

Virtual reality approaches for enhancing postural stability and mobility in the elderly: A mini review

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Abstract

The elderly population is growing rapidly, with a significant portion facing challenges related to balance and mobility. Importance of implementation of an effective fall prevention and balance training programme as an essential activity of daily living for elderly is still understated in national literature and policy. Conventional postural stability (PS) and mobility training programmes often face limitations in terms of provision of adequate challenge, engagement and adherence. Virtual reality (VR) technology has emerged as a promising tool in healthcare, with potential applications in PS training for the elderly. VR based PS training provides a fun and engaging environment resulting in enhanced motivation, with appropriate intensity and high frequency intervention. While individually designed VR systems are expensive; a range of commercially available full body motion platform based gaming systems such as Nintendo Wii Fit, Xbox Kinect, PlayStation eyetoy etc. serve as potential and suitable alternatives. This review article provides a synthesis of current evidence related to available systems, protocols and potential limitations of individual systems with an aim to enhance utilization of VR based PS training as fall prevention approach to improve quality of life and promote healthy aging among elderly.

Keywords: Elderly, Fall Risk, Kinect, Postural Stability Training, Virtual Reality, Wii Fit.

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Introduction

Falls among the elderly have become a global health challenge.^{1,2} Globally, More than 25% of elderly suffer falls.³ This percentage rises with age indicating decline in postural stability and impaired mobility. Age related decline in postural stability and balance is a significant health issue among elderly leading to a risk of fall,

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functional dependence in daily activities and a decline in overall wellbeing and quality of life. Falls in the elderly can result in serious injuries such as fractures, head trauma, and even death. Although research has shown the importance of implementing effective fall prevention and balance training programmes for postural stability as part of daily living for the elderly, national literature and policy still understate this need.⁴

Fall prevention programmes for older adults have garnered increased attention in recent decades. Engagement of elderly in regular physical activity has shown to improve balance; enhancing activities of daily living and preventing fall related injuries and mortality. Exercise programmes including physical training, aerobic training, resistance exercises, balance training and Tai Chi etc have proven to be effective as postural stability training regimes. However, literature is suggestive that such programmes often suffer from low adherence, with inadequate exercise challenge or poor compliance reducing their effectiveness.¹ Conventional exercises even though are effective they often do not sufficiently target cognitive aspect of balance and mobility.⁵ Furthermore the retention effects of conventional exercise programme are also unclear, along with lack of ability to targetting multiple component of balance such as strength, endurance, and sensory integration etc.

Virtual reality – A Balance breakthrough:

Virtual reality (VR) technology has recently emerged as a promising tool in healthcare, particularly in PS training for the elderly. Virtual reality (VR) is a computer-generated artificial environment that allows users to interact within the simulated world. VR Technology is convenient due to its easy applicability, engaging both motor and sensory systems within a dynamic environment. This not only provides a fun and engaging setting, but also enhances motivation and allows for higher repetition exercise with adequate cognitive engagement for mobility and balance.⁶

VR simulates real-world environments where patients can safely practice therapeutic activities that may transfer to real-world scenarios, which might otherwise be impossible due to availability and safety concerns.

Additionally, VR provides audiovisual feedback, allowing patients to adjust their movements and facilitating motor skill learning. Positive feedback upon successful task completion enhances patient motivation, thereby improving adherence to rehabilitation programmes.^{1,7} Interactive video games have shown promising effects for fall prevention, by enhancing balance assessment and rehabilitation.⁴ Repeated and systematic training is another important aspect of rehabilitation, and VR applications offer repetitive exercises that gradually increase difficulty while decreasing guidance by the therapist. These tools allow the elderly to practice repetitive physical functions in a safe and enjoyable environment, tailored to their needs and abilities, thus improving their independence.⁸

VR systems Availability and Clinical potential

While custom-designed VR systems can be excessively expensive, various commercially available game-based systems offer suitable alternatives for healthcare settings in low and middle income countries. These include Nintendo Wii Fit, Microsoft Xbox Kinect, and PlayStation Move. Additionally, the emerging head mounted display (HMD) VR systems and cave automatic virtual environment (CAVE) have unique advantages for training postural stability in elderly population and may be potential future approaches suitable for high end health care setups.^{1,7}

Microsoft Xbox Kinect VR system

Microsoft Kinect uses motion-sensing technology to capture full-body movements, enabling a wide range of interactive and augmented reality exercises to improve postural stability in older adults. This system does not require a hand held controller to track movement which allows for a more natural exercise experience. Kinect Xbox can be used as home-based therapy offering convenience and flexibility to patients.⁹

Kinect-based exercises regimes significantly enhance balance, postural stability, and mobility through full-body engagement. The system allows for dynamic base of support changes, multi-directional exercises, and eccentric lower limb activities, contributing to strength and cardiopulmonary benefits as well. Kinect games vary in difficulty, from basic movements to advanced exercises requiring full body multi direction activities. Kinect games, such as those in Kinect Adventures, vary in difficulty and target different skill sets. Protocols typically involve 5-12 weeks of training with 3-4 sessions per week, each lasting 30-90 minutes. Difficulty can be adjusted based on the participant's performance and exertion

level. The Kinect system is user-friendly with built-in instructions, requiring minimal setup assistance. However, it requires ample space and may not be suitable for individuals with severe balance issues due to the risk of falls associated with multi-directional movements.

Nintendo Wii Fit based VR System:

The Nintendo Wii Fit uses a console, hand held controllers and a balance board to track movements and provide visual feedback via game play, offering a range of exercises aimed at improving balance and coordination. Studies have shown that Wii Fit exercises can significantly improve balance and reduce fall risk among elderly users. The system's interactive nature and immediate feedback mechanisms enhance user engagement and motivation, making it a popular choice for home-based rehabilitation. There are multiple different types of games available on Wii fit including "Yoga" and "Strength Training" exercises which focuses on flexibility and core strength, while "Balance Games" such as "Balance Bubble" and "Tightrope Walk" are mostly used to improve balance and postural stability. Most of these games begin with basic level progressing to more advanced levels increasing difficulty level. While effective, the Wii Fit has limitations. The balance board, relying on pressure and inertial sensors, requires users to remain within a limited base of support. This may benefit those with limited balance initially but does not offer sufficient postural stability challenges for advanced exercises.¹⁰ Additionally, while refurbished Wii Fit systems are relatively affordable (PKR 5,000 to 15,000) because of being more than a decade old technology, their availability is inconsistent.

PlayStation EyeToy:

In the early 2000s, Sony introduced the PlayStation 2 EyeToy, an accessible and affordable gaming application allowing users to interact with virtual objects on a TV monitor. This system captures real-time images without the need for intense lighting, thereby simplifying the setup. However, EyeToy's limitations include difficulty grading the level of challenge for severely involved individuals and the lack of systematic performance recording, which hinders tracking progress over time.¹¹ It offers various kinds of games including sports champions and The Fight: Lights Out for physical fitness and the structured workouts. Literature has mixed evidence regarding its effectiveness on physical performance in different populations. Furthermore there is limited evidence available on for balance and mobility training in elderly population. This can be because its initial purpose was more of entertainment, so its games were not specifically tailored for rehabilitation; as well more superior systems were introduced early in market.¹²

Head Mounted Display VR system:

Commercially available Head mounted display (HMD) for VR systems immerses users in a virtual environment allowing them to move within a fully immersive 3D virtual environment via real time 3D hand and head tracking technology. This integrated challenge to balance senses may improve balance and mobility. However, Research on the effectiveness of HMDs for gait and postural stability training is still limited, however the growing popularity of VR is likely to drive further exploration.¹³ A notable example is the Apple's Vision Pro. This system features high resolution displays and advanced spatial audio, providing an immersive virtual experience with enhanced visual and auditory accuracy. With a sophisticated tracking and interaction capabilities, it is designed deliver a realistic virtual environment, offering new opportunities for developing effective VR based interventions to improve balance and mobility in the elderly.¹⁴

Advantages of VR as postural stability regime:

One of the primary benefits of VR systems is increased motivation level by transforming traditional exercise into more interactive games. Training through VR system can be customized and adapted according Participant's of postural stability and mobility by adjusting difficulty level, intensity and type of exercise, by changing the type of game, the level or difficulty of game play and increasing the time of game play. A systematic review reported that individualized tailored VR programmes result in better improvement in balance and mobility as compared to traditional programmes. Additionally, the ability to provide real-time feedback and adjust the difficulty of exercises ensures that participants are challenged continually resulting in better progress.¹⁵

Relevance to Pakistan

In a lower-middle-income country like Pakistan, with limited healthcare resources, the use of commercially available VR gaming systems (such as Xbox Kinect) for postural stability training presents a unique opportunity. These systems offer an affordable and engaging alternative to expensive, specialized hospital based VR setups, potentially increasing access to fall prevention interventions for the elderly. By using the existing gaming technology, healthcare providers can address the growing burden of falls related injuries in a cost-effective manner. However, implementing VR-based interventions in Pakistan will be challenging. Limited awareness among healthcare professionals and the general public about the potential benefits of VR, along with concerns about technological literacy and access to compatible gaming

systems, may hinder widespread adoption. Additionally, ensuring the cultural relevance and adaptability of gaming content to the Pakistani context is crucial for maximizing engagement and adherence. Despite these challenges, the potential for VR to revolutionize fall prevention in Pakistan is significant, provided that efforts are made to address these shortcomings to provide tailor interventions to the specific needs as per population.

Conclusion

Game based VR technology utilizing commercially available gaming devices can serve as potential alternative to costly VR system. Such devices hold significant promise for enhancing postural stability training in the elderly, offering engaging, customizable, and effective interventions. Considering challenges and limitations associated with individual VR systems along with consideration for patient needs is essential for deciding appropriate VR approach for PS training in elderly participant. Such approaches can be considered for adoption in healthcare settings with aim to improve balance rehabilitation facilities for elderly.

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