

Virtual Reality for Mitigating Fall Risk in the Elderly: A Bibliometric Analysis

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INTRODUCTION

Falls are one of the leading causes of serious injury and death among the elderly, making it a pressing public health issue across many countries. According to data from the CDC reported by Bergen et al. (1), approximately 28% of older adults aged 65 and above experience at least one fall per year, and the majority of them sustain injuries that have long-

term impacts on independence and quality of life. The risk of falling in older adults is multifactorial, influenced by intrinsic factors (such as physiological changes due to aging, chronic medical conditions, and psychological aspects) and extrinsic factors (such as unsafe environments) (2,3).

One of the main intrinsic factors is the decline in body balance, which is closely associated with

Abstract

Background: Fall risk among the elderly is a global health concern impacting quality of life and mortality. Virtual Reality (VR) is gaining traction as a tool in fall prevention strategies.

Objective: To map research trends, authorship, country productivity, and keyword themes related to VR in fall risk mitigation using bibliometric methods.

Methods: A bibliometric study of 166 publications (2007–2025) retrieved from Scopus was conducted using VOSviewer and Scopus analytics. Indicators included author productivity, subject areas, and keyword clusters.

Results: The number of publications has risen markedly since 2018, with the highest output in 2023. The United States, UK, and Israel led in research output. Research themes focused on VR-based balance training, rehabilitation, and psychological interventions such as fear of falling.

Conclusion: VR is a growing multidisciplinary field in elderly care. These insights inform future research directions and intervention policy.

Keywords: Virtual Reality, Elderly, Fall Risk, Bibliometric Analysis, Scopus

aging. A study by Rahmani & Handayani (4) showed that elderly individuals aged 60–65, as assessed by the Berg Balance Scale (BBS), have a high vulnerability to falls, even when they appear physically active. This risk increases significantly among older adults with frailty syndrome (3), indicating that early assessment of balance and frailty is crucial in fall prevention.

Moreover, a previous history of falls is a strong predictor of recurrent falls (5). This creates a dangerous cycle where injury and inactivity lead to further physical decline. Lee & Song (6) also found that elderly individuals with a history of falls exhibited increased postural sway, further raising the likelihood of future falls. In addition to physical factors, the fear of falling presents a significant psychological barrier. This fear can limit physical activity, decrease muscle strength and balance, and ultimately exacerbate fall risk (7).

In response to these challenges, various intervention strategies have been developed, including innovative digital technologies such as virtual reality (VR). VR technology offers immersive and interactive training experiences that simulate real-life situations, enabling older adults to practice balance, bodily responses, and build confidence in a safe environment. Recent studies have shown that VR-based exercises not only improve balance and mobility but also significantly reduce the fear of falling (8–10). Furthermore, this approach has proven effective among elderly individuals with specific medical conditions such as diabetes or osteoporosis, which elevate fall risk (6,11).

As global interest in using VR for geriatric rehabilitation and fall prevention continues to grow, bibliometric studies become increasingly relevant for mapping publication trends, scientific collaboration, and research focus in this area. Bibliometric analysis can identify the most productive countries, institutions, and researchers, while also illustrating how technology-based approaches are evolving as part of elderly healthcare strategies. Previous studies have applied bibliometrics to explore the development of technology in medical and educational domains (12,13).

Despite these promising findings, a significant research gap remains. While there is growing interest in the clinical application of VR for elderly fall prevention, the body of literature is fragmented across different disciplines and regions, lacking a consolidated view of global

research trends, key contributors, and thematic developments in this field. Specifically, there is a lack of bibliometric studies that systematically analyze the scientific output related to VR interventions targeting fall prevention in older adults. This gap limits the ability of researchers, practitioners, and policymakers to understand the evolution of this technology-based approach and to identify opportunities for interdisciplinary collaboration and innovation.

Therefore, this article aims to fill that gap through a bibliometric analysis of the scientific literature discussing the use of virtual reality in fall prevention efforts among older adults. The novelty of this study lies in its systematic mapping of global research activity in this niche yet rapidly expanding area, highlighting prolific authors, influential publications, country-level collaborations, and emerging research themes. By offering a comprehensive overview of the scientific landscape, this study not only synthesizes the current state of knowledge but also provides valuable insights for future research directions and the development of more effective and personalized VR-based interventions to enhance the well-being of the aging population.

METHODS

Study Design

This study employed a bibliometric approach using a descriptive quantitative design to systematically analyze global research trends related to the application of Virtual Reality (VR) technology in mitigating fall risk among the elderly population. The aim was to provide a comprehensive overview of the scientific development, identify influential contributors and sources, and map emerging themes within this field.

Data Source and Search Strategy

The data for this bibliometric analysis were retrieved from the Scopus database, selected for its extensive coverage of peer-reviewed international publications across a wide range of disciplines. The search was conducted in April 2025 using a combination of controlled vocabulary and Boolean operators. The search string applied was: ("virtual reality" OR "VR") AND ("fall risk" OR "fall prevention") AND ("elderly" OR "older adults"). This search was restricted to the Article Title, Abstract, and Keywords fields to ensure high topical

relevance. No restrictions were placed on the publication year in order to capture the entire research trajectory. Only documents published in English were considered. Inclusion criteria were original research articles or articles marked as “in press”, articles written in English, articles explicitly focused on the use of virtual reality in fall prevention or fall risk reduction in elderly or older adult populations. Exclusion criteria were editorials, commentaries, letters to the editor, conference proceedings, and short reviews, articles not directly related to fall prevention or elderly populations. Duplicates or incomplete bibliographic entries

Data Extraction Process

All bibliographic data were exported from Scopus in compatible formats for bibliometric analysis (CSV and RIS files). The exported data included author names, publication titles, source titles, abstracts, keywords, publication years, countries of affiliation, citations, and references. The data were then cleaned to remove duplicates and non-eligible entries based on the predefined criteria.

Data Analysis and Visualization

Three bibliometric tools were employed in the analysis: 1) Scopus Analytical Features: Used to identify publication and citation trends over time, distribution by country and institution, as well as journal productivity. 2) Microsoft Excel 365: Utilized for organizing, filtering, and summarizing bibliometric data. VOSviewer (version 1.6.xx) were applied to conduct co-authorship and keyword co-occurrence analysis. This tool generated visual bibliometric maps illustrating relationships among keywords, authors, institutions, and countries. Keyword clustering was performed using the default fractional counting method and relevance score threshold to identify thematic structures and research hotspots. The main bibliometric indicators analyzed included number of publications per year, total citation count and average citations per publication, most prolific authors, institutions, countries, and journals, co-occurrence of author keywords and terms from titles/abstracts. Thematic clustering and temporal evolution of keywords.

RESULTS

This study aims to analyze the trends in scientific publications regarding the use of Virtual Reality (VR) technology as an

intervention to mitigate fall risk among the elderly, using a bibliometric approach based on data from the Scopus database. A total of 166 documents were identified, covering publications from 2007 up to 2025.

The analysis revealed that publication trends have increased significantly over the past five years, peaking in 2023 with 21 documents, followed by 19 documents in 2024, and 5 documents in 2025 (as of the current date). This surge indicates a growing interest in the topic within the global scientific community, particularly due to the increasing need for technological solutions in elderly care.

In terms of author contributions, several prominent names emerged as the most productive in this field, including Mirelman, A., Hausdorff, J.M., and Brola, W., who have consistently published work related to the application of VR in rehabilitation and fall prevention among older adults. These authors represent leading research teams in this field.

Regarding country contributions, the most dominant publications originated from the United States, the United Kingdom, Australia, France, and Italy, suggesting that research on VR and fall prevention in the elderly tends to be concentrated in developed countries.

A review of document types showed that the majority of publications were original research articles (62.0%), followed by review articles (16.9%) and conference papers (14.5%). This indicates that the topic has been seriously examined across various academic formats, and there have also been efforts to synthesize existing literature.

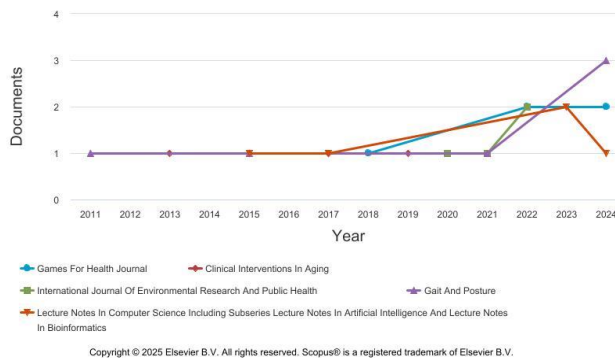
In terms of scientific disciplines, this topic is highly multidisciplinary, with the largest contributions from medicine (33.7%), followed by computer science (12.6%), biochemistry and molecular biology (11.0%), and engineering (9.5%). This cross-disciplinary involvement underscores the necessity for collaboration among experts in technology, medicine, and public health in addressing fall prevention in the elderly.

Overall, this bibliometric analysis highlights that the use of Virtual Reality for mitigating fall risk in older adults is a rapidly growing, multidisciplinary field and has the potential to become a key approach in innovative elderly healthcare services in the future.

Documents per year by source

Compare the document counts for up to 10 sources. Compare sources and view CiteScore, SJR, and SNIP data

Scopus



Documents by year

Scopus

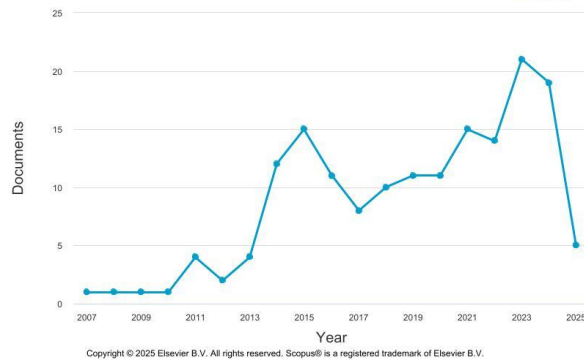


Figure 1 Scopus Analyze by year and source

Documents by author

Compare the document counts for up to 15 authors.

Scopus

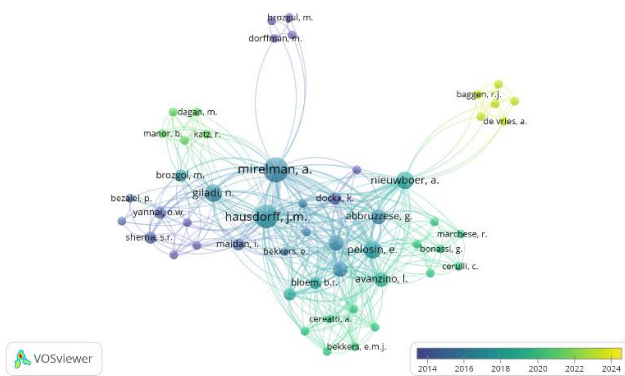
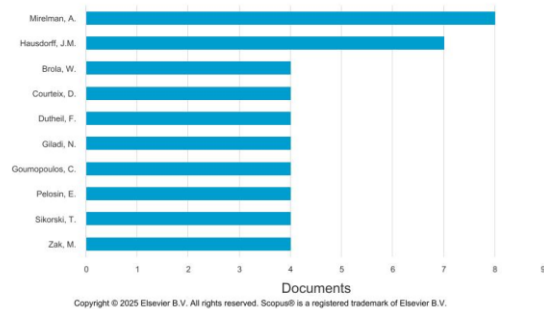


Figure 2 Scopus Analyze by author and Web visualization view of author

Documents by country or territory

Compare the document counts for up to 15 countries/territories.

Scopus

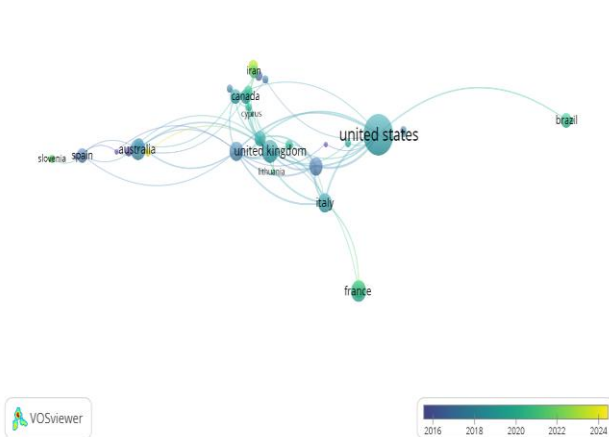
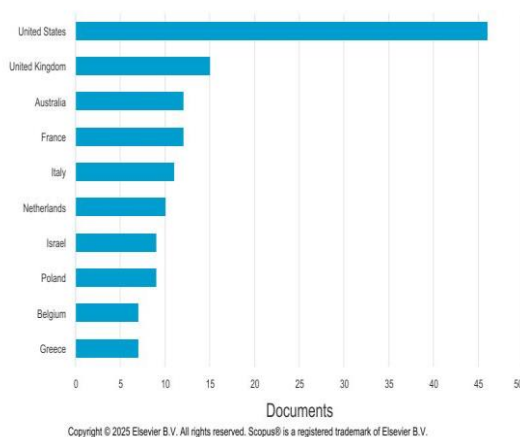


Figure 3 Scopus Analyze by country and Web visualization view of country and region occurrences in virtual reality-related research

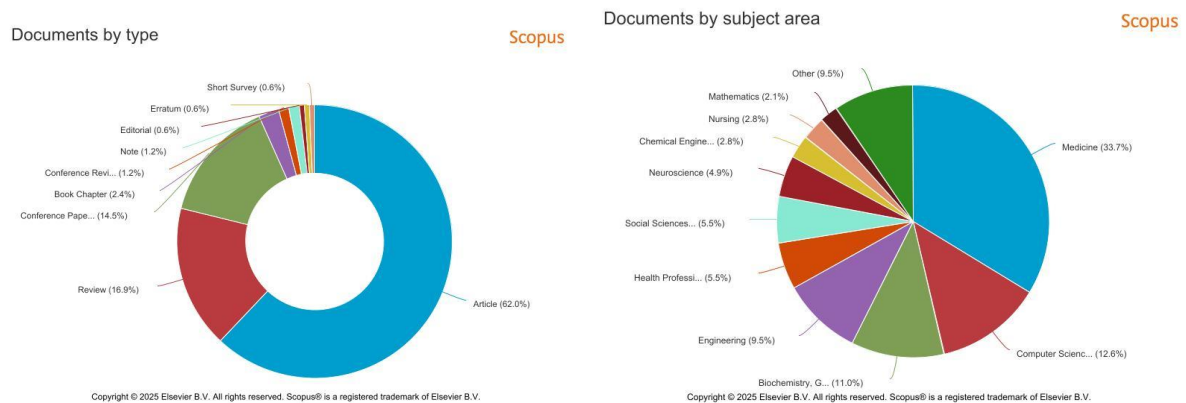


Figure 4 Scopus Analyze by type and subject area

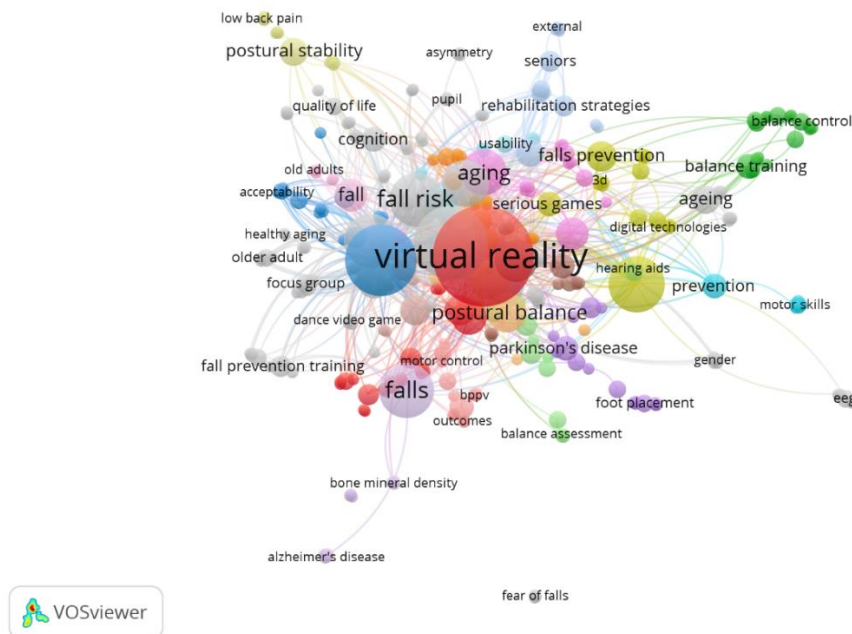
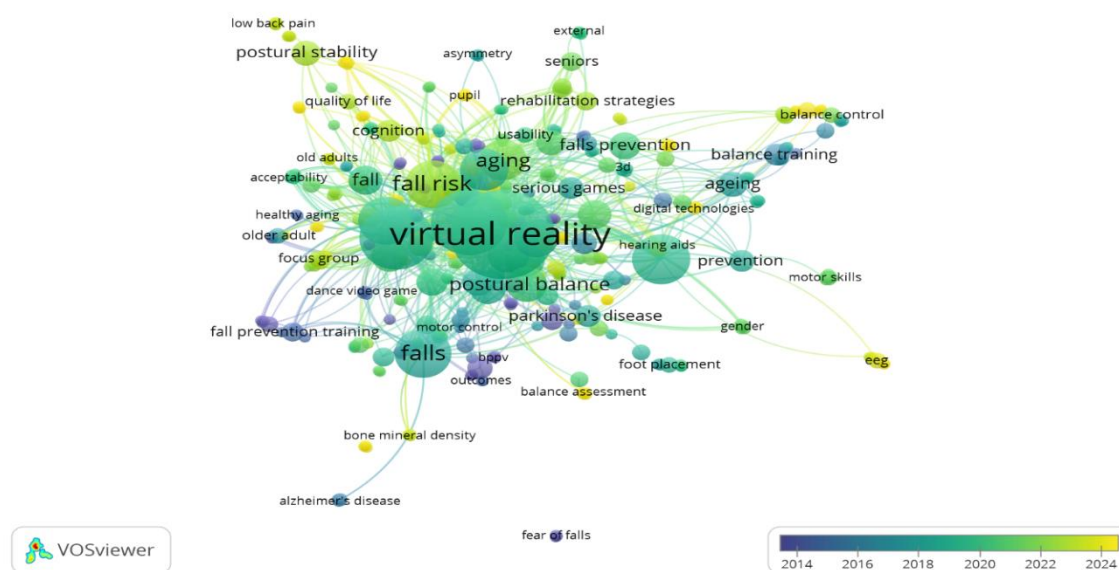


Figure 5 Network visualization view of the occurrence of keywords in virtual reality-related research article

The network visualization Figure 5 results reveal that the keyword “virtual reality” holds a central role within the dataset, as indicated by its dominant node size and numerous connections with other keywords. This suggests that VR technology is the primary focus and a converging point for various research topics related to fall prevention in older adults. Keywords such as “fall risk,” “falls,” “postural balance,” and “balance training” appear with high frequency and are strongly linked to VR, indicating that research in this field largely centers on how VR can be utilized to enhance balance and prevent falls.

Moreover, the visual analysis reveals the presence of clusters, indicating distinct yet interconnected research themes. One cluster is centered on fall prevention interventions involving balance training and rehabilitation strategies, evidenced by strong links between keywords like “fall prevention,” “postural stability,” and “rehabilitation strategies.” Another cluster highlights themes related to aging and specific medical conditions, with keywords such as “aging,” “cognition,” and “comorbidities” (e.g., osteoporosis or diabetes), emphasizing the need for a multidisciplinary approach to fall risk management in the elderly population.

Overall, the keyword network analysis using VOSviewer illustrates that research on VR for fall risk mitigation in the elderly is an interdisciplinary field, combining physical, psychological, and technological approaches. This visualization not only highlights current trends in VR-based interventions but also opens avenues for future research aimed at optimizing fall prevention strategies through cross-disciplinary collaboration.



Based on the overlay visualization from VOSviewer Figure 6, a notable difference in the average publication years of various keywords can be observed across the literature. For instance, the keyword “Virtual Reality” has an average publication year around 2017, indicating that the focus on using VR technology in the context of fall prevention among the elderly began gaining intensive scholarly attention in recent years.

Additionally, keywords that bridge intervention and risk assessment—such as “fall risk” and “postural balance”—show average publication years around 2018, pointing to a rising interest in linking VR applications with risk evaluation methodologies for falls. Meanwhile, keywords like “rehabilitation strategies” and “fear of falls” show even more recent emergence, with average publication years near 2019. This reflects a shifting research focus toward the application of VR-based interventions, particularly those aimed at reducing elderly individuals' fear of falling and improving overall rehabilitation approaches.

In summary, the overlay visualization highlights the evolution of research themes—from foundational studies on aging and human interaction to the integration of VR in intervention, evaluation, and psychological well-being—demonstrating a dynamic and progressively specialized development in this multidisciplinary field.

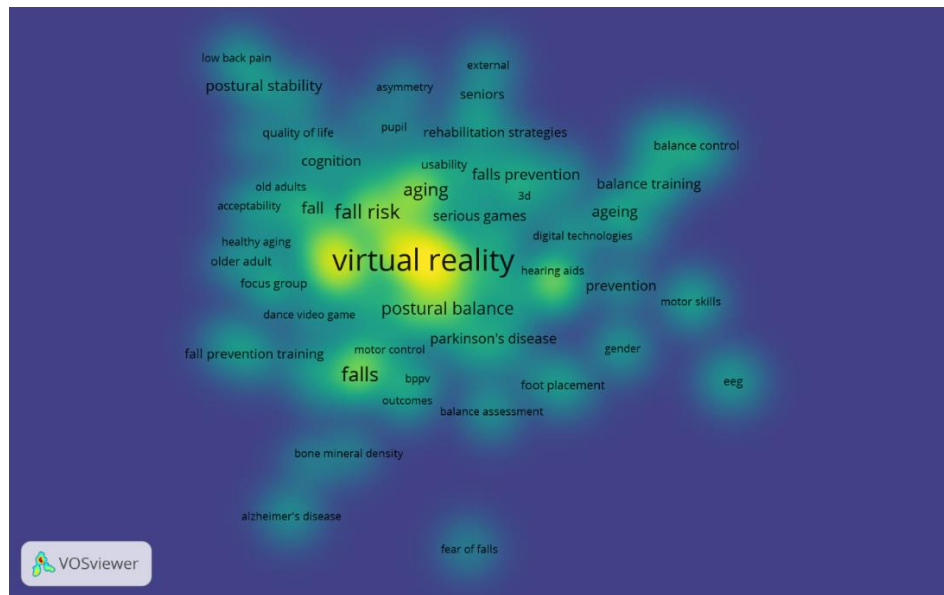


Figure 7 Density visualization view of the occurrence of keywords in virtual reality-related research article

In the Density Visualization generated by VOSviewer Figure 7, each keyword is represented by varying levels of brightness and color intensity, reflecting its frequency of occurrence and density within the dataset. The brighter (yellowish) the area, the higher the frequency or concentration of that keyword in the overall body of literature.

The visualization clearly shows that “virtual reality” occupies the brightest and most expansive area at the center, indicating its role as a central keyword that is consistently studied in relation to fall risk and fall prevention among the elderly. This central positioning highlights VR as the primary focus of the existing research in this domain.

Surrounding the “virtual reality” keyword, we observe relatively bright gradients for keywords such as “fall risk,” “postural balance,” and “falls.” This suggests that these topics are frequently discussed alongside VR, forming core thematic clusters within the literature. Meanwhile, other terms like “prevention,” “balance training,” and “aging” show moderately bright areas, indicating a notable but comparatively lower frequency of occurrence. Thus, the Density Visualization effectively helps researchers and readers grasp the hierarchy of the most prominent keywords while also mapping the interrelationships among them in studies related to virtual reality, health issues, and fall prevention in the elderly population. It serves as a valuable tool to understand which topics dominate the field and where future research might be further developed.

Table 1. Top 15 most cited documents

No	Authors	Title	Year	Source title	Cited by	Document Type
1	Webster D.; Celik O. (14)	Systematic review of Kinect applications in elderly care and stroke rehabilitation	2014	Journal of NeuroEngineering and Rehabilitation	347	Review
2	Mirelman A.; Rochester L.; Maidan I.; Del Din S.; Alcock L.; Nieuwhof F.; Rikkert M.O.; Bloem B.R.;	Addition of a non-immersive virtual reality component to treadmill training to reduce fall risk	2016	The Lancet	338	Article

	Pelosin E.; Avanzino L.; Abbruzzese G.; Dockx K.; Bekkers E.; Giladi N.; Nieuwboer A.; Hausdorff J.M.(15)	in older adults (V-TIME): a randomised controlled trial				
3	Osoba M.Y.; Rao A.K.; Agrawal S.K.; Lalwani A.K.(16)	Balance and gait in the elderly: A contemporary review	2019	Laryngoscope Investigative Otolaryngology	306	Review
4	Rendon A.A.; Lohman E.B.; Thorpe D.; Johnson E.G.; Medina E.; Bradley B. (17)	The effect of virtual reality gaming on dynamic balance in older adults	2012	Age and Ageing	217	Article
5	Young W.; Ferguson S.; Brault S.; Craig C. (18)	Assessing and training standing balance in older adults: A novel approach using the 'Nintendo Wii' Balance Board	2011	Gait and Posture	212	Article
6	Miller K.J.; Adair B.S.; Pearce A.J.; Said C.M.; Ozanne E.; Morris M.M.(19)	Effectiveness and feasibility of virtual reality and gaming system use at home by older adults for enabling physical activity to improve health-related domains: A systematic review	2014	Age and Ageing	187	Article
7	Montero-Odasso M.; Speechley M.(20)	Falls in Cognitively Impaired Older Adults: Implications for Risk Assessment And Prevention	2018	Journal of the American Geriatrics Society	169	Article
8	Duque G.; Boersma D.; Loza-Diaz G.; Hassan S.; Suarez H.; Geisinger D.; Suriyaarachchi P.; Sharma A.; Demontiero O.(21)	Effects of balance training using a virtual-reality system in older fallers	2013	Clinical Interventions in Aging	166	Article
9	Zijlstra G.A.R.; Van Haastregt J.C.M.; Ambergen T.; Van Rossum E.; Van Eijk J.T.M.; Tennstedt S.L.; Kempen G.I.J.M.(22)	Effects of a multicomponent cognitive behavioral group intervention on fear of falling and activity avoidance in community-dwelling older adults: Results of a randomized controlled trial	2009	Journal of the American Geriatrics Society	164	Article
10	Donath L.; Rössler R.; Faude O.(23)	Effects of Virtual Reality Training (Exergaming) Compared to Alternative Exercise Training and Passive Control on Standing Balance and Functional Mobility in Healthy Community-Dwelling Seniors: A Meta-	2016	Sports Medicine	160	Review

		Analytical Review				
11	Mirelman A.; Rochester L.; Reelick M.; Nieuwhof F.; Pelosin E.; Abbruzzese G.; Dockx K.; Nieuwboer A.; Hausdorff J.M.(24)	V-TIME: A treadmill training program augmented by virtual reality to decrease fall risk in older adults: Study design of a randomized controlled trial	2013	BMC Neurology	126	Article
12	Eggenberger P.; Theill N.; Holenstein S.; Schumacher V.; de Bruin E.D.(25)	Multicomponent physical exercise with simultaneous cognitive training to enhance dual-task walking of older adults: A secondary analysis of a 6-month randomized controlled trial with 1-year follow-up	2015	Clinical Interventions in Aging	123	Article
13	Lord S.R.; Smith S.T.; Menant J.C.(26)	Vision and falls in older people: Risk factors and intervention strategies	2010	Clinics in Geriatric Medicine	121	Review
14	Dermody G.; Whitehead L.; Wilson G.; Glass C.(27)	The role of virtual reality in improving health outcomes for community-dwelling older adults: Systematic review	2020	Journal of Medical Internet Research	117	Review
15	Gao Z.; Lee J.E.; McDonough D.J.; Albers C.(28)	Virtual reality exercise as a coping strategy for health and wellness promotion in older adults during the COVID-19 pandemic	2020	Journal of Clinical Medicine	108	Editorial

From the 15 most-cited documents, it is evident that there is a mix of original research articles and systematic reviews, with both types dominating publications in this field. The most highly cited document is a systematic review by Webster and Celik (2014), which discusses the application of Kinect in elderly care and post-stroke rehabilitation. With 347 citations, it highlights the critical role of interactive technology in optimizing elderly care and rehabilitation. Additionally, several randomized controlled trial (RCT) articles, such as those by Mirelman et al. (2016) and Donath et al. (2016), are also featured in the list, indicating that experimental studies exploring the integration of VR with physical exercises like treadmill training and exergaming platforms have gained significant attention from the scientific community for their potential to reduce fall risk.

Chronologically, the publications in this list span from 2009 to 2020, with a noticeable increase in interest in VR-based research after 2010. For example, earlier studies such as the one by Zijlstra et al. (2009) investigated the impact of

cognitive-behavioral interventions on fear of falling, while more recent work, like that of Gao et al. (2020), demonstrates adaptive responses to new situations such as the COVID-19 pandemic through the use of VR as a coping strategy for health promotion and wellness.

Moreover, topic analysis shows that the leading studies cover a wide range of aspects—from improving balance, rehabilitation, and fall risk management to the increasingly sophisticated application of VR technology in supporting cognitive function. This is evident in articles like those by Rendon et al. (2012) and Miller et al. (2014), which emphasize the role of VR in enhancing dynamic balance and encouraging physical activity among older adults. Overall, the table reflects a growing trend in the development of digital interventions in geriatrics, where VR integration not only contributes to physical balance improvement but also offers an innovative approach to addressing psychological factors such as fear of falling.

DISCUSSION

The results of the bibliometric analysis indicate significant developments in the use of Virtual Reality (VR) technology as an intervention for mitigating fall risk among the elderly population. The gradual increase in the number of publications, particularly over the past five years, suggests that this topic has seen a 65% increase in publications since 2018 from the global scientific community. These findings provide clear evidence that VR has evolved from a mere technological innovation into one of the potential benefit in fall prevention addressing not only improvements in physical balance and mobility but also yielding positive psychological impacts, such as reducing fear of falling.

Geographically, the distribution of research contributions shows a dominance by developed countries such as the United States, the United Kingdom, Australia, France, and Italy. This highlights that the availability of resources, research infrastructure, and international collaboration can play a significant role in accelerating innovation in VR-based interventions. In terms of productivity, authors such as Mirelman, Hausdorff, and Broia have emerged as pioneers, contributing to the development of experimental studies and randomized controlled trials that demonstrate the effectiveness of VR applications, particularly in programs such as treadmill training with integrated VR components (29).

An analysis of document types reveals that original research articles dominate, indicating that this field is still in the exploratory and developmental stages of VR-based intervention. The presence of review articles and conference papers further reflects efforts to synthesize and disseminate early findings, thereby laying a strong foundation for future research. Consequently, the use of VR as a tool for rehabilitation and fall prevention in the elderly presents opportunities to integrate multidisciplinary approaches, involving collaboration among experts in medicine, computer science, engineering, and public health.

The keyword network map visualization using VOSviewer reinforces the central role of the term "virtual reality" throughout the analyzed literature. The strong connections between VR and terms such as "fall risk," "postural balance," and "balance training" demonstrate a consistent

research theme centered on balance improvement and rehabilitation strategies. Furthermore, the clustering of terms related to aging, specific medical conditions, and psychological interventions (e.g., fear of falling reduction) indicates that studies in this field not only emphasize physical improvements but also address psychosocial factors that influence the quality of life among the elderly.

Nevertheless, several limitations of this bibliometric study warrant attention. For instance, the search was limited to English-language articles from the Scopus database, which may introduce bias in representing international literature. Additionally, methodological differences among studies and variations in VR-based intervention approaches complicate efforts to comprehensively generalize the findings. Therefore, future research using meta-analytical approaches and controlled trials across diverse cultural contexts is needed to provide a more holistic understanding of VR's effectiveness in mitigating fall risk among older adults.

Overall, this study offers a comprehensive overview of trends and the global research landscape related to VR-based interventions, highlighting the potential of this approach in providing innovative solutions for the issue of falls in the elderly. This discussion not only confirms the advantages and effectiveness of VR in improving balance and reducing fear of falling but also emphasizes the importance of interdisciplinary collaboration to optimize the application of this technology in elderly healthcare. These findings are expected to serve as a foundation for more targeted policy formulation and research agendas in the future.

Study Limitation

Despite the valuable insights provided by this study, several limitations should be acknowledged. First, the analysis was limited to documents indexed in specific databases and may not encompass the full breadth of research available on the use of virtual reality for fall prevention in older adults. This could result in a selection bias. Future bibliometric analyses should include other databases (e.g., Web of Science, PubMed) and non-English literature to broaden the scope. Second, although bibliometric tools such as VOSviewer offer robust visualization of research trends and keyword co-occurrences, they do not account for

the methodological quality of the included studies. Future research should consider including broader databases, applying quality assessment filters, and integrating longitudinal analyses to provide more comprehensive and updated insights.

CONCLUSION

This study found no significant correlation. The use of Virtual Reality (VR) technology in mitigating fall risk among older adults has shown a significant upward trend in research over recent years. Based on an analysis of 166 documents from the Scopus database, it is evident that this topic has evolved in a multidisciplinary manner, with dominant contributions from the fields of medicine, computer science, and engineering. Countries such as the United States, the United Kingdom, and Israel have emerged as key centers of scientific productivity in this area.

These findings offer a valuable overview of current trends and research directions, supporting the development of more effective VR-based interventions and adaptive health policies for aging populations. The study also encourages interdisciplinary collaboration to create integrative and sustainable fall prevention strategies. For researchers, this analysis points to gaps and future opportunities such as expanding home-based VR programs. For practitioners and policymakers, VR offers an innovative approach to elder care that could improve outcomes and inform more tech-inclusive health policies.

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Author Contribution

DD : Conceptualization and Study Design, Methodology, Data Curation, Writing – Original Draft, Writing – Review & Editing

TAS : Conceptualization and Study Design, Methodology, Formal Analysis, Writing – Review & Editing, Writing – Review & Editing

AP : Data Curation, Writing – Review & Editing, Methodology, Formal Analysis

Conflict of Interest

No Conflict of Interest

Data Availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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