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THE EFFICACY OF TASK SPECIFIC VR TRAINING VERSUS COGNITIVE BEHAVIORAL THERAPY IN FALL PREVENTION AMONG ELDERLY – A PILOT STUDY

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ABSTRACT

Background: Falls represent a major public health crisis among older adults, contributing significantly to morbidity, mortality, and healthcare costs worldwide. The number of falls escalates with age for people over 65. These falls account for 30-50% of hospital admissions. VR improves neuroplasticity and motor learning by giving multisensory feedback, repetitive practice over and over again and mainly through gamification. Cognitive Behavioural Therapy (CBT), originally a psychological approach which has been modified for physical rehabilitation to address fear of falling and maladaptive behaviours. Despite individual benefits, no studies have directly compared task-specific VR training, Cognitive Behavioural Therapy and conventional exercises directly for preventing falls and improving balance in the elderly.
Method: A total of 24 participants both male and female aged 65–80 years were selected using simple random sampling. Screening was done using standardized tools such as the Mini-Mental State Examination (MMSE), Falls Efficacy Scale (FES). After obtaining consent Participants were then randomly allocated into three small groups consisting of 8 subjects in each group. Group A received cognitive behavioral therapy, Group B received task specific virtual reality training and group c received Conventional physiotherapy. The outcome measures selected for this pilot study included the Berg Balance Scale (BBS) to assess functional balance, Balance Assessor for evaluating fall risk and stability. All assessments were carried out at baseline, 6th week and 12th week.
Result: The findings indicate that the groups were similar at baseline, but differences became more evident over time, particularly at 12 weeks for BA Fall, SLS, and LOS, and at both 6 and 12 weeks for BBS. With $F(2,21) = 5.160$, $p = 0.015$ for BBS, $F(2,21) = 7.236$, $p = 0.004$ for BA Fall, $F(2,21) = 5.186$, $p = 0.015$ for SLS, $F(2,21) = 10.913$, $p = 0.001$ for LOS at 12 weeks.
Conclusion: The enhanced sensory feedback, task relevance and motivational appeal of VR appear to drive superior neural and functional adaptations. While CBT and traditional exercises retain important roles particularly for addressing psychological barriers and general fitness. .

KEYWORDS: Prevalence of Falls, fear of falling, multisensory feedback, Cognitive Behavioral Therapy ,virtual reality in elderly.

INTRODUCTION

Falls represent a major public health crisis among older adults, contributing significantly to morbidity, mortality, and healthcare costs worldwide. Fall is defined as 'inadvertently coming to rest on the ground, floor, or other lower level, excluding intentional change in position to rest'(1). The world health organization states that the falls are the second most common cause of accidental death around the world and people over 60 have the highest death rates from falls (2). In 2017, there were more than 684,000 fatal falls around the world and every year about 37.3 million falls required medical attention. The number of falls escalates with age for people over 65. These falls account for 30-50% of hospital admissions and often results in fractures, traumatic brain injuries, head injuries and hip fractures (3). Every year falls send more than 3 million older people to the emergency room in the United States alone, costing the healthcare system $50 billion (4). These statistics show how important it is to use preventive measures, especially in older populations where changes in demographics amplify the problem. By 2050, the global population aged 60 and older is projected to reach 2.1 billion, necessitating scalable, effective interventions to mitigate fall risks. Elderly populations health concerns are quite complex as it is multifactorial namely medical, psychological and social problems. Falls are also termed as one of the "geriatric giants" as they are one of the major problems in the elderly leading to a significant proportion of morbidity (5).

Balance impairment is a primary modifiable risk factor for falls among the elderly. Age-related changes such as sarcopenia (loss of muscle mass and strength), diminished proprioception, visual decline and vestibular dysfunction undermine the postural stability (6). The Sensory systems such as visual, vestibular and somatosensory work together to maintain balance, but their break down leads to increased sway and postural instability (7). Studies using clinical instruments like the Berg Balance Scale (BBS) and Timed Up and Go (TUG) test consistently indicate that elderly individuals with BBS scores below 45 or TUG times surpassing 12 seconds are at a 2-4-fold increased risk of falling (8,9). Multifactorial contributors including polypharmacy, environmental hazards and cognitive decline, significantly heighten vulnerability (10). Cognitive factors are especially important; executive dysfunction and attention deficits affects dual-task performance, where individuals struggle to balance while performing cognitive tasks, like walking and talking (11). consequently, interventions addressing both physical and cognitive domains are imperative for comprehensive fall prevention.

Traditional exercises have been the mainstay of fall prevention for a long time, focusing on building strength, flexibility and balance. The Otago exercise program and Tai Chi have been shown to be effective in lowering fall rates by 20 – 35% through progressive resistance and dynamic balance exercises (12,13). A meta-analysis of 108 trials demonstrated that exercise interventions lower fall risk by 23% with maximal efficiency observed from high-dose, challenging balance tasks (13). However, adherence remains a challenge, with dropout rates as high as 40% due to boredom, low motivation and problems with accessibility in community settings (14). Furthermore, traditional exercises frequently neglect cognitive components, thereby constraining their efficacy on dual-task deficits.

Task-specific virtual reality (VR) training emerges as an innovative alternative, leveraging immersive technology to simulate real-world tasks. VR improves neuroplasticity and motor learning by giving multisensory feedback, repetitive practice over and over again and mainly through gamification (15). Task-specific VR targets activities that are important for falling like stair climbing, navigating uneven terrain and getting around obstacles. This helps people make balance adjustments that are specific to the activity and situation. A randomized controlled trial demonstrated that VR training enhanced BBS scores by 8.5 points and decreased TUG times by 2.3 seconds in elderly individuals who had fallen surpassing the conventional therapy (16). Similarly, a systematic review of 21 studies indicated that VR excels in dynamic balance owing to its capacity to modify difficulty in real time and enhance engagement (17). VR also helps with cognitive-motor integration; dual-task VR paradigms improve gait variability under cognitive load, reducing fall risk by 15-25%. Despite promise, evidence on long-term fall reduction is emerging and comparative efficacy against other modalities remains underexplored.

Cognitive Behavioral Therapy (CBT), originally a psychological approach which has been modified for physical rehabilitation to address fear of falling and maladaptive behaviors. FOF, which affects 20-50% of elderly who falls, limits their activities, decondition them and strangely enough makes them fall more often thereby increasing the fall rates (10). CBT restructures detrimental beliefs, enhances self-efficacy and promotes incremental exposure to balance difficulties. An RCT demonstrated that CBT lowered Fear Of Falling by 12 points when measured using FES - I and falls by 30% over 6 months, with sustained effects lasting for 12 months (18). CBT improves results when combined with exercise. A meta-analysis found that combined interventions cut falls by 39% compared to exercise alone (18). The cognitive focus of CBT works well with physical training because it deals with psychological barriers that motor focused therapies often ignore.

Despite individual benefits, no studies have directly compared task-specific VR training, Cognitive Behavioural Therapy and conventional exercises directly for preventing falls and improving balance in the elderly. Existing literature reveals gaps like conventional exercises excel in accessibility with reduced adherence, VR offers immersion but requires technology thereby challenges in accessibility, CBT mitigates FOF but lacks motor specificity. A comparative analysis could identify the most efficient, cost-effective approach informing clinical guidelines.

This pilot study addresses these gaps through a comparative analysis of task-specific VR training, CBT and conventional exercises on falls incidence and balance outcomes in elderly individuals. By employing validated measures like BBS, Fall risk, Single leg stance, Limits of stability across randomized groups, we aim to quantify effects and interactions. Findings could guide personalized rehabilitation, reducing the global fall burden.

METHODOLOGY

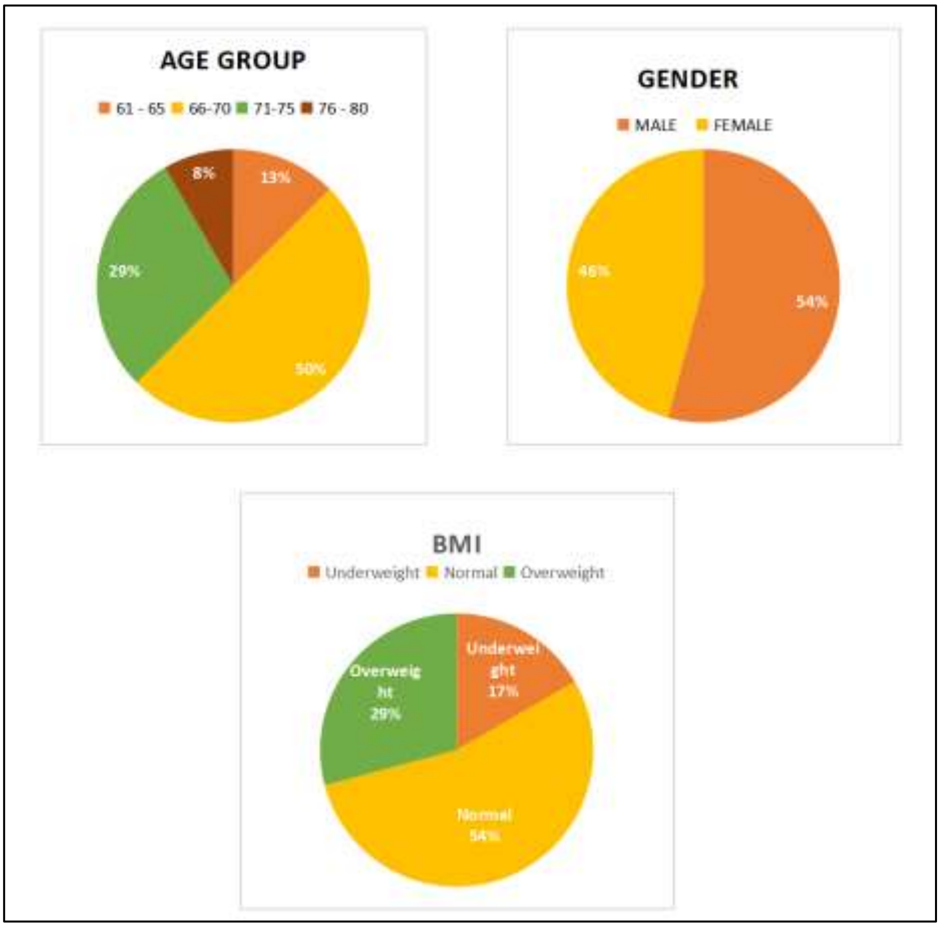
This pilot study was conducted to assess the feasibility of implementing Cognitive Behavioral Therapy and task specific virtual reality training in elderly with balance compromise. A total of 24 participants were selected using simple random sampling from Sri Lalithambigai Medical College and Hospital, ACS Medical College and Hospital outpatient departments, and surrounding communities. Both male and female participants aged 65–80 years were included. Screening was done using standardized tools such as the Mini-Mental State Examination (MMSE), Falls Efficacy Scale (FES). Subjects who were able to walk for 10 minutes without assistance, those who were able to follow a 2 step command, tolerate brief screen exposure were included in the study. Participants with impaired vision or hearing, inability to stand independently for at least 60 seconds, mental instability, or non-cooperation were excluded. Individuals with acute severe pain, neurological conditions, vestibular disorders, cardiovascular or respiratory diseases, and significant dizziness were also excluded.

Prior to the intervention, all participants underwent a basic history taking and physical examination. The study procedure was explained, and informed consent was obtained. Participants were then randomly allocated into three small groups consisting of 8 subjects in each group. Group A received cognitive behavioral therapy described by Zijlstra et al. (2009), Group B received task specific virtual reality training described by Duque et al. (2013) and Phu et al. (2019) and group c received Conventional physiotherapy described by Halvarsson, Franzén, and Ståhle (2015). Each group received the respective intervention for a period of 12 weeks to assess feasibility, participant response and clarity of the protocol.

The outcome measures selected for this pilot study included the Berg Balance Scale (BBS) to assess functional balance, Balance Assessor for evaluating fall risk and stability. All assessments were carried out at baseline, 6th week and post-intervention to evaluate feasibility, participant response, and clarity of the assessment procedures. The collected data were tabulated and analyzed using descriptive statistics, and preliminary inferential analysis was performed using Analysis of Variance (ANOVA) to identify trends between groups. The findings of this pilot study were used to refine the outcome measures and assessment timeline for the main study.

RESULT

Twenty four participants in total were included with eight in each group. During the baseline the groups showed no significant differences in the outcome measures showing they were comparable before the intervention.



For Berg Balance Scale (BBS), the between-group comparison was not significant at pretest, F (2,21) = 0.015, p = 0.985. Significant group differences were observed at 6 weeks, F (2,21) = 4.662, p = 0.021 and at 12 weeks, F (2,21) = 5.160, p = 0.015. Post hoc analysis using Tukey HSD indicated that Group B achieved significantly higher BBS scores than Group C at both follow-up assessments.

For Fall risk assessment using balance assessor (BA FALL), no significant group differences were found at pretest, F (2,21) = 2.247, p = 0.131, or at 6 weeks, F (2,21) = 0.074, p = 0.929. A significant difference emerged at 12 weeks, F (2,21) = 7.236, p = 0.004. Tukey HSD post hoc testing showed that Group C differed significantly from both Group A and Group B at 12 weeks.

For Single leg stance (SLS), no significant between-group differences were observed at pretest or 6 weeks. At 12 weeks, the groups differed significantly, F (2,21) = 5.186, p = 0.015. Post hoc comparisons showed a significant difference between Group B and Group C.

For the Limits of Stability (LOS) measure, no significant between-group differences were found at pretest or 6 weeks. At 12 weeks, there was a significant group effect, F (2,21) = 10.913, p = 0.001. Post hoc analysis showed that Group C differed significantly from Group A and Group B, while the difference between Group A and Group B was not statistically significant.

Overall, the findings indicate that the groups were similar at baseline, but differences became more evident over time, particularly at 12 weeks for BA Fall, SLS, and LOS, and at both 6 and 12 weeks for BBS.

Table 1 - ANOVA

Measure	**Timepoint**	**SS Between**	**df**	**MS**	**F**	**p**
BBS	Pre	0.333	2	0.167	0.015	.985
BBS	Post 6	166.333	2	83.167	4.662	.021
BBS	Post 12	170.333	2	85.167	5.160	.015
BA Fall	Pre	50.583	2	25.292	2.247	.131
BA Fall	Post 6	2.250	2	1.125	0.074	.929
BA Fall	Post 12	112.583	2	56.292	7.236	.004
SLS	Pre	241.000	2	120.500	1.723	.203
SLS	Post 6	416.583	2	208.292	1.742	.199
SLS	Post 12	540.750	2	270.375	5.186	.015
LOS	Pre	3003.583	2	1501.792	1.252	.306
LOS	Post 6	1045.333	2	522.667	0.539	.591
LOS	Post 12	11633.083	2	5816.542	10.913	.001

This table presents the between-group analysis of variance for each outcome measure at pretest, 6 weeks, and 12 weeks. It reports the sum of squares, degrees of freedom, mean square, F value, and significance level used to determine whether the groups differed statistically. Significant p values indicate that at least one group mean differed from the others for that outcome and time point

Table 2 - TURKEY HSD COMPARISON

Measure	**Timepoint**	**Comparison**	**Mean Diff.**	**p value**	**Result**
BBS	Post 6	GB vs GC	6.250	.020	Significant
BBS	Post 12	GB vs GC	6.500	.011	Significant
BA Fall	Post 12	GA vs GC	-3.750	.035	Significant
BA Fall	Post 12	GB vs GC	-5.125	.004	Significant

Measure	Timepoint	Comparison	Mean Diff.	p value	Result
SLS	Post 12	GB vs GC	-11.625	.011	Significant
LOS	Post 12	GA vs GC	32.625	.026	Significant
LOS	Post 12	GB vs GC	53.500	<.001	Significant

This table presents the significant Tukey HSD pairwise comparisons for BBS, BA Fall, SLS, and LOS across the follow-up time points. It shows the group comparisons, mean differences, adjusted p values, and statistical significance, indicating that most significant differences were observed at 12 weeks, with BBS also showing significant differences at 6 weeks

DISCUSSION

The Objective of this pilot study was to compare the effects of Task specific virtual reality (VR) training, cognitive behavioral therapy (CBT) and conventional exercises on balance and fall risk in elderly. Results showed that Taks specific VR training significantly improved the balance performance and reduced the fall rates more than CBT and traditional exercise interventions. The results suggest that immersive and task-oriented VR interventions have the potential to enhance motor control, confidence and physical function in geriatric rehabilitation.

The Significant difference observed in the VR group can be explained by the immersive and interactive nature of the VR training that provides real time feedback and stimulates real world environments that challenge postural control and motor coordination. In contrast to the conventional training, VR training is acting on a multimodal sensory system, including visual, vestibular and proprioceptive inputs and allowing neural plasticity and motor learning. The specific design of the VR exercises for the specific tasks likely allowed certain improvements in balance skills, which is ideal for reducing falls. Sustaining patient engagement remains one of the most pressing challenges in geriatric rehabilitation. This is in accordance with emerging evidence that highlights the potential of VR interventions to enhance functional mobility and confidence in elderly users, leading to increased adherence and motivation during rehabilitation19,20.

In line with prior research, this study contributes to the growing body of evidence that VR interventions are superior to the conventional approaches in enhancing balance metrics such as the Berg Balance Scale (BBS) and Timed Up and Go (TUG) test. For Example, a randomized control trial by Kim et al. (2020)19 inferred that elderly subjects who performed VR based balance exercises had significantly greater improvement in dynamic postural control than those who performed a standard balance program. Similarly, Cho and Lee (2021)21 concluded that VR training was more effective than traditional rehabilitation methods to reduce fear of falling and to improve the gait parameters. In recent years, VR technologies have been increasingly adopted across medical fields including rehabilitation due to their ability to simulate controlled therapeutic environments and provide multisensory feedback to users

The moderate improvements Observed in the CBT group suggest that addressing psychological factors such as fear of falling and anxiety may be an important component in reducing fall risk. CBT may improve balance indirectly by increasing confidence, decreasing activity avoidance and promoting safer movement patterns22. However, the effect on balance parameters might be less significant than VR that involves physical practice23. CBT Mainly addresses the cognitive and emotional aspects rather than direct physical training. Several studies revealed the effectiveness of CBT in reducing depressive and anxiety symptoms, which can be indirect support to fall prevention efforts24. CBT remains a useful adjunctive strategy, However, as fear of falling and depressive symptoms often contribute to decreased physical activity and increased fall risk. Thus, Integrating CBT Principles into VR environments could theoretically enhance adherence and outcomes25.

The conventional exercise group showed least improvement but still had some potential benefits. This reflects the recognized role of physical activity in maintaining musculoskeletal strength and balance26. However, Traditional exercises may lack the focus or engagement necessary to induce significant neuroplastic changes or behavioral adaptations among elderly, especially those at higher risk of falls27. The lower effectiveness of conventional exercises in this pilot study may also relate to factors such as reduced motivation, limited feedback, less variety in tasks compared to immersive task specific VR28.

However, Successful integration of VR technology in clinical settings requires attention to user's comfort with technology, cost factors and safety. Some older adults may initially struggle with VR devices due to motion sickness or being unfamiliar with the technology. Therefore, Supervised sessions and gradual acclimatization protocols are recommended to ensure optimal benefit and compliance29,30.

As a pilot study, these results provide preliminary evidence supporting the feasibility, applicability and efficacy of VR based interventions in fall preventions among the elderly. Several limitations must be acknowledged. The pilot nature of the study and the relatively small sample size may limit the generalizability of the findings. The short duration of the intervention may not capture the long-term adherence and sustained effects on fall prevention. Moreover, potential confounding factors such as baseline physical activity levels, cognitive status and comorbidities were not extensively controlled, which could influence responsiveness to the different interventions. Future research should incorporate randomized controlled designs with stratification to address these variables.

Further research should explore the multimodal interventions integrating VR and CBT, Possibly with tele-rehabilitation frameworks. Studies incorporating neuroimaging and kinematic analyses can clarify the neurophysiological mechanisms underlying VR-mediated motor recovery. Additionally, cost-effectiveness analyses and longitudinal designs assessing fall incidence over extended periods would offer critical policy insights.

CONCLUSION

In conclusion, the results of this pilot study indicate that task specific virtual reality training is more effective than cognitive behavioural therapy and traditional exercise programs in improving balance and resucing falls in the elderly. The augmented sensory feedback, task relevance and motivational component of VR seem to promote better neural and functional adaptations. While CBT and conventional exercises maintain important roles, especially for tackling psychological barriers and general fitness, VR on the other hand is a revolutionary tool in geriatric rehabilitation, offering safety, engagement and measurable results. The addition of VR to fall prevention interventions is promising for future healthcare models that focus on accessible, technology assisted ageing support. 3

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