

Exploration of Remote Nutrition Intervention for Metabolic Diseases Supported by Multimodal Dietary Data

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Abstract. The prevalence rate of metabolic syndrome, type 2 diabetes and dyslipidemia in adults in China continues to rise, and the affected population is becoming younger. Nutritional intervention is a key measure for the control of metabolic chronic diseases. Traditional offline guidance is constrained by time and space, and dietary data relies on subjective recollection, which has shortcomings such as large errors and insufficient personalization. This article aims to explore new intervention pathways that are suitable for long-term management of chronic diseases. This study integrates multi-dimensional data on diet, physiology, metabolism, and behavior, relying on image recognition, wearable devices, and cloud technology, to build a remote nutrition intervention system that integrates data collection, intelligent analysis, individualized intervention plans, and online follow-up and guidance. Combining authoritative monitoring data and scientific research achievements, the architecture and application path are sorted out. The results confirm that multimodal data can overcome the inherent limits of traditional nutritional interventions and effectively improve the level of dietary management and the effectiveness of chronic disease control. This model is suitable for the development needs of primary healthcare and can provide theoretical and practical support for digital remote nutrition management of metabolic diseases.

Keywords: Multimodal dietary data, Metabolic chronic diseases, Remote Nutrition Intervention, Dietary monitoring, Digital Chronic Disease Management.

1. Introduction

Metabolic diseases are chronic disease clusters caused by the imbalance of glucose, lipid and protein metabolism, covering common clinical types such as type 2 diabetes, obesity, nonalcoholic fatty liver, hyperuricemia and metabolic syndrome. According to publicly available data from the National Health Commission, the number of adults with metabolic chronic diseases in China is large, and the coexistence of multiple diseases in the population is significant. The chronic disease prevention and control system has now moved away from a single drug diagnosis and treatment model, and lifestyle regulation and nutritional intervention have become important components of the comprehensive prevention and control system. Nutritional intervention has also become a core non-pharmacological means to stabilize physiological indicators such as blood sugar, blood lipids, and weight in patients.

Offline outpatient consultation is still the main form of nutrition intervention at present, and nutritionists develop general dietary guidance plans based on physical examination results and patients' self-reported diets. The fixed follow-up mechanism cannot cover the entire process of daily dietary behavior, and recall-based dietary records are prone to data bias and difficult to reproduce the true intake situation. The standardized development of standards ignores individual metabolic traits, intestinal adaptability, and dietary preferences, greatly reducing the actual effectiveness of intervention programs [1].

The popularization of digital technology and intelligent sensing devices is promoting the remote management of chronic diseases. Multimodal dietary data integrates multi-dimensional information such as dish images, physiological monitoring, physical parameters, and eating behavior to achieve long-term objective collection of dietary and metabolic status. Cloud based big data computing can generate nutrition intervention plans that are tailored to individual characteristics, breaking the limitations of traditional services at the spatiotemporal level.

This article takes remote nutritional intervention for metabolic diseases as the research object, combines domestic digital nutrition research and grassroots medical situation, analyzes the

shortcomings of traditional nutritional intervention, builds a multimodal diet data collection framework, explores the construction and implementation methods of intervention models, points out the problems of technical application, and provides optimization directions. Below, this paper first analyzes the real-world dilemmas of nutritional intervention, and then elaborates on the specific application paths of multimodal data.

2. Current Status and Challenges of Nutritional Intervention for Metabolic Diseases

Metabolic diseases originate from the metabolic dysfunction of human glucose, lipid and protein. The common clinical types include type 2 diabetes, obesity, nonalcoholic fatty liver, hyperuricemia and metabolic syndrome. Dietary structure and daily eating behavior directly affect the development process of such chronic diseases. Standardized nutritional regulation can slow down the progression of the disease and effectively reduce the probability of complications. Primary healthcare has incorporated nutrition guidance into routine services for metabolic diseases, but the actual implementation effect varies greatly, and there is still a lot of room for improvement in overall management effectiveness.

The population of metabolic diseases in China presents significant characteristics of wide coverage, younger onset, and multiple comorbidities [2]. Overweight and obesity are important risk factors for metabolic syndrome. In clinical diagnosis and treatment, most patients with type 2 diabetes and hyperlipidemia generally have abnormal weight. The number of middle-aged and young people following long-term high-fat, high-sugar diets, irregular daily routines, and sedentary lifestyles is increasing year by year. The daily work pace of this group is tight, making it difficult to adhere to regular offline outpatient follow-up visits, and the long-term continuity of nutrition guidance is difficult to maintain.

There are obvious shortcomings in traditional offline outpatient nutrition services. Metabolic diseases cannot be separated from long-term dietary regulation. The fixed medical treatment mode cannot keep up with daily dietary status in real time, and it is also difficult to adjust intervention plans according to physical changes. The 24-hour dietary review method and food frequency questionnaire are still the main ways to collect dietary data at the grassroots level. Relying on personal memory to complete information filling will result in data bias and cannot truthfully restore the true dietary intake situation of the public.

The current nutrition guidance plan is mostly formulated based on general industry standards, without considering the differentiated characteristics of individual metabolic functions. The same type of food affects people with different constitutions, causing varying fluctuations in blood sugar and blood lipids, making it difficult to achieve precise chronic disease control through standardized management. Most online nutrition service platforms on the market rely solely on users manually entering dietary text information, lack professional equipment for objective monitoring, limited data dimensions, and the intervention effect cannot be maintained stably.

Traditional intervention methods are no longer suitable for the large-scale, long-term, and individualized management demands of metabolic diseases. Developing a digital remote nutrition intervention system based on multi-dimensional objective monitoring data can not only solve the existing problems in nutrition management of chronic diseases at the grassroots level, but also provide a feasible path for the digital transformation of grassroots medical care [3].

3. Multimodal dietary data acquisition technology system and implementation logic

The key to the effectiveness of remote nutritional intervention for metabolic diseases lies in the high-quality collection of multimodal dietary data. Compared to the crude approach of traditional single text recording, the multimodal fusion framework relies on intelligent technical system to

integrate dietary records, physiological indicators, and daily behavior dimension information, complete efficient data transmission and standardized archiving, and lay a solid foundation for building a personal exclusive health database.

The entire collection system consists of three modules: perception collection, network transmission, and cloud storage application. The perception collection layer is the core hub of the system operation. With the help of Chinese cuisine image recognition technology installed on smartphones, relying on deep learning algorithms to distinguish food categories and estimate eating portions, it perfectly adapts to the recognition scenarios of home-style dishes and mixed meals, and is currently the most widely recognized information collection method among the public [4]. Wearable devices such as smart bracelets and health watches can continuously monitor physical indicators like heart rate and body fat, and daily activity, and capture details of eating behavior, and provide reliable basis for judging dietary patterns. Professional medical equipment such as dynamic blood glucose monitoring can track blood glucose fluctuations around the clock, clearly presenting the real-time changes in human metabolism caused by different dietary intake.

Mobile network provides basic support for terminal data cloud upload. Edge Computing preprocesses redundant information to effectively improve transmission efficiency. Unified communication interface also resolves the problem of incompatible data formats of different devices. The cloud platform strictly follows the medical privacy guidelines to build a storage system, encrypts and protects sensitive health data, and connects the ports of hospital electronic medical records and community chronic disease archives to achieve medical data sharing and interoperability.

Building this system requires a balance between practical experience, data accuracy, and unified standards. Simplifying operational logic and relying on intelligent recognition to reduce manual filling can effectively lower the threshold for public use; Multi-dimensional information cross validation can compensate for the inherent errors of a single collection method; Standardize data statistics and lay the foundation for subsequent model analysis and data fusion.

Multiple domestic public health research institutions have conducted field tests, and this system is suitable for home use, with simple operation and significantly better data integrity and authenticity than traditional manual recording methods. It can lay a solid data foundation for the construction of personalized intervention models in the future [5].

4. Construction of personalized nutrition intervention model under multimodal data fusion

Building personalized intervention models based on multimodal diet and physiological monitoring data is an important foundation for precise remote nutrition guidance. The model follows the implementation process of data cleaning and sorting, feature extraction, intelligent matching, and dynamic adjustment, and combines the dietary characteristics of domestic residents and clinical diagnosis and treatment standards for metabolic diseases to develop personalized nutrition regulation plans.

Carry out basic data cleaning and sorting and feature screening work. Integrate dietary images, blood glucose signs, and lifestyle behaviors related data stored in the cloud to complete unified cleaning and screening. Eliminate equipment failures, duplicate and redundant invalid data, and lock in core evaluation indicators such as daily calorie intake, macro nutrient composition, dietary glycemic properties, daily blood glucose fluctuations, and daily activity levels. Integrate multidimensional information, establish patient-specific dietary metabolism profiles, and clarify dietary structure defects and metabolic susceptibility weaknesses.

Using intelligent algorithms to achieve multi-source data fusion and conduct metabolic risk stratification assessment. Set differentiated weights for dietary intake, physiological indicators, and lifestyle behavior data, and divide them into high, medium, and low metabolic risk levels. Intensify health monitoring and online guidance frequency for high-risk groups, and implement normalized cycle management for medium and low-risk groups. The hierarchical management model can

improve intervention efficiency, balance medical resource allocation and clinical intervention capacity.

Referring to the "Chinese Dietary Guidelines for Residents" and the dietary standards for metabolic diseases, combined with individual height, age, basal metabolism, and disease type, determine the daily calorie supply standard and optimize the ratio of the three macronutrients. Based on personal dietary preferences, regional dietary habits, and the body's food tolerance, adjust the types and timing of meals, avoid blood lipid and blood sugar sensitive ingredients, and develop standardized daily dietary plans and dietary taboos [6].

The model's dynamic adaptability also needs to be fully utilized. Continuously access daily multimodal monitoring data to track trends in dietary adherence and physiological indicators. In case of abnormal fluctuations in blood sugar and stagnant improvement in body fat and weight, the nutrient ratio and dietary structure will be automatically adjusted, and a professional nutritionist will complete manual review to construct an intervention system that combines algorithm calculation and professional quality control [7].

The data-driven intervention model can address the homogenization issue in traditional nutrition guidance. Offering dietary recommendations using multimodal actual data is also suitable for long-term refined management of metabolic diseases.

5. Implementation process and application value of remote nutritional intervention for metabolic diseases

Based on multimodal diet and physiological monitoring data, remote nutritional intervention for metabolic diseases has a mature standardized implementation path. This study establishes a collaborative system among community healthcare workers, clinical nutritionists, chronic disease patients, and intelligent service platforms. The entire intervention process is divided into three parts: baseline assessment, regular cyclic intervention, and stage effect review. The formulation and dynamic adjustment of various intervention plans are based on multimodal measured data as the core support.

The enrolled subjects completed routine physical examinations and biochemical screening, synchronized and archived their health information, and established standardized electronic health records for chronic diseases. This study provides participants with intelligent monitoring devices and mobile service ports for subjects, completing device debugging and practical guidance, ensuring that subjects can independently complete basic operations such as daily meal photography and real-time uploading of physiological data. The intelligent platform integrates the multimodal information collected in the first phase to generate a baseline report on individual dietary structure and metabolic status. Medical staff and nutritionists combine the report content to develop personalized intervention goals, including practical directions such as weight control, stable blood sugar regulation, and optimization of daily dietary structure [8].

The intelligent platform adopts non-invasive real-time monitoring, automatically analyzing the daily dietary composition, eating rhythm, and blood glucose fluctuation characteristics of the subjects. When physiological indicators are abnormal or dietary ratios are imbalanced, the platform will promptly send health alerts and provide targeted dietary adjustment suggestions. Establish a normalized online follow-up mechanism for the project, conduct weekly text or voice communication, and organize monthly online video review and communication. Based on the dynamic changes of multimodal data, timely adjust nutritional intervention strategies and guide subjects to correct their unhealthy eating and sleeping habits. The platform provides targeted recommendations for practical content such as dietary health knowledge, standardized cooking techniques, and replacement plans for similar ingredients, helping participants develop habits of self-directed health management.

The study will also compare key indicators such as blood glucose, blood lipids, and weight before and after intervention, and assess patient adherence to dietary plans and the improvement effect of lifestyle habits in patients [9]. Summarize the shortcomings in the process based on the actual

situation such as the adaptability of the solution and the difficulty of equipment operation. This model still faces several practical hurdles in large-scale promotion.

6. The practical shortcomings and optimization path of multimodal remote nutrition intervention

The application of multimodal dietary data in remote nutritional intervention for metabolic diseases has mature technical support and practical cases. If promoted on a large scale, this model still has obvious shortcomings in technology application, affordability and accessibility, digital adaptation, and privacy management, and needs to be improved and optimized according to the current industry situation.

There are two practical challenges at the technical level. Faced with complex food scenarios such as mixed dishes, buffets, and hotpot, image recognition and portion estimation are prone to errors, and the accuracy is difficult to meet clinical intervention requirements; Various intelligent terminals and health platforms have different interface standards, and industry brand barriers have led to data silos, making it difficult to integrate data across devices and platforms. The industry can gradually optimize the Chinese food image recognition model and expand the sample library of home and local dishes; Synchronize and unify health data interface specifications, rely on HL7 FHIR standards to connect device and medical platform data links, and improve the efficiency of multi-source data fusion [10].

The high cost of purchasing and long-term use of monitoring equipment brings economic pressure to ordinary residents and also affects the willingness of low-income and elderly groups to use it. Relying on domestic medical hardware research and development upgrades can gradually lower terminal prices, while incorporating remote nutrition intervention into community chronic disease public welfare services. Grassroots medical institutions can centrally configure equipment to reduce personal expenditure burdens [11].

The population of elderly metabolic disease patients is huge, and many elderly people are not familiar with the operation of smart devices, making it difficult for them to independently complete basic processes such as dish shooting and data uploading; There is a significant shortage of registered nutritionists in China, making it difficult to support large-scale remote service supply. The platform can add an aging-friendly interface and voice guidance to reduce the operating threshold; By utilizing intelligent algorithms to provide basic dietary guidance, nutritionists can focus on reviewing complex cases and answering difficult questions, using technology to fill talent gaps.

Diet and physiological monitoring data are both sensitive personal health information, and there is a risk of leakage in the cloud storage and transmission process. Relevant platforms should comply with medical data security regulations, implement end-to-end encryption and role-based authorization, and use data only for chronic disease management and not for commercial purposes. It also clarifies the responsibilities of the platform, medical staff, and patients.

7. Conclusion

The routine prevention and control of metabolic diseases cannot be achieved without long-term and personalized nutritional interventions. Traditional offline outpatient nutrition management is limited by time and space, subjective evaluation, and homogeneous intervention plans, making it difficult to meet the refined management needs of the domestic chronic disease population. Based on dietary image recognition, wearable monitoring, and cloud data fusion technology, multimodal dietary data can integrate multidimensional information such as dietary intake, physiological signs, and daily behavior, providing solid data support for remote nutritional intervention for metabolic diseases.

This article reviews the current status and practical problems of nutritional intervention for metabolic diseases, establishes a three-layer collection system for multimodal dietary data, explains

the logic of constructing personalized intervention models, and clarifies the complete process of baseline evaluation, periodic intervention, and effectiveness review. At the same time, summarize the shortcomings in the implementation of the model, including the accuracy of food recognition, equipment usage costs, elderly digital adaptation, data privacy and security, and propose feasible optimization paths based on the current domestic medical situation.

Remote nutrition intervention empowered by multimodal data replaces subjective experience with objective data, fills the gap in offline follow-up with long-term online management, and breaks the limitations of homogeneous intervention through personalized plans. It not only conforms to the medical characteristics of lifelong management of metabolic diseases, but also adapts to the basic national conditions of uneven distribution of medical resources and a large population of chronic diseases in China. It can effectively improve patients' dietary compliance, stabilize metabolic indicators, and save personal medical costs and primary medical resources.

At present, this model is still in the stage of promotion and improvement, and there is still room for improvement in the adaptability and standardization of services at the grassroots level. Further development can be deepened in three aspects: optimizing the custom recognition algorithm for Chinese cuisine, promoting the localization and affordability of monitoring equipment, improving medical data privacy standards and industry standards, and building a digital nutrition management system that links hospitals, communities, and families. In the future, with the continuous development of digital healthcare, this intervention model will become a core mode for grassroots chronic disease management at the grassroots level, and can also provide practical reference for the prevention and control of chronic diseases in Healthy China.

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