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The Effectiveness of Virtual Reality Exercise to Reduce Risks of Fall in Elderly with Balance Disorders: A Literature Review †

Triana Karnadipa *, Iman Santoso, Aditya Denny Pratama and Nahdiya Nurul Aulia

Physiotherapy Department, Vocational Education Program, University of Indonesia, Depok City 16424, Indonesia
* Correspondence: trianakarnadipa@gmail.com
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Abstract: Virtual reality is a fun training tool to increase elderly patient motivation to continue the fall prevention program. This study aims to evaluate the effectiveness of virtual reality exercise to reduce the risk of falling in the elderly with balance disorders. PUBMED, Ebscohost and Proquest were sought for articles involving the elderly aged over 64 years with balance disorders trained with virtual reality. JBI Critical Appraisal and Data Extraction Form for Experimental Studies were used for evaluation and extraction. Data synthesis was carried out using a simplified approach. Decrease in the risk of falling and improvement balance in the elderly were found after 8 weeks of virtual reality exercise with an intensity of 30–60 min, 3 times a week. Decreases in muscle strength, postural stability, quality of life, personality changes, and depression were the most identified factors.

Keywords: virtual reality; fall; elderly; balance disorders

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1. Introduction

Every year an estimated 684,000 people die from falls in general of which more than 80% are in low- and middle-income countries. The main population at risk of falling is the elderly aged 65 years and over. 37.3 million people fall severe enough to require medical attention and this happens every year to reduce the risk of falling [1].

In Indonesia, the population who suffered a fall injury over the age of 55 reached 49.4% and those over the age of 65 reached 67.1%. In the world, other studies estimate the prevalence of falling each year to be 16.5–37.4% [2]. After a fall, the elderly would experience detrimental and long-term consequences including significant reduced mobility, loss of independence, decreased quality of life, also frequent visit to emergency department and premature death within one year [3].

The older a person gets, the higher their risk of falling. One of the causes of the risk of falling in the elderly is balance disorders. In addition, this balance disorder can be done using virtual reality (VR) which can develop fine and gross motor functions, can improve balance and coordination [4].

Virtual Reality (VR) is a medium of interaction between humans and personal computers in the form of interactive simulations that can bring out the influence of feelings of existence in a virtual environment through various kinds of feedback such as virtual channel sensors, aura, touch and smells.

The advantages of virtual reality technology in the elderly with balance disorders can fully control the stimuli given to the patient. In addition, virtual reality is a fun training tool to increase patient motivation to continue rehabilitation [5]. The drawback of virtual reality technology is that users will experience a loss of feeling of reality when they interact or see the artificial world instead of the real world [6].

The purpose of this article is to determine the effectiveness of virtual reality exercise to reduce the risk of falling in the elderly with balance disorders which includes doses and

factors so that people can add and gain insight into virtual reality so that people can apply it in their daily lives.

2. Methods

This literature review search articles or journals using keywords and Boolean operators (AND, OR NOR or AND NOT) which are used to expand or specify the search strategy. The inclusion criteria are as follows; (1) Elderly over 65 years with balance disorders, (2) Virtual reality intervention, (3) Measuring the risk of falls and balance disorders, (4) Using English or Indonesian, (5) Range of publication years 2016–2021, (6) experimental controlled trials. The exclusion criteria are as follows; (1) Individuals under the age of 65 years without balance disorders, (2) Interventions do not use virtual reality, (3) Do not measuring the risk of falls and balance disorders, (4) Do not use English or Indonesian, (5) The year of publication is 2016–2021. EBSCOHOST, ProQuest and Pubmed databases were sought for potential published studies from March to June 2021.

The strategies used to find articles using the PICO framework are:

1. Population is elder*, older adult*, geriatric, frail*, geriatric
2. Intervention is virtual reality, augmented reality, computer assisted, computer stimulation
3. Comparison is other intervention
4. Outcome is to risk of fall, accidental fall*, fall

The critical appraisal and data extraction methods used the JBI Critical Appraisal Checklists and JBI Data Extraction Form for Experimental Studies [7]. The data synsthesis was carried out using a simplified approach by Aveyard [8].

3. Results

After conducting searches on three databases, 121,295 hits were found. The titles and abstracts were screened and 82 articles meet the inclusion criteria. After eliminating the duplicate articles and applied automation tools, 16 papers were found. After full-text analysis, 11 articles did not meet the inclusion and exclusion criteria. Finally, 5 journals were further reviewed (Figure 1).

3.1. Participants

Four Randomised Controlled Trials (RCTs) and one quasi experimental trial included 355 participants. Age ranged from 60 to 79 years old. There is no significant difference in numbers of male (49.3%) and female participants (50.7%). Balance status of the participants ranged from medium to high risks of fall measured with Berg Balance Scale (BBS); moderate to high concern of falling measured with Fall Efficacy Scale International (FES-I); or have predictive risks of fall measured either with dynamic gait index (DGI) or Fullerton Advance Balance [9].

3.2. Description of Studies and Intervention

Three studies were from Iran, two studies were from Brazil and Australia. The studies are conducted from 2019–2021. Three studies used Xbox Kinect, one used Oculus Rift VR and one study used virtual reality system Balance Rehabilitation Unit to deliver the balance program. Most of the studies employed games or activities that challenged balance and required postural control such as kicking, stomping, goal keeping, and bask head. A study compared the VR training with daily activities, three studies with conventional balance training, and one with Otago Exercise Program. Overall dosage ranged from 30 to 60 min over two to nine weeks (Table 1).

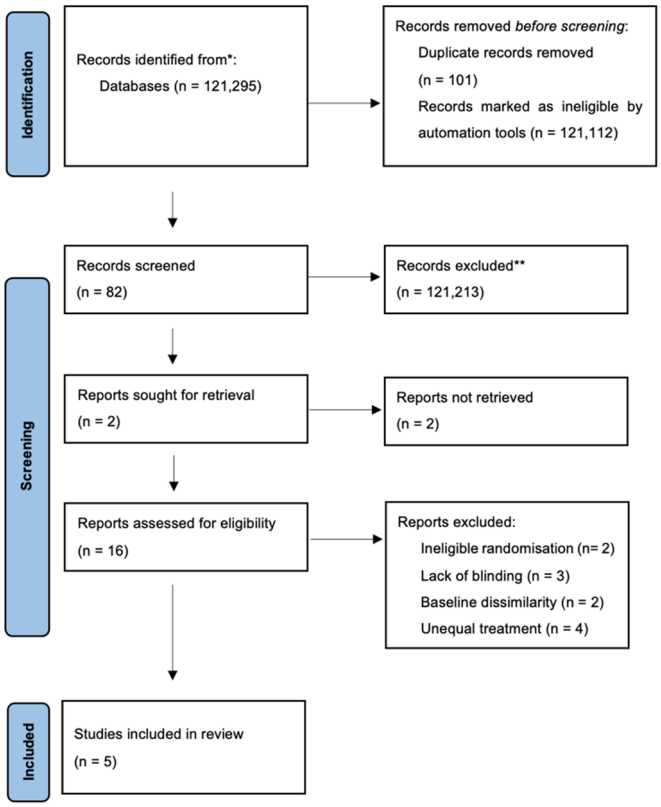

Figure 1. Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) chart of included and excluded studies. Truncation (*): is used to expand search by including multiple word endings and spellings.

Table 1. Intervention and Dosage.

Study	Experimental Group	Control Group	Dosage
Sadeghi et al. [10]	Virtual Reality Group: This exercise using the Xbox Kinect Sport includes the The Light Race (Stomp It) minigame, Target Kick, and the Goalkeeper minigame. Three consoles were used during the VR session. An introductory exercise session was conducted prior to the start of training, which involved playing each of the 3 games twice. As participants increase, they progress with increasing difficulty of VR games.	Comparison Group: *Balance training* Exercises such as single leg stance with eyes open and closed, heel or toe standing, tandem and semitandem foot stances, tandem walking, backward and forward walking, and weight transfer. An introductory exercise session is conducted before the start of training, involving 1 to 2 sets of 6 to 8 repetitions of each exercise.	40 min, 3 times per week for 8 weeks
	Mix Group Warm up 5 min, BT workout 15 min, VR workout 15 min, and cool down 5 min 3 times a week for 8 weeks	Control Group: Continuing to carry out daily activities and avoiding starting a new exercise program during the study period.	

Table 1. *Cont.*

Study	Experimental Group	Control Group	Dosage
Babadi et al. [11]	Virtual reality training using Kinect box, console, and monitor. During the first three weeks of the exercise program, stand in two positions, raise heels and feet, and walk in place. During the next three weeks exercises of neck hyperextension, free leg swing, and neck and trunk rotation were performed in addition to standing in two positions, lifting heels and feet, and walking in place. Then, over the last three weeks exercises touching the floor, walking sideways, walking, and standing on one leg were added to the training.	Perform daily routine activities for balance	Each session lasts about 1 h (10 min of warm-up exercise, 40 min of exercise, and 10 min of cool-down) for 9 weeks, 3 times a week, and with one day in between.
Zahedian-Nasab et al. [1]	Stimulate balance training using Xbox Kinect as well as with games. Selected games (Kinect Sports 1 and 2) include penalty, goalkeeping, skiing and darts and each session covers a different aspect to improve balance	Routine nursing home programs, including jogging at the nursing home, table tennis, and some art activities.	two 30–60 min sessions each week for 6 weeks.
Rebêlo F. et al. [12]	The exercises are carried out in virtual reality and include four games namely BoxVR, Baskhead, InCell and Roller Coaster Thrills and Chills. Each game is played for 8 min, with a three minute rest interval between games. All games are played in all sessions.	Balance exercises in a straight line, exercises on unstable surfaces, gait/balance exercises on the mat. Exercise changes every week, with increasing postural instability and exercise intensity. The protocol is performed in circuit mode, each exercise is performed for 2 min, and the entire circuit is repeated three times per session, with a three-minute rest interval between each repetition.	50 min morning sessions twice a week for 2 months.
Phu et al. [13]	Virtual reality balance exercises using the BRU program, namely rehabilitation exercises and postural exercises for about 15 min each and virtual reality headsets.	Exercise program based on OEP. Modified OEP in which exercises are completed in a group setting following a circuit style, including post-exercise warm-up and cool-down, and various stretching exercises.	60 min, twice a week, for a total of 12 sessions over 6 weeks

3.3. Outcome Measures

Four balance and fall risk measures were used in the included studies. The Timed Up and Go Test (TUG) is a test for dynamic balance disorders in the elderly. This test aims to assess mobility, balance, walking ability and risk of falls in older adults. The TUG has good reliability with an ICC (intraclass correlation coefficien) of 0.99. TUG has good validity with a value (r = 0.81).

Tinetti Falls Efficacy Scale questionnaire containing 10 items to assess the perception of balance and stability during activities of daily living and to assess the fear of falling in the elderly. Each item is rated from 1 (very confident) to 10 (not confident at all). The total score ranges from 10 (best possible) to 100 (worst possible). FES has good reliability with

an ICC of 0.71. FES has good validity with the Activities Specific Balance Confidence Scale (ABC Scale) with a value (r = 0.84).

The Fullerton Advanced Balance Scale is a balance assessment test that aims to measure balance in higher functioning in active older adults. This test examination consists of 10 performance-based activities in both static and dynamic phases. A score of 0–40 points is possible (higher scores are better). Each item has 5 points with a score of 0–4. FABS has good reliability with an ICC of 0.995–0.999. FABS has good validity with a total score of 0.93–1.00.

Berg Balance Scale (BBS) is a test to assess static balance and fall risk in adults. This measurement uses a 14-item objective. These 14 items include standing on one leg, standing without support and so on. BBS has good reliability with an ICC of 0.98. BBS has good validity with a total score of 0.679–0.977. The scores ranged from 0–56. The BBS interpretations include 0–20: wheelchair bound (high risk of falling); 21–40: Walks with assistance (low fall risk); 41–56: Independent.

4. Discussion

4.1. Dosage of Exercise

Based on the included articles, there is an average dose that is more effective in the study of Sadeghi H, et al. which was carried out for 8 weeks with a frequency of 3 times per week because the exercise was carried out with virtual reality with Xbox Kinect for 30 min with games, balance training such as single leg stance with eyes closed and open, tandem walking, tandem and semitandem foot stance, walking backwards and forwards, 1 to 2 sets of 6 to 8 repetitions of each exercise and mixed exercises (VR and BT). The more often you do the exercise the more effective with these doses which can result in improvements in leg strength, balance and functional mobility. (Table 2) Therefore, the intervention in the study of Sadeghi H, et al. can be applied. The exercises involved static and dynamic stretching focused on the lower limbs, such as calves, hamstrings, quadriceps, tensor fasciae latae and gluteal muscles [10]. The Xbox Kinect has the advantage to use the upper and lower extremities while standing [11]. In addition, it is effective because virtual reality has the principle of balance training, namely providing visual, vestibular, and proprioceptive stimuli statically and dynamically [12].

Table 2. Virtual Reality Balance Training Strategy.

Study	Media	VR Type	Games	Balance Activity	Dosage	Format
Sadeghi et al. [10]	Xbox Kinect	Immersive	The Light Race, the Target Kick, Goalkeeper	Lower limb challenged activities: stomping, kicking, side-stepping	16 h	Individual
Babadi S. et al. [11]	Kinect box, konsol, dan monitor	Immersive	Sports Pack 1 and 2	Upper and lower extremities activities while standing such as boxing, table tennis, and soccer.	27 h	Individual
Zahedian-Nasab et al. [1]	Xbox Kinect	Immersive	Kinect Sports 1 and 2	Penalty, goalkeeping, ski, and darts,	Max 12 h	Individual
Rebêlo F. et al. [12].	Oculus Rift virtual reality	Immersive	BoxVR, Baskhead, InCell, Thrills and Chills Roller Coasters	Combination of trunk movements, limb movements, balance stability challenges, weight transfer, multidirectional steps, jumping, and crouching	13.3 h	Individual
Ph et al. [13]	Balance Rehabilitation Unit Program	Immersive	Balance Rehabilitation Unit	Ring/block collecting	12 h	Individual

This is in line with the results of a systematic review by Meng Liu, et al. which stated that virtual reality exercises were more effective for 8 weeks to improve mobility and functional balance in older adults. In addition, immersive virtual reality with intervention sessions longer than 8 weeks with a high frequency of 3 times/week can provide more effective results [14].

4.2. The Effectiveness of Exercise in Reducing the Risk of Falling and Improving Balance in the Elderly

The five articles found that virtual reality exercises was significant in reducing the risk of falling in the elderly measured with the Time Up and Go Test (TUG) parameter. The practice of virtual reality with balance disorders in the elderly has also proven to be quite effective in improving balance in the elderly with the parameters SLS (single leg stance), BBS (berg balance scale), FRT (functional reach test), DGI (dynamic gait index), Tandem stance test, 5STS (five times sit to stance) and FSST (four square steps test).

Exercises performed such as tandem walking, single leg stance with eyes closed and open, walking backward and forward, sideways walking and walking in place [10]. This can happen because virtual reality exercises can provide visual, vestibular, and proprioceptive stimuli statically and dynamically. Visual stimuli can provide the perception of movement [12]. In addition, the exercise involves muscle strength such as the hamstring, quadriceps and calf so that it can improve balance and also reduce the risk of falling. The risk of falling can be affected by a decrease in muscle strength and poor functional mobility [10].

This is in line with the results of a systematic review by Diego Eduardo dos Santos, et al. stated that virtual reality can reduce the risk of falling because VR can also prevent falls, improve balance in the elderly and reduce the risk of falling [15]. Virtual reality is quite effective in reducing the risk of falling and improving balance because the exercise requires the use of the upper and lower extremities; eye, hand and foot coordination so that the participant is able to maintain his balance. Virtual reality can improve motor and cognitive abilities such as weight transfer, attention, concentration, visual and hearing which can generate motivation for the elderly [12].

In addition, virtual reality exercises can reduce fatigue, stress, depression and provide relaxation, can improve the quality of life of the elderly, increase functional mobility, reduce the sense of risk of falling and can improve functional mobility. Thus, this virtual reality program can be done at home.

4.3. Factors Affecting the Effectiveness of Virtual Reality

Factors that can affect virtual reality training on the risk of falling and balance include age-related changes that often occur in the elderly over 65 years. At the age of 65, a decrease in muscle strength in the extremities, especially the lower extremities, dan development chronic diseases most likely to be happened [1].

Factors that decrease physical function are decreased physical function due to aging resulting in balance disorders, causing problems in daily life and increasing the risk of falls, limitations in physical activity, postural instability and decreased muscle strength [10]. Also, the limitations of the proprioceptive and vestibular systems as well as a decrease in the physical performance of the elderly can occur as indications of these factors [13].

In addition, psychological and environmental factors can also affect the risk of falling and balance against virtual reality includin isolation, anxiety, personality and mood changes (depression), self-esteem and lack of social protection, low social activity, experience falls and limitations in physical activity. Thus, the quality of life and the motivation and the mobility lifestyle becomes low [11].

5. Research Limitations

There are limitations in this literature review. Meta-analysis was not conducted due to high heterogeneity. Two articles did not give a clear description of dosage such as intensity

and time. There is no follow-up after the intervention period in all included article, thus the effect retention cannot be determined. The intervention location, procedure and provider were not decribed in detail. One study designs used quasi-experimental instead of RCTs. Thus, the quality of evidence used in this literature can be deemed to be at least moderate.

6. Conclusions

Virtual reality exercises can be recommended to reduce the risk of falling and improve balance. More frequencies of exercise is more effective with moderate intensity doses 3x/week for 8 weeks. Factors that can affect the exercise include decreased physical function associated with decreased muscle strength and postural instability. In addition, psychological factors can also affect including chronic disease, isolation, anxiety, personality and mood changes (depression) and decreased quality of life.

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