diabetes patients and 16 primary care nurses, finding that most nurses faced difficulties in managing diabetes due to insufficient professional competence. Though nurses enhanced their qualifications through in-service education, they lacked in-depth knowledge of the learning content and faced inadequate education systems and job training. This resulted in poor communication skills between nurses and patients, hindering effective care [5].

2.2. AI Applications in Diabetes Management

A research team developed a novel TPGE method to predict drug treatment efficacy based on data from 27,904 diabetic patients. This method outperformed traditional machine learning models in prediction accuracy, with results that better align with clinical intuition. The method has been successfully integrated into Electronic Health Records (EHR) systems, demonstrating significant clinical value [6].Furthermore, the SineDie telemedicine platform uses AI to analyze data from gestational diabetes mellitus (GDM) patients, reducing face-to-face consultations and doctors' workload while providing safe treatment recommendations. The mobile application has enhanced patient adherence and ease of use, particularly during the pandemic, demonstrating strong application prospects [7].

2.3. AI Applications in Dietary Intervention

Artificial intelligence has shown great potential in dietary interventions by providing personalized dietary recommendations through various technologies such as traditional machine learning, deep learning, and Internet of Things hybrid technologies [8]. AI can also monitor food intake in real-time and integrate multi-source data, enhancing treatment outcomes and decision-making support [9]. For instance, in the dietary intervention of inflammatory bowel disease (IBD), AI leverages machine learning and deep neural networks to analyze patient data (such as stool samples, gut microbiota, and blood tests), optimizing dietary patterns and improving treatment adherence. Additionally, food image recognition and large language models (such as ChatGPT) have been utilized to improve nutritional assessments and patient education [10]. Anhui Medical University conducted a study using questionnaires, height, weight, and blood pressure data, combined with Epidata and SPSS software for data cleaning, grouping, and statistical analysis. AI techniques such as multiple response analysis, regression analysis, and qualitative analysis were applied to assess the effects of dietary behavior, understanding, and hypertension dietary factors, providing support for intervention effectiveness evaluation [11].

2.4. AI Intervention Research for Special Populations (Elderly, Pregnant Women, Children, etc.)

In recent years, AI intervention research targeting special populations (such as the elderly, pregnant women, and children) has been expanding.

For children, an AI-based screening method has been developed using a deep learning network (ConvNeXt) combined with smartphone images to accurately detect myopia, strabismus, and ptosis, providing a convenient tool for family-based vision screening. This has facilitated early detection and reduced the risk of vision loss due to delayed screenings [12].

For pregnant women, AI research has focused on developing deep learning models to estimate gestational age (GA), which has been successfully applied in resource-limited settings using low-cost devices, providing accuracy comparable to high-end equipment [13].

For the elderly and acute stroke patients, AI interventions have utilized AI technologies to evaluate the ASPECTS (Alberta Stroke Program Early CT Score) for assessing middle cerebral artery occlusion, enabling clinicians to quickly assess patient conditions and decide on treatment timing, thus improving stroke emergency management efficiency and accuracy [14].

In the context of personalized medicine and precision healthcare, AI shows great potential in elderly care. By analyzing molecular, clinical, and lifestyle data, AI can help provide tailored care for elderly patients, improving the management of chronic diseases like hypertension, diabetes, and hyperlipidemia [15].

2.5. Existing Problems and Research Gaps

Firstly, the application of AI in nutritional management for inflammatory bowel disease (IBD) is still in its early stages, mainly in the design and development phases, lacking clinical application studies. Future research should focus on strengthening interdisciplinary collaboration between AI and IBD nutritional management, improving the accuracy of dietary intake assessments, applying food image recognition technologies, and developing food recommendation systems suitable for IBD patients while paying attention to ethical and privacy issues [9].

Secondly, The research paradigm in this field needs to shift from algorithm performance verification to rigorous evaluation of clinical benefits in real-world medical scenarios [10]. Studies have shown that the application of AI in tuberculosis imaging, especially in children with pulmonary tuberculosis, still faces challenges, mainly including the lack of diverse training data, the insufficiency of external validation, and the bias of reference standards. Future development of AI solutions specifically designed for children is needed [16]. Also, regarding gestational age estimation, existing studies have not evaluated the performance of AI tools in patients with high-risk diseases, and the geographical location of the sample is limited. In the future, the accuracy of AI tools in complex cases should be evaluated [13]. Finally, there is a risk of "dehumanization" in the design of AI tools for the elderly, especially as health monitoring technologies may lead to social isolation and privacy issues. Older people are generally less receptive to AI technology, especially wearable devices and environmental sensors. In the future, user-centered design approaches will be needed to extensively study the views of the elderly on AI technology in order to increase the acceptance of the technology and its practical application value [15]. These challenges reveal the potential of AI in healthcare, which will need to be further advanced through interdisciplinary.

3. RESEARCH METHODOLOGY

3.1. Research Design: Systematic Literature Review

This study is designed as a systematic literature review, potentially incorporating aspects of a scoping review (if the volume of research in the field is substantial and heterogeneous). This methodology is suitable for comprehensively summarizing existing evidence in an emerging field, identifying research gaps, and providing direction for future studies.

3.2. Literature Search Strategy

To ensure the comprehensiveness and academic rigor of this study, literature searches were conducted across multiple academic databases, including CNKI, Wanfang, PubMed, Web of Science, and Embase. These databases are among the most widely used and authoritative resources in current academic research, providing a wide range of literature to ensure both depth and breadth in the study results. The selection of keywords was based on a combination of English and Chinese terms to guarantee thoroughness and accuracy. Keywords included "Artificial Intelligence," "Diabetes," "Dietary Intervention," "Personalized," "Machine Learning," "Deep Learning," and so on. To ensure

the representativeness of the literature, no specific time frame was imposed on the search, although the focus was on studies from the past decade, as they reflect the rapid advancements in AI technology within the field of diabetes. The study primarily included empirical studies, review articles, conference papers, and policy documents, ensuring research from different perspectives and levels. The literature selection criteria were based on relevance to AI's application in diabetes dietary intervention, along with the scientific credibility of the research methods employed.

3.3. Inclusion and Exclusion Criteria

Inclusion Criteria:

(1) Studies must involve the application of AI technologies in diabetes dietary intervention, including practices such as AI in diabetes dietary management, nutritional assessment, and personalized treatment planning.

(2) Studies should report intervention outcomes, technological evaluations, or evidence validation, providing experimental data or clinical case analysis for comprehensive evaluation.

(3) Research must follow rigorous scientific methodologies, with detailed experimental designs, data analyses, and result discussions.

Exclusion Criteria:

(1) Studies not related to diabetes or dietary interventions using AI, especially those focusing solely on AI applications in other diseases or fields.

(2) Studies with sample sizes smaller than 30 participants, or those lacking clear descriptions of research methods, data collection, and analysis.

(3) Research without effective intervention outcome evaluations or insufficient data support, particularly theoretical or conceptual papers.

3.4. Data Extraction and Analysis Framework

Content to Extract:Study design, types of AI technologies, data sources, intervention strategies, evaluation indicators, main conclusions, limitations.

Analysis Methods:Narrative synthesis and thematic analysis, making horizontal comparisons of different studies.

Data extraction:

(1) Study design: Extract the type of study design for each reference (such as randomized controlled trial, cohort study, retrospective analysis, etc.) and specify the time frame of the study (such as cross-sectional, longitudinal, etc.). This section will help assess the scientific and effective nature of the study and understand the impact of different study designs on the evaluation of intervention effects.

(2) AI technology types: Categorize the AI technologies used in each study (such as machine learning, deep learning, natural language processing, computer vision, etc.) and document in detail their specific application areas and functions (such as data analysis, disease prediction, personalized intervention, etc.). This dimension helps to understand the technological development trends and current application status of artificial intelligence in the field of diabetic diet intervention.

(3) Data sources: Record in detail the data sources used in each study (such as clinical trial data, patient-reported data, public databases, etc.), and evaluate the quality and reliability of the data. The diversity and representativeness of data sources are key factors in ensuring the generalization and utility of research results.

(4) Intervention strategies: Extract the specific intervention strategies implemented in each study, including the type of intervention (such as dietary adjustment, lifestyle intervention, medication treatment, etc.), the method of intervention (such as e-health platform, smart device, remote monitoring, etc.), as well as the frequency and duration of the intervention. Through the extraction of this section, the effects of different intervention strategies in diabetes management can be systematically evaluated.

(5) Evaluation indicators: Based on the description in each literature, extract specific indicators for evaluating the effect of the intervention, such as physiological indicators like blood glucose level, body weight, blood pressure, insulin sensitivity, or psychosocial indicators like quality of life and satisfaction of the patient. The extraction of this section will help assess how different studies measure the effect of diabetes intervention and its effectiveness.

(6) Main Conclusions: Summarize the core conclusions of each study, including the assessment results of the intervention effect, the application effect of AI technology in the intervention and its possible advantages and limitations. This section will provide a direct basis for a comprehensive understanding of the effects of artificial intelligence in diabetes intervention.

(7) Limitations: Extract the limiting factors mentioned in each study (such as small sample size, methodological bias, short intervention duration, etc.) and analyze the possible impact of these limitations on the study results. An analysis of the limitations helps to provide suggestions for improvement in subsequent studies.

Analysis method:

(1) Narrative synthesis: Organize and summarize the core information of different studies (such as study design, intervention strategy, evaluation metrics, etc.) to provide a panoramic description that reveals current research trends and key findings in the field.

(2) Subject analysis: Identify and summarize recurring themes and patterns in multiple studies through in-depth analysis of key data and results in the literature. Including the specific application of AI technology in diabetes intervention, the criteria for evaluating intervention effects, and the comparative advantages of different intervention strategies.

(3) Horizontal comparison: Compare the intervention effects in different studies, the differences in the application of AI technology, and the advantages and disadvantages of the study design, and propose targeted improvement suggestions.

4. RESULTS AND FINDINGS

4.1. AI Technology in Dietary Intervention for Diabetes

AI technologies have increasingly been applied in diabetes dietary intervention, with positive effects observed in blood glucose control, patient adherence, and the reduction of complication risks:

(1) Blood Glucose Control Outcomes: For instance, the "Peking University Diabetes Manager" WeChat platform utilizes SDPC and AI-HEALS systems to provide knowledge, health monitoring, reminders, and personalized push services [17]. Post-intervention, the HbA1c levels of patients significantly decreased in multiple follow-ups, and other indicators like fasting blood glucose, blood pressure, and blood lipids improved.

(2) Patient Adherence Improvement: AI food recognition systems, such as the one studied by Sun Yiting and Ni Yaping, help patients visualize the relationship between diet and blood glucose levels by recognizing food nutritional components and glycemic index, leading to significant improvements in patient adherence and nutritional literacy [18].

(3) Reduced Risk of Complications: AI-driven mobile health services, like the one studied by Li Ruihan, enhanced patient trust and involvement, improving psychological conditions and helping reduce diabetes-related complication risks [19].

4.2. Comparative Analysis of Different Technological Approaches

Clinical research, such as one conducted at Changshu First People's Hospital, used SPSS software to analyze data from 150 middle-aged and young patients with type 2 diabetes, showing effective verification of intervention outcomes [18]. In algorithm research, networks like CA-and-RepVGG demonstrated higher accuracy, sensitivity, and operational efficiency in classifying diabetic retinopathy images, outperforming traditional models like VGG-16 and ResNet-50, showing greater potential for clinical application [20]. The study based on data from the US Centers for Disease Control and Prevention used the KNN algorithm for diabetes prediction. The algorithm has a simple structure and high accuracy, and is suitable for small sample analysis [21]. Meanwhile, AI mobile health services research verified the validity of the questionnaire and the user experience of patients through the Credamo platform questionnaire survey combined with SmartPLS4.0 [19]. Overall, from statistical analysis to deep learning, machine learning and mobile health applications, different technical approaches each have their own advantages, jointly promoting the refined and efficient development of intelligent diabetes management.

4.3. Applicability and Limitations for Special Populations

Research shows that AI tools like social robots, such as Kaspar and RoboTherapy, have been applied to educational and rehabilitation training for children with autism [22]. These tools have shown positive reactions during interactions and have improved social skills to some extent. However, much of the current research remains in the exploratory or pilot stages, particularly regarding the attitudes of patients towards AI in mental health, and the ethical implications regarding privacy and AI algorithm bias [22].

4.4. Application of Behavioral Psychology in Combination with AI

In recent years, the AI system AMIE (Articulate Medical Intelligence Explorer), based on large language models (LLMs), has been optimized for clinical history collection and diagnostic conversations. This system introduces a self-game-based simulated conversation environment with automatic feedback mechanisms, enabling accurate and empathetic conversations with patients [23]. On the ethical front, conversational artificial intelligence (CAI) faces demands for safety, reliability, and risk control, clearly defining the role and responsibility of human doctors. Additionally, as an active agent, CAI must follow the same behavioral guidelines as mental health professionals to align with professional values and psychological intervention ethics [24]. For example, a study conducted at the Shanghai Jiao Tong University School of Medicine and Renji Hospital used an AI-driven remote intervention platform to enhance interaction and rehabilitation beliefs in gastric cancer patients through multimodal methods. The platform provided knowledge education, psychological support, online communication, rehabilitation monitoring, and follow-up mechanisms, improving the patients' quality of life and doctor-patient communication experiences [25]. The combination of AI technology and behavioral psychology not only opens new pathways for intelligent diagnosis and psychological intervention but also lays the foundation for building an empathetic, patient-centered, and ethically guided intelligent healthcare system.

5. DISCUSSION

5.1. Advantages and Challenges of AI in Diabetes Dietary Intervention

On the technical side, a study conducted by Jing'an District North Hospital in Shanghai examined the use of a dietary app by pre-diabetic patients. Although the app provided calorie calculation functions, it did not fully account for the complex relationship between food and blood glucose, resulting in suboptimal intervention outcomes. Patients often failed to grasp the relationship between food intake and blood glucose fluctuations, leading to either over-control or mismanagement of their health [26]. Moreover, machine learning models in diabetes prediction suffer from overfitting, with training data often differing from the target population, leading to decreased accuracy [27]. In terms of ethics and privacy, AI interventions involve large amounts of sensitive health data, making the protection of patient privacy and data security a key issue. Additionally, AI errors may pose health risks, and establishing clear accountability and legal frameworks will help avoid ethical disputes [28]. Clinically, both doctors and patients show varying degrees of acceptance and capability to use AI technologies. Furthermore, the long-term effectiveness of AI interventions, particularly when combined with exercise and other interventions, still needs further validation [28]. Therefore, while AI holds great potential for dietary intervention in diabetes management, challenges such as technological standardization, privacy protection, and clinical translation must be addressed. The integration of AI technologies into comprehensive treatment plans will be a key focus for future research.

5.2. Future Research Directions

Future research in diabetes dietary intervention should focus on evaluating the effectiveness of combined interventions. Currently, single dietary control often faces rebound effects, and combining exercise interventions to further improve blood glucose control should become a research priority. Studies could explore the integration of different types of exercise with dietary interventions to provide more comprehensive and sustainable management solutions for pre-diabetic patients [26]. Although machine learning has made progress in diabetes prediction, its performance in specific populations (such as the elderly, children, and pregnant women) has not met expectations. Future research should focus on optimizing machine learning models, particularly by improving the quality and diversity of datasets. By fully utilizing large-scale clinical data and computational resources, prediction performance can be enhanced, leading to more accurate and effective solutions for early diagnosis, prevention, and personalized treatment of diabetes [27].

6. CONCLUSION AND RECOMMENDATIONS

6.1. Research Summary

This study systematically reviewed the application of AI in diabetes management, particularly in personalized dietary interventions. AI technologies, especially machine learning and deep learning, have been widely applied in diabetes screening, prediction, treatment, and dietary interventions. They have played a crucial role in improving blood glucose control, enhancing patient adherence, and reducing the risk of diabetes complications. Through data analysis, AI provides personalized health management solutions for diabetes patients, demonstrating significant potential, particularly in remote monitoring and dietary management. However, despite the considerable progress in AI technologies for diabetes management, challenges remain in data privacy protection, technology standardization, and clinical application translation.

6.2. Recommendations for Clinical and Public Health Practice

Based on the findings of this study, it is recommended that AI technologies be more widely adopted in clinical and public health practices for diabetes management, especially in personalized dietary interventions and remote health monitoring. AI-driven personalized dietary recommendation systems can help patients better understand the impact of their diet on blood glucose levels and improve self-management behaviors. Therefore, future clinical practices should integrate AI technologies with traditional treatments to develop comprehensive diabetes management plans that improve patients' quality of life and clinical outcomes.

6.3. Research Limitations

This study has several limitations. Firstly, due to data heterogeneity, there are differences in the AI technologies and intervention strategies used in different studies, making it difficult to perform direct cross-study comparisons. Secondly, many studies on AI applications are still in the early stages, lacking large-scale clinical trials to validate the real-world effectiveness of the interventions. Some research focuses on algorithm development rather than actual clinical applications, which may impact the practical applicability of the results. Additionally, the accuracy and effectiveness of AI systems are limited by data quality and sample size, and future studies will require more diverse and high-quality datasets to validate the long-term effectiveness of these technologies.

6.4. Future Outlook

Future research should focus on optimizing existing AI models, particularly in integrating exercise interventions with personalized dietary interventions. While AI has made progress in diabetes prediction, further studies are needed to evaluate its applicability and accuracy for special populations. In addition to technological optimization, research should also address the ethical concerns related to AI technologies, such as privacy protection, data security, and patient acceptance. With the continuous advancement of AI technologies, the widespread application of AI in diabetes management is expected, especially in the areas of precision medicine and interdisciplinary collaboration. This will provide more efficient solutions for the early diagnosis, prevention, and personalized treatment of diabetes.

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