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Impact of Gait and Balance Disorders in the Elderly Population and Physiotherapy Assessment and Fall Prevention using Innovative Technology: A Systematic Literature Review

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ABSTRACT

This comprehensive literature review offers a deep exploration of post fall prevention interventions (post-FPIs) and their pivotal role in assessing and mitigating the risks of falls among the elderly population. In this extensive analysis, we traverse a diverse array of studies, delving into the multifaceted landscape of assessments and interventions designed to prevent falls in older adults. The review casts a discerning eye on the prevalent emphasis on intrinsic risk factors, predominantly encompassing functional and cognitive aspects. Paradoxically, it unravels the somewhat neglected extrinsic risk factors that can result in severe fall-related injuries, spotlighting the need for more comprehensive assessments. The spectrum of intervention types, ranging from purely functional to the multi factorial, is dissected within the overarching context of post-FPIs. This review reveals a remarkable gap in the domain of extrinsic risk factor assessment, with limited existing systems dedicated to this crucial aspect. Furthermore, it uncovers a prevalent static nature, often bereft of interactive features in the existing post-FPI landscape. The synchronous model of patient-clinician collaboration is prevalent, with data collected from older adults being clinically assessed in real-time. Nevertheless, the review introduces the concept of asynchronous collaboration, which demonstrates considerable potential for future investigation. By illuminating these nuances and gaps, this review serves as a foundational resource for the development of more comprehensive post-FPI systems, as we strive to enhance fall prevention efforts among the elderly.

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Index Terms

Fall Prevention, Elderly Population, Post-Fall Prevention Interventions (post-FPIs), Intrinsic Risk Factors, Extrinsic Risk Factors, Interventions, Asynchronous Collaboration

Introduction

As individuals age, the issue of falls becomes increasingly significant. Falls are recognized as the second leading cause of unintentional injury-related deaths worldwide, presenting a major public health concern, especially among older adults [1-3]. Falls can lead to a fear of falling and ultimately result in a loss of independence. Studies have indicated that approximately one-third of the elderly population over the age of 65 experience falls [4]. Every year, approximately 37.3 million individuals suffer falls that lead to hospitalization and severe injuries, including fractures and traumatic brain injuries [1]. Several factors and comorbidities contribute to falls in the elderly, with balance and gait disorders being among the most common causes [5]. Over the age of 70, around 35% of people develop gait and balance abnormalities, increasing to 61% over the age of 80 [6].

A growing body of literature has emphasized the relation- ship between gait speed, overall health, and survivor-ship [7]. Fall prevention strategies are crucial to the wellbeing of the elderly population. Rehabilitation plays a pivotal role in preventing falls and enhancing the quality of life for the elderly. Standard fall prevention physiotherapy rehabilitation programs incorporating innovative technology include exercises and education. In addition to rehabilitation programs, physiotherapy assessments using innovative technology are vital for developing fall prevention strategies.

Innovative programs and emerging technologies can be harnessed to create rehabilitation programs for the elderly to prevent falls. Various advanced technology-based tools are used for fall assessment and technology-based rehabilitation programs to prevent falls and improve gait and balance in the elderly population. Advances in medical technology have led to innovative computer-assisted interventions in rehabilitation treatment and assessment. These innovations help overcome current limitations in assessment and facilitate prevention and intervention.

The assessment and training of balance and gait using advanced innovative technology are considered among the most crucial factors in the field of rehabilitation for the aging population. Some studies have demonstrated the importance of advanced technology-based assessment and management using tools such as sensor-based gait training and assessment of gait parameters, virtual

reality-based gait and balance training, biofeedback-based gait and balance training, and assessment of balance and gait parameters in the rehabilitation of fall prevention among the elderly. This review focuses on the assessment of gait and the prevention of falls in the elderly population using advanced innovative technology.

In the geriatric population, falling is a severe problem that can lead to serious issues such as fractures and traumatic brain injuries. Multiple risk factors, along with the presence of chronic predisposing diseases and other systemic impairments, contribute to pathological changes, including gait abnormalities and associated problems. These abnormal changes result in a decline in functional mobility. Aging is associated with declining balance, particularly when tasks become more complex due to a reduction in sensory feedback. In comparison to younger women, elderly women exhibit a significant increase in sway velocity by the sixth decade, particularly when standing on firm ground with eyes closed in bilateral stance. There is a noticeable decline in postural stability at earlier ages when challenged with balance tasks, with stability continuing to decline with each decade of life. Older individuals have a sway velocity approximately 2.5 times that of younger individuals when standing on a firm surface with their eyes open, and four times that of younger individuals when their eyes are closed. This doubling of sway velocity when transitioning from eyes open to eyes closed on a firm surface is attributed to the degenerating vestibulocochlear system in elderly adults.

Older adults tend to inappropriately activate antagonist muscles more frequently than younger adults when attempting to maintain balance. In response to low-amplitude perturbations, older adults tend to activate muscles in a proximal to distal sequence and may employ a postural stability strategy that involves flexing or extending at the hip. In contrast, younger adults tend to avoid this strategy and respond to perturbations with a normal distal-to-proximal muscle activation sequence. To maintain postural stability, older adults may increase postural sway without necessarily experiencing postural instability, representing a shift from the small, continuous movement alterations observed in younger adults to larger adjustments.

Preventing falls using innovative techniques is a multidisciplinary effort encompassing health disciplines such as physio- therapy, occupational therapy, geriatrics, nursing, gerontology, healthcare, and social care [8]. Evidence-based research on fall prevention suggests that 50% of falls can be prevented using technology-based interventions in geriatric populations [9]. Numerous clinically established prevention interventions target fall-related risk factors. Several recent meta-analyses and systematic reviews have examined a comprehensive range of falls prevention intervention studies for preventing falls in community-dwelling older individuals.

While a number of systematic reviews have been conducted in the fall's prevention domain, these reviews tend to focus mainly on specific subdomains within the broader context of technology-based interventions. To the best of our knowledge, no existing research comprehensively surveys and categorizes the entire falls prevention intervention landscape, including the types of existing technology-based fall prevention systems, their key collaborative functions, the technologies they utilize, and the specific types of falls prevention interventions they support. Additionally, there is limited existing research that, through this holistic perspective, identifies areas of clinical practice that are well-addressed and areas that require more attention.

Research Method Literature Searching Strategy

In our literature search, a comprehensive keyword search strategy was employed to gather relevant studies from five major electronic databases: Scopus, Science Direct, PubMed, Web of Science, and ProQuest. This strategy involved the use of keywords such as 'exergame' or 'exergaming,' 'ageing' or 'aging' or 'aged' or 'old' or 'older' or 'elderly,' 'fall' or 'falling,' 'balance,' and 'interactive prevention' or 'intervention,' and various combinations thereof. The search extended up to September 30, 2015. Initially, 8,984 articles were retrieved from these searches. After excluding 2,294 articles due to duplication, 6,690 articles remained for further evaluation of their relevance.

Inclusion Criteria and Selection of Studies

The 6,690 articles obtained during the literature search underwent a systematic screening process to determine their relevance for this review study. This screening was carried out independently and in duplicate by the authors. Initially, the titles of the articles were screened, followed by the screening of their abstracts. Any discrepancies between the authors were resolved through consensus, following the methodology described by Rodrigues et al. (2014). As a result of this process, 191 abstracts were identified as potentially relevant and were selected for full-text review to assess their eligibility for inclusion in the final review. After a thorough review, 166 articles were excluded based on predefined exclusion criteria. This led to the inclusion of 25 papers in the final review and analysis. All 25 of these included studies involved at least one group of older adults (aged 60 years or above), tested at least one exergame based intervention, and employed a pre-post training or intervention design.

Discussion

Post-fall prevention interventions (post-FPIs) serve a vital role in assessing patients for both intrinsic and extrinsic fall risks by employing a range of physical, cognitive, and environmental assessment interventions. Upon a review of these systems, several observations emerge in relation to fall risk assessment.

Firstly, it is apparent that most post-FPI systems predominantly focus on assessing intrinsic risk factors, including functional ability deficits and cognitive impairments. However, limited attention is given to extrinsic risk factors, despite their potential to lead to serious fall injuries.

Secondly, various intervention types are utilized in post- FPIs to assess fall risks. While some systems solely employ functional assessments to gauge an individual's risk of falling, others incorporate both functional and cognitive assessments to evaluate multifactorial risks.

Table 1: List of Reviewed Literature

Study	Intervention	Duration	Sample	Result
Agmonetal., 2011	Wii(Wii-Fit) Quasi-experimental pre-post single group design E: Wii-Fit Balance Training (Basic Step, Soccer Heading, Ski Slalom, and Table Tilt)	30 × 3 × 12 weeks (at least) Total: ≥ 1080 min	Older adults with impaired balance	
Bateni, 2012	Quasi-experimental pre- post control group design E1: Receiving both physical therapy training and Wii Fit training (PW) E2: Receiving Wii Fit training alone (WI)E3: Receiving physical therapy training alone (PT)	3 sessions × 4 weeks Total: not reported.	Older adults from physical therapy's departments in hospitals and rehabilitation centers	Bubble test score and berg balance score improves in experimental group
Batistaetal., 2014	Pre-post single-group design E: Playing the Wii Games-Deep Breathing, Penguin Slide, Ski Slalom, Soccer Heading, Tightrope Walk, Table Tilt	30 min × 3 times × 20 sessions (weeks) Total:1800 min	Elderly female patients with a deficit balance	Increase in berg balance score in experimental group
Bieryla and Dold, 2013	Pre-post single-group design E: Playing the Wii Games-Deep Breathing, Penguin Slide, Ski Slalom, Soccer Heading, Tightrope Walk, Table Tilt	30 min × 3 times × 3 weeks Total: 270 min Total: not reported.	Healthy older adults from local senior living community	Increase in berg balance and tug score in experimental group
Choetal., 2014	Pre-post control group design E: Playing virtual reality games (Wii Fit balance games: Ski Slalom, Table Tile, and Balance Bubble)	30 min × 3 times × 8 weeks Total: 720 min Total: not reported.	Healthy older adults from local senior living community	Increase in berg balance and tug score in experimental group
Bieryla and Dold, 2013	Pre-post control group design E: Playing Wii Fit games (Yoga: halfmoon, chair, warrior; Aerobic: torso twists; Balance games: soccer heading, ski jump) C: Doing normal activities	Pre-post control group design E: Playing Wii Fit games (Yoga: halfmoon, chair, warrior; Aerobic: torso twists; Balance games: soccer heading, ski jump) C: Doing normal activities	Healthy older adults from local senior living community	Increase in berg balance and tug score in experimental group
Choetal., 2014	Pre-post control group design E: Playing virtual reality games (Wii Fit balance games: Ski Slalom, Table Tile, and Balance Bubble)	30 min × 3 times × 3 weeks Total: 720 min Total: not reported.	Healthy elderly people	Increase in berg balance and tug score in experimental group
Daniel, 2012	Pre-post control group design E1: Playing Wii games (including Bowling, Tennis and Boxing) E2: Participating in study staffdirected group exercise sessions. C: Continuing whatever physical activity hey participated in before	45 min × 3 times × 15 weeks Total: 2025 min	Pre-frail older adults (from local Senior centers and resident al living centers)	SFT: There were improvements on several measures in SFT for E1 and E2

Table 2: List of Reviewed Literature

Study	Intervention	Duration	Sample	Result
Francoetal., 2012	Pre-post single group design E: Playing Wii Fit balance games and receiving gait training using BWS	40 min × 2 times × 6 weeks Total: 480 min	Old men with transdermal amputations	Limits of Stability test score improves in experimental group.
Keoghetal., 2014	Pre-post single group design E: Playing Wii Fit balance games and receiving gait training using BWS	40 min × 2 times × 6 weeks Total: 480 min	Old men with transdermal amputations	Limits of Stability test score improves in experimental group.
Parketal., 2015	Pre-post control group design E1: Playing virtual reality games (Wii Fit balance games: Soccer Heading, Snowboard Slalom, and Table Tilt) E2: Doing ball exercises.	30 min × 3 times × 8 weeks Total: 720 mins	Elderly individuals living in local community.	Improve in gait parameters in experimental group
Rendonetal., 2012	Randomized pre-post control group design E: Receiving three different Wii Fit balance interventions. C: Receiving no intervention	35-45 min × 3 times × 6 weeks	Older adults from the retirement community	Improvement in gait and balance parameters
Chenetal., 2012	A prospective, case-controlled study E: Doing video-game-based power training exercise C: Performing slow speed sit-to-stand movements, as well as strengthening and balance exercises	30 min × 2 times × 6 weeks Total: 360 min	Older people from the community	Improvement in mechanical time parameters
Lamothetal., 2012	E1 & E2: Performing a balance task in three conditions: no feedback (NF), real-time visual feedback (VF), real time visual feedback with a competitive game element (VFG)	Not specified	Healthy elderly (61 to 77 year) and young adults (19 to 26year)	Improvement in all parameters including balance and gait
Laietal., 2013	Prospective, randomized, crossover, single blind design. E1: Undergoing interactive video game based (IVGB) training for 6 weeks and receiving no intervention in the following 6 weeks. E2i: Receiving no intervention during the first 6 weeks and then participating in training in the following 6 weeks	Not specified	Community-living older adults	Improve in time up and go and berg balance scale score improvement
Schoeneetal., 2013	Single-blinded randomized controlled trial design E: DDR game training: Playing a step game as accurately as possible C: No - intervention (performing usual activities)	15 min (median) × 2.75 sessions (median) × 8 weeks Total: 330min	Older adults (residents of independent living units of retirement village)	

Although Post-FPI systems play a crucial role in reducing the risk of falling, particularly by assessing fall risks, only a few systems address extrinsic factors. Notably, there is a single system designed for assessing the patient's home environment for extrinsic risks. This system involves the use of a remotely operated robot that navigates the patient's home while a clinician follows a checklist of factors. However, this system is not fully autonomous, making it susceptible to handling errors, which can impact its reliability. Additionally, it still requires clinicians' time to conduct the assessment tasks remotely.

Moreover, most Post-FPI systems are characterized by their static nature, offering no means for users to interact with the systems. This suggests that limited efforts are directed toward developing interactive systems for fall risk assessment.

An area that remains unexplored in this domain is patient- clinician collaboration. The majority of systems provide synchronous collaboration, where data is sourced from older adults, and responses are provided in real-time. In contrast, some studies reviewed here present asynchronous systems, where data sourced from older adults is not clinically assessed at the time it was performed. This asynchronous approach offers potential for further investigation

Conclusion

In summation, this in-depth review has provided a panoramic analysis of post-fall prevention interventions, offering insights into their strengths and areas for advancement. The exploration of intrinsic and extrinsic risk factors accentuates the need for a more balanced approach in assessing and mitigating fall risks. The focus on intrinsic factors is justified, as they significantly contribute to fall risks. Still, there is an essential need to amplify the consideration of extrinsic risk factors, as they can precipitate serious fall-related injuries and are often underemphasized. Our analysis of intervention types underscores the multifaceted nature of fall risk assessment, with functional and cognitive assessments playing indispensable roles. While these assessments remain foundational, there is untapped potential in multifactorial assessments, which encompass both intrinsic and extrinsic factors, providing a more holistic approach to fall prevention. The prevalent static nature of existing post-FPI systems underscores the need for more interactive and dynamic approaches to engage users effectively. The introduction of the asynchronous model of patient-clinician collaboration introduces a promising avenue for future investigation, potentially revolutionizing the way we approach fall risk assessment and intervention. By addressing these gaps and enhancing the current state of post-FPIs, we can make substantial progress in reducing fall-related injuries among older adults, ultimately improving their quality of life and preserving their independence. As we move forward, we are poised to redefine the landscape of fall prevention, bridging the gaps and innovating our approaches to ensure the well- being of our elderly population [10-40].

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