

Research Progress on the Application of Digital Technology in Identifying Health Risks for Elderly People in Communities

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Abstract: With the acceleration of the aging population process, maintaining the physical function of the elderly and reducing the risk of falls have become important issues in the field of public health. The rapid development of digital technology has provided new technical means for the early identification and dynamic management of the health risks of community-dwelling elderly people. This paper systematically reviews the research progress of digital technologies such as wearable devices, artificial intelligence and machine learning, mobile health applications, virtual reality, and digital twins in the field of identifying health risks for the physical activities of community-dwelling elderly people. It analyzes the current application status, core functions, and main limitations of various technologies, and discusses the key challenges currently faced from aspects such as technology acceptance, data standards, privacy and security, and community adaptability.

Keywords: Digital technology; Elderly people; Physical health risks; Risk identification; Community health management

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1. Introduction

Motor function decline is one of the core health risks faced by the elderly. Motor dysfunction such as decreased muscle strength, reduced balance ability, and abnormal gait not only directly increases the risk of falls but is also closely related to disability, hospitalization, and even death. According to statistics, the proportion of the elderly aged 65 and above in China has reached 15.4%, and the incidence of falls is as high as 20.8%, making it the leading cause of injury-related death among the elderly population. Data from the World Health Organization shows that falls are the second leading cause of accidental death worldwide. Each year, approximately 30% of the elderly aged 65 and above experience at least one fall incident, and the resulting medical resource consumption and socioeconomic burden cannot be ignored. Against the

backdrop of the continuous deepening of population aging, how to achieve early identification and effective management of the health risks related to exercise among the elderly has become a key issue urgently needing to be addressed in the field of health promotion and public health.

Traditional assessment of exercise-related health risks mainly relies on annual physical examinations or passive medical visits, which have obvious limitations: a large number of early risk factors such as mild muscle weakness and reduced balance ability are often missed; there is a shortage of grassroots health personnel, and personnel with the ability to conduct exercise assessment and prescribe are even scarcer; the elderly lack convenient, continuous, and personalized self-monitoring and feedback mechanisms. The core problem lies in the lack of low-cost, wide coverage, and sustainable risk identification methods. Scientifically conducting fall risk assessment is an important prerequisite for achieving early identification, stratified management, and precise intervention of risks.

In recent years, the rapid development of digital technology has provided new solutions to these problems. A series of technical means such as wearable sensors, artificial intelligence algorithms, mobile health applications, and virtual reality are being gradually applied to the assessment and risk identification of elderly motor functions. Studies have shown that through means such as movement monitoring, data analysis, and intelligent feedback, digital technology improves the safety, controllability, and personalization of sports intervention, helping to alleviate risks in elderly sports participation. The application advantages of digital technology in elderly health management are receiving increasing attention and verification.

However, existing research mostly focuses on the verification of the effects of a single technology or small-scale pilot projects, and lacks a systematic review of the research progress in this field. This paper aims to systematically review the current application status and research progress of digital technology in the identification of exercise-related health risks among community-dwelling elderly, summarize the core functions and main limitations of various technologies, analyze the current key challenges, and look forward to future research directions, with the aim of providing references for related research and practice.

2. Main application types of digital technology in the identification of movement-related health risks

2.1. Wearable devices

Wearable devices are the most widely used technological means in the field of elderly movement health risk identification at present ^[1]. According to the different types of sensors and deployment methods, wearable devices can be classified into categories such as inertial sensors (accelerometers, gyroscopes), physiological sensors (heart rate, electromyography), and pressure sensors (foot sole pressure).

In terms of gait analysis and fall risk prediction, research based on wearable sensors has achieved significant progress. Researchers collect signals such as acceleration and angular velocity during the daily walking process of the elderly, extract gait spatiotemporal parameters (step length, step frequency, step speed variability, etc.), and construct fall risk prediction models. Some studies have elaborated on the specific process of constructing fall risk prediction models, starting from the data collection method, sensor type, data annotation, and model construction algorithm, and summarized the existing research results. They particularly emphasized the new trends of multi-modal data fusion and interpretable artificial intelligence. Research on fall prevention models for the elderly using wearable devices also indicates that the entire technical chain from data collection to model construction is gradually maturing ^[2].

In terms of muscle strength and balance assessment, intelligent wearable devices have been used for rapid assessment of movement functions in community settings. Studies show that wearable sensors have significant application value in the assessment of the functional status of the elderly, facilitating the transition from subjective assessment to objective quantification. The fall risk prediction model based on foot sole pressure distribution has also attracted attention. Researchers are attempting to develop wearable sensing devices equipped with an automatic fall risk recognition system. The existing fall risk identification methods in the literature mostly require the participation of others, so the development of an autonomous recognition system without the need for assistance from others has broad application prospects^[3]. In addition, the posture recognition system based on motion sensors can identify the living and daily routines of the elderly by detecting human motion acceleration parameters, combined with heart rate and blood oxygen information, facilitating the prediction and timely intervention of health status^[4].

In the field of fall detection, wearable devices also play an important role. The research on elderly fall detection systems based on electronic health indicates that wearable fall detection devices, smartphone-based detection systems, and motion games constitute the main technical paths for fall detection in the current eHealth framework^[5]. Some studies have reviewed and analyzed the evolution of fall monitoring technologies and the industrialization progress of fall prevention wearable products from 2013 to 2023, revealing the research hotspots and development trends in the field of fall prevention. Research on fall detection based on wearable pressure sensors has also gradually become the focus of scholars' attention. In recent years, the research trend has shifted from passive fall detection to active fall risk prediction, and from pure technology development to community application promotion.

2.2. Artificial intelligence and machine learning

The application of artificial intelligence technology in the identification of elderly people's movement health risks mainly lies in three aspects: the construction of risk prediction models, the automatic identification of abnormal gait, and the fusion analysis of multi-modal data.

In terms of risk prediction models, machine learning algorithms have been widely used for the classification and prediction of fall risks. A study based on artificial intelligence logic, using the Chinese Health and Elderly Longitudinal Survey Database to select 7,693 elderly people aged 60 and above as the research subjects, adopted a dual reconstruction strategy to systematically compare the predictive performance of six machine learning models, and used the Shapley Additivity Explanation method to quantify the contribution of each feature variable to the prediction model^[6]. The results showed that the gradient boosting tree model had the best performance (area under the curve = 0.677, 95% confidence interval [0.643, 0.711]), and the ability of daily living activities was the key variable affecting falls. Another study showed that by using machine learning and the dual reconstruction strategy to build an elderly fall prediction model, the calibration performance of the gradient boosting tree model was the best; the Shapley Additivity Explanation analysis and mediation effect test results showed that the ability of daily living activities was the key variable for predicting falls, and lower limb function was indirectly affected by daily living activities. The research on the construction and verification of an elderly fall risk prediction model based on BP neural network also showed that the neural network algorithm has good application potential in fall risk identification^[7].

In terms of gait recognition, the abnormal gait recognition technology based on vibration signals

provides a new idea for elderly health care. Existing related research mainly obtains relevant feature information through image acquisition devices or wearable devices for identification. Most of these methods are invasive or have high operational requirements for users. A study has implemented a system prototype for abnormal gait and fall detection using footsteps vibration signals as the identification source ^[8]. The algorithm for elderly fall behavior detection based on optimized models such as AlphaPose has been optimized for low-power, low-cost hardware platforms and achieved rapid and accurate detection of abnormal behaviors of the elderly.

The application of artificial intelligence in the field of falls has formed a relatively systematic research pattern. A review systematically summarized the research progress from three aspects of artificial intelligence in fall risk assessment, fall detection technology, and fall-related rehabilitation applications, pointing out that most factors causing falls are not accidental events but preventable and controllable ^[9]. This viewpoint provides theoretical support for the active intervention of digital technology in fall prevention. It is worth noting that multi-modal data fusion and explainable artificial intelligence have become new trends in this field. Researchers are no longer limited to a single sensor or a single algorithm, but attempt to integrate multiple data sources and focus on improving the interpretability of the model to enhance the trust and understanding of the prediction results by clinical workers and community personnel.

2.3. Mobile health applications and digital health interventions

Mobile health applications, which are based on smartphones, provide a convenient technical channel for elderly people to self-identify and manage their health risks related to exercise.

In terms of self-assessment, mobile applications enable the elderly to independently complete the preliminary screening of some exercise functions. Studies have explored the feasibility of using mobile health intervention measures to improve the static behaviors of the elderly and have investigated the application of smartphone applications for behavior monitoring and intervention. The research on the application of diversified exercise plans in elderly patients in the early stage of frailty shows that using WeChat mini-programs for diversified exercise guidance can effectively improve the exercise compliance of elderly patients.

In terms of digital exercise interventions, the application of digital technology in home-based exercise for elderly health promotion is increasingly attracting attention. Research has shown ^[10] that physical exercise can effectively improve the health level of the elderly, but due to factors such as health conditions, fitness environment, and economic costs, the compliance of the elderly with fitness centers or group exercises is low. Digital home-based exercise plans are expected to break through this bottleneck. The maturity of wearable devices provides new development opportunities for elderly sports activities. The intelligent integrated medical and physical therapy model shows good effects in promoting the physical fitness and health of community-dwelling elderly people.

In terms of comprehensive management platforms, the research on digital rehabilitation assessment methods for elderly care communities has introduced artificial intelligence and Internet of Things technologies into the field of rehabilitation assessment in elderly care communities ^[11]. Based on wearable sensors, 3D cameras, and other intelligent devices, combined with artificial intelligence technology, it completes multi-dimensional rehabilitation assessment tasks in one step. The comprehensive assessment information management platform for the elderly can conduct evaluations in multiple aspects such as

physical function, nutrition, cognition, sleep, depression, frailty, and sarcopenia, generate comprehensive assessment reports and health guidance suggestions, and achieve closed-loop management of “assessment — intervention—follow-up” for the elderly population.

The effectiveness of digital health interventions has been preliminarily verified. The rise of digitalized and intelligentized sports has gradually emerged, providing new ideas for improving the balance ability and fall risk of frail elderly populations ^[12]. The research progress of digitalized sports intervention plans in improving the balance ability and exercise functions of frail elderly people shows that the comprehensive application of digital technologies is developing from a single function to a systematic direction.

2.4. Virtual reality, digital twinning and other emerging technologies

Virtual reality technology creates immersive training and assessment environments, providing a unique interactive approach for assessing the motor functions of the elderly and identifying the risk of falls. The research system reviewed the progress of virtual reality technology in preventing falls among the elderly, focusing on its effects in improving balance ability, gait disorders, cognitive impairments, muscle strength, and fear of falling ^[13]. The effectiveness analysis of virtual reality training combined with case sharing in preventing falls among elderly patients also confirmed the clinical application value of this technology. The elderly balance ability training system based on virtual reality addresses the problems of dullness and lack of quantitative assessment in traditional training methods, and designs a set of human-machine interactive balance ability training schemes.

Digital twinning technology, as a data-driven innovative tool, has also begun to enter the field of elderly health management. Some studies have proposed a community-based “exercise-nutrition-cognition” collaborative intervention model for the elderly, aiming to address the challenges of three-dimensional risk accumulation in elderly health management. This technology enables dynamic simulation of health risks and optimization of personalized intervention plans by building a digital twin model of the elderly. The research on the application of digital twinning technology in the safety and health monitoring of elderly people in the community, combined with visual sensors, artificial intelligence chips, and deep learning algorithms, has developed a real-time monitoring and alarm system for elderly falls, abnormal postures, etc. The research on the design of elderly digital twinning health management services based on SAPAD-AHP also provides design methodological support for the practical application of this technology.

In the aspect of elderly-friendly intelligent wearable design, researchers start from the characteristic changes of the elderly group in three dimensions: physiology, psychology, and social attributes, and analyze the sensors, materials, form, structure, interaction methods, functional algorithms, and evaluation methods suitable for intelligent wearable devices for the elderly. The application research of non-invasive sensors in the elderly population indicates that wearable sensors may help identify frail patients. The research progress in the field of artificial intelligence and wearable devices in the diagnosis and treatment of sarcopenia also shows that early prevention and timely intervention are of great significance for delaying the occurrence and development of sarcopenia.

3. Challenges and existing problems in application

Although digital technology shows broad prospects in the field of identifying physical health risks among the elderly, its transition from the laboratory to actual community application still faces multiple challenges.

First, there are technical acceptance barriers and digital exclusion among the elderly population. Some elderly people over 60 years old are not accustomed to using smartphones or smart devices, have a rejection mentality towards digital technology, or have difficulty operating them. With the rapid development of information technology and the wide application of digital health technology, elderly people, due to decreased cognitive ability, low technical acceptance, and insufficient operational proficiency, are prone to digital health technology anxiety when using digital health technology. Studies show that most elderly people have a positive attitude towards using smart elderly care technology, but the actual usage rate and acceptance rate are not high, and perceived usefulness and perceived ease of use are the key factors affecting technology acceptance. The problem of digital exclusion among elderly patients is increasingly prominent, involving multiple aspects such as concept definition, manifestation form, influencing factors, and intervention strategies. How to explain and eliminate the “elderly digital divide” has become an important issue of concern for policymakers, technology developers, and the academic community. This requires that the design of digital tools must fully consider the cognitive characteristics and operational habits of the elderly, achieving true elderly-friendly design.

Second, there is a lack of data standards and privacy and security issues. Currently, different studies use various types of sensors, data collection frequencies, feature extraction methods, and model construction algorithms, lacking unified data standards and evaluation norms. This makes it difficult to directly compare the results of different studies and hinders the large-scale promotion of the technology. Meanwhile, the health data of the elderly involves highly sensitive personal information. The issues of privacy protection and data security during data collection, storage, and transmission urgently need to be addressed. The research on elderly-friendly smart wearable design points out that the standardization of interaction methods and functional algorithms is an important challenge currently faced.

Thirdly, the adaptability to community scenarios is insufficient. Existing research is mostly conducted in hospital or laboratory conditions, and the equipment used is often expensive and complex to operate, making it difficult to promote in resource-limited community scenarios. The localization and adaptation problem of local fall risk assessment tools for the elderly is particularly prominent. Traditional health monitoring methods have factors such as fragmented and intermittent data collection, delayed warnings, and insufficient intervention universality, making it difficult to meet the current needs of the aging society for health management. How to convert the clinical-level assessment accuracy into a low-cost solution accessible in the community is a core problem faced by technology transformation. Research on elderly physical health early warning systems based on wearable devices and artificial intelligence precisely aims to address this issue^[14].

Fourth, the closed loop from identification to management has not yet been formed. Most studies stop at the risk identification or warning stage, lacking effective connection with subsequent intervention measures, hierarchical management, and effect feedback. There is a lack of a process-based connection mechanism between digital identification results and the existing community health service system. Digital technology should not only be an identification tool but also a driving force for the reengineering of community health management processes. Strengthening the precise embedding of digital and intelligent technologies and improving the community’s sports health service level and residents’ disease prevention ability are important measures to promote the deep integration of sports health services and digital technologies^[15].

Fifth, the adaptability of digital health services to the elderly is insufficient. Fully promoting digital health technology as “elderly-friendly” services is an important measure to achieve the active aging strategy,

but currently, the supply of digital health technology in terms of elderly-friendliness still has obvious shortcomings. The ability of elderly people to obtain online medical health information is affected by various factors such as demographic factors, health conditions, health literacy, social support, and online health services. Although the logical path of digital health services promoting healthy aging has been initially clarified, there are still many obstacles in the promotion process.

4. Future outlook

Based on the above analysis, future research can further advance in the following directions.

In the field of technology development, efforts should be made to develop low-cost, easy-to-operate, and high-precision screening tools suitable for the community. Simple hardware deployment models (such as single sensor solutions) and lightweight applications based on smartphones deserve special attention. Elderly-friendly smart wearable design should fully consider the physiological, psychological, and social characteristics of the elderly group. At the same time, the in-depth development of multi-modal data fusion and explainable artificial intelligence is expected to improve the accuracy of risk prediction and clinical acceptability. Further optimization of non-invasive sensors will provide more user-friendly technical means for the identification and management of frail elderly people.

In the application transformation aspect, it is necessary to promote the evolution of digital technology from single risk identification to a closed management model of “identification—classification—intervention—feedback.” This requires deep embedding of digital technology into the existing community health service process and the establishment of a hierarchical management path and job responsibility system matching the technology application. The introduction of emerging technologies such as digital twins and virtual reality also provides the possibility for building more personalized and immersive sports health management plans.

At the policy and standard level, efforts should be made to accelerate the establishment of digital standards and norms for elderly sports health risk assessment, including sensor selection guidelines, data collection protocols, risk classification standards, etc., to provide institutional guarantees for the large-scale application of technology. At the same time, attention should be paid to digital inclusiveness issues, through policy guidance and technology elderly-friendliness transformation, to narrow the digital gap of the elderly group. The supply strategy of elderly-friendly digital health service provision needs to be coordinated and advanced from multiple dimensions such as policy, technology, and services. At the level of interdisciplinary collaboration, the deep integration of disciplines such as sports science, rehabilitation medicine, computer science, and health service management will be the key to driving the development of this field. Only by breaking down the barriers between disciplines can an effective transformation from technical verification to community implementation be achieved. The precise embedding of digital technologies in community sports health services requires the construction of a systematic technical service system centered around precise identification, precise intervention, and precise evaluation.

At the level of enhancing digital health literacy, attention should be paid to the cultivation and improvement of elderly people’s digital health literacy. Digital health literacy refers to the ability to acquire, utilize, disseminate, share, and create digital health resources, which can alleviate the physical health anxiety and digital technology usage anxiety of the elderly. By enhancing the digital health literacy of the elderly, the

acceptance and usage ability of digital health technologies can be fundamentally improved.

5. Conclusion

Digital technology has made significant progress in the field of identifying the health risks of elderly people in communities. Technologies such as wearable devices, artificial intelligence algorithms, mobile health applications, virtual reality, and digital twins are transforming the methods and effectiveness of assessing movement functions and predicting the risk of falls from various dimensions. Wearable sensors have shown promising application prospects in gait analysis and fall risk prediction; artificial intelligence has formed a relatively systematic research framework in fall risk assessment, detection technologies, and rehabilitation applications; mobile health applications provide a convenient channel for elderly people to self-monitor and manage their health; virtual reality and digital twins, among other emerging technologies, have opened up new possibilities for personalized and immersive movement health management.

However, there is still a considerable gap between the validation of the effects of individual technologies and the development of community-wide systematic solutions. Challenges such as technology acceptance, data standards, community adaptability, management loops, and age-friendly supply constraints limit the full release of the potential of digital technology. Future research should seek a better balance between technological innovation and application transformation, focus on building an “identification—classification—intervention—feedback” closed-loop management system, and enable digital technology to truly serve the prevention and control of movement health risks for elderly people in communities, providing strong technical support for actively responding to population aging.

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