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Systematic review

Metaverse technologies in managing frailty among older individuals: A systematic review

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Abstract

Introduction: Frailty, characterized by declines in physical, psychological, and social functions, presents challenges to aging populations. While multicomponent exercise programs have shown efficacy, accessibility can be limited. Virtual Reality (VR) technologies, including Metaverse integration, show promise for frailty management. Studies have demonstrated positive impacts from VR on physical function in older adults, but research on Metaverse technologies specifically for frailty remains limited.

Aim: This systematic review aimed to explore the utilization of Metaverse technology in frailty management among older individuals.

Methods: The systematic review adhered to PRISMA guidelines, searching databases for studies from January 2013 to December 2023. Inclusion criteria focused on Metaverse use for frailty in individuals ≥ 65 years old. Two researchers screened articles, leading to the evaluation of full-text papers.

Results: Despite screening 35 articles, none were suitable for data extraction, indicating a gap in the literature regarding the application of Metaverse technologies to frailty management.

Conclusion: While Metaverse technologies hold promise for personalized frailty interventions, research in this area is limited. Future studies should focus on evaluating the effectiveness of Metaverse interventions and promoting collaboration between healthcare providers and technology developers to advance frailty management in older individuals.

Highlights:

- Frailty, a decline in physical, psychological, and social functioning with age, poses challenges for older individuals.
- VR exercise programs show promise in managing frailty, but accessibility can be limited by various factors.
- The Metaverse, integrating VR and AR technologies, offers immersive experiences with the potential for frailty management.
- Despite potential benefits, current literature lacks studies on Metaverse technologies specifically for frailty management.
- Future research should explore the effectiveness of Metaverse interventions in improving outcomes for older individuals with frailty.

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Abbreviations

AI: Artificial Intelligence; BEAR: Balance Exercise Assist Robot; IoT: Internet of Things; PRISMA: Preferred Reporting Items for Systematic Review and Meta-Analyses; QOL: Quality of Life; VR: Virtual Reality

Introduction

Frailty refers to a state of decline in physical, psychological, and social functioning associated with aging. This condition is primarily seen in older individuals and is characterized by reductions in muscle mass and strength, decreased endurance, low activity levels, fatigue, and weight loss [1]. Frailty represents more than simply getting older, instead implying a deterioration in the health status of the individual, an increased risk of diseases, potential loss of independence, and a decline in Quality of Life (QOL) [2-5]. Physical frailty relates to declines in bodily functions [1], while psychosocial frailty is linked to psychological and social aspects such as social isolation, loneliness, and depression [6]. Managing frailty requires suitable interventions, including regular physical activity, strengthening social support networks, adequate nutrition, and medical care, as needed [7]. In particular, multicomponent exercise programs, including various exercises and adherence strategies, have been effective in managing frailty [8,9]. However, accessibility to such programs can be limited by factors like supervision requirements, geographic distance, availability, and costs. Alternative programs and behavior change strategies are therefore needed for sustainable frailty management in older people.

Recently, interest has been growing in utilizing VR technologies as an innovative approach to rehabilitation. A 2023 meta-analysis by Lee, et al. [10] investigated the effects of interactive VR training programs on walking speed and balance in older people with frailty, finding that such interventions can significantly improve outcomes. VR exercise programs, such as those using Nintendo Wii Fit games, Kinect system-based virtual exergaming, and the Balance Exercise Assist Robot (BEAR), have achieved improvements in gait speed and balance [11-16]. VR exercise programs provide real-time visual and audio feedback as the user interacts with virtual objects by calibrating the accuracy of motions, postures, speeds, and duration of activity [17]. The fusion of VR gaming technologies and exercise programs provides accessible health care that enables positive behavioral modifications and promotes independence at home and in the community [18]. The advantages of VR exercise programs include all-weather usability, flexible designs, and customizable settings for individualized training [19,20]. Ongoing advances in VR technology are spearheading innovative approaches to healthcare and rehabilitation.

The emergence of the Metaverse, as an integration of VR and Augmented Reality (AR) technologies, offers further opportunities for immersive experiences and applications in healthcare and rehabilitation. Unlike traditional VR, the Metaverse integrates digital and physical worlds, economies, social lives, identities, and assets, using technologies like high-speed communication networks, Internet of Things (IoT), AR, VR, cloud computing, edge computing, blockchain, and artificial intelligence (AI) [21]. In a healthcare-related Metaverse, users navigate three-dimensional spaces using avatars and engage in real-time interactions worldwide. The avatar, as a digital twin representing a virtual version of a physical existence, dynamically connects with its real-world counterpart [22]. Within the Metaverse, users navigate through three-dimensional compositions using the avatar as an alter ego. Through avatars, users can engage in real-time interactions with others worldwide and participate in various entertainment experiences or activities. Metaverse technologies may thus have the potential to have greater impacts on frailty management compared to VR exercise programs. A systematic review was conducted to investigate the utilization of Metaverse technologies in the management of frailty among older individuals.

Material and methods

The methodology employed in this systematic review adhered to the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guideline [23]. This investigation is registered to the PROSPERO International Prospective Register of Systematic Reviews (registration number: CRD42024501053). This systematic review of the literature was conducted in January 2024, utilizing data from PubMed, Web of Science, Ichu-shi Web of Japanese Journals, Science Direct, and Cochrane Library databases. To ensure the inclusion of the latest evidence in the field, the present review analyzed manuscripts and articles published from January 2013 to December 2023. Selection from this period was made to strike a balance between comprehensiveness and currency. This time frame allowed for the inclusion of the most recent and relevant studies, ensuring that the review reflects the latest advances and understanding in the field. In addition, a decade-long period was considered sufficient to capture significant research trends and developments, without overwhelming the review process with older studies that may no longer be as relevant due to changes in technology, methodologies, or understandings of the subject matter. In formulating the inclusion criteria, the PICOS (P = population, I = interventions, C = comparator, O = outcome, and S = study design) format was adopted.

Inclusion criteria were as follows: 1) use of the Metaverse for improving or preventing frailty; and 2) papers with main targets ≥ 65 years old. Exclusion criteria were as follows: 1) papers lacking availability of the full text; and 2) papers classified as guidelines.

The search strategy employed three categories of keywords (Table 1), with keywords within each category combined using the "OR" Boolean operator. Subsequently, to retrieve relevant papers, the results of these searches were combined using the

Table 1: Keywords used for the search strategy

Keywords		
Elderly Older adults Older people Age ≥ 65 years	Metaverse	Frail Frailty Prefrail Prefrailty

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"AND" Boolean operator. The search was limited to the Title/Abstract search field and filtered for articles available only in English or Japanese.

Following the initial search, a total of 35 articles were identified from Science Direct, and none from PubMed, Web of Science, Ichu-shi Web of Japanese Journals, or Cochrane Library databases. These findings were analyzed and screened by two experts from the research team, comprising a rehabilitation medicine researcher and an engineering researcher. This collaborative effort allowed us to consider both geriatric and technical perspectives. The initial screening was based on the titles and abstracts of identified articles. The same experts then evaluated the full text of each selected paper. In the case of conflicting opinions, consensus was reached through discussion among the two experts.

Results

The initial search for titles and abstracts from a pool of 35 records identified through Science Direct led to the exclusion of 21 papers due to various mismatches in the target population, outcomes, or publication type. Specifically, 8 papers targeted incorrect populations, 7 reported irrelevant outcomes, and 6 were excluded based on their publication type. This left 14 papers eligible for full-text evaluation. However, upon detailed review, none of the papers were deemed suitable for data extraction. The reasons for exclusion at this stage were: two papers mentioned Metaverse technologies in healthcare but were specifically aimed at managing frailty [22,24], 10 papers did not focus on Metaverse technologies as required by our study criteria, and two were excluded due to the unavailability of the full text (Figure 1).

Discussion

This systematic review aimed to explore the utilization of Metaverse technologies in managing frailty among older individuals. Following an extensive search of multiple databases and a meticulous screening process, two articles were identified that mentioned Metaverse technology in healthcare, but Metaverse technology was applied to the management of frailty. Thus, no suitable studies were identified for inclusion in the proposed final analysis. This finding highlights a significant gap in the current literature regarding the applications of Metaverse technologies to frailty management.

Two articles were identified in our study that used Metaverse technology, but not for the management of frailty. Song, et al. [22] discussed Metaverse-based personal healthcare-related technologies, exploring four major research areas of VR-aided therapy: post-traumatic stress disorder; anxiety and fear-related disorder; diseases of the nervous system; and pain management [25]. Dwivedi, et al. [24] provided a multidisciplinary perspective on emerging technologies, describing the Metaverse beyond terms used for marketing. They discussed the advantages and challenges of healthcare in the Metaverse, noting that while the technology

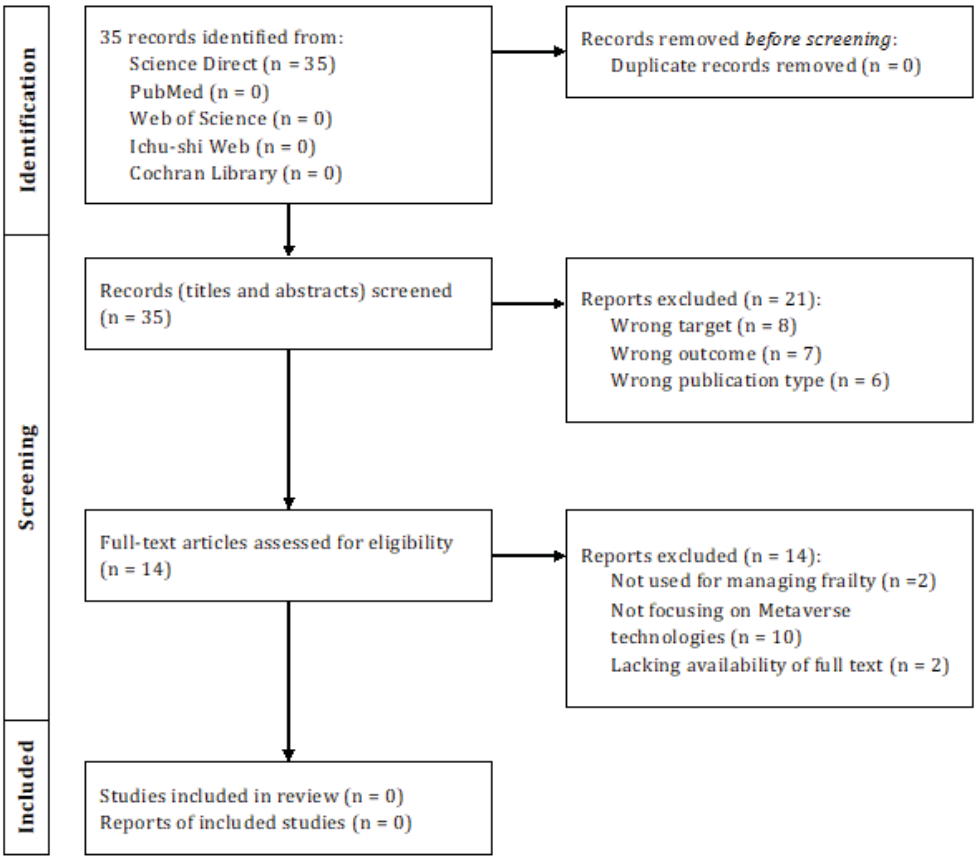

Figure 1: Flowchart of search strategy.

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offers convenience, challenges remain such as a need for institutional arrangements for issues like surrogate treatment for drugs [24]. In addition, they emphasized the importance of handling medical information carefully, including user permission and privacy [21]. Despite these challenges, the Metaverse offers innovative solutions, such as monitoring the habits and problems of users and conducting psychiatric group therapy [26], reducing time burdens, and solving space problems. Furthermore, hierarchical segregation and tagging in the Metaverse for complex organ surgeries reduce errors, creating an effective tool for medical research and treatment [27,26].

Several factors may have contributed to the lack of studies on Metaverse technologies in managing frailty among older individuals. First, the concept of the Metaverse is relatively new and rapidly evolving, with healthcare applications still being explored and developed. As such, limited research may have been conducted specifically on the use of Metaverse technologies for frailty management. In addition, the complexity and interdisciplinary nature of the Metaverse, combining elements of VR, AR, and digital twins, may pose challenges for researchers and healthcare providers in designing and implementing studies in this area. Furthermore, the inclusion criteria of the systematic review may have contributed to the limited number of eligible studies. The restriction to papers with main targets aged 65 years and older may have excluded relevant studies involving younger populations or those with broader age ranges. In addition, the requirement for the availability of full texts may have excluded studies published in non-traditional formats or languages other than English or Japanese.

Despite the lack of identified studies, the potential for Metaverse technologies to facilitate frailty management remains promising. The immersive and interactive nature of the Metaverse could provide engaging and personalized interventions for older individuals with frailty [28]. For example, virtual environments could be designed to simulate daily living activities, allowing individuals to practice tasks that improve physical function and reduce fall risks in a safe and controlled setting. In addition, the social aspects of the Metaverse could facilitate social interactions and combat psychosocial frailty by connecting older adults with peers and support networks. Future research in this area should focus on designing well-controlled studies to evaluate the effectiveness of Metaverse interventions in improving physical, psychological, and social outcomes in this population [29]. Collaborations between healthcare providers, researchers, and technology developers will be essential in advancing the field of Metaverse-based frailty management and improving QOL for older individuals.

Conclusion

The absence of identified studies underscores a significant gap in research on Metaverse technologies for managing frailty in older individuals. Despite the promising potential, factors such as the novelty of Metaverse and stringent inclusion criteria may have contributed to this absence of evidence. Nevertheless, the immersive and interactive nature of Metaverse platforms suggested they could offer engaging and tailored interventions for addressing frailty. Future research should focus on well-designed studies to evaluate their effectiveness, fostering collaboration between healthcare providers and technology developers to advance frailty management in older individuals.

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Author contributions

E.T. designed this study, conducted the data collection, and drafted the manuscript. K.N. and H.M. performed the data analysis. T.F. and I.K. provided supervision. Y.I. contributed to Funding acquisition and Project administration. All authors have read and agreed to the published version of the manuscript.

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