DOI: 10.7860/JCDR/2026/85067.22818

Original Article

Physiotherapy Section

Improving Gait Speed, Functional Mobility and Fall-related Confidence in Older Adults: A Quasi-experimental Comparison of Physiotherapy-based Training and Virtual Reality-based Training

NEHA CHAUHAN[1], BHUVNESH KUMAR[2], PRITI SUROSHE[3], HIMANSHU DEVKI NANDAN SHARMA[4], SHANTANU SHARMA[5]

ABSTRACT

Introduction: Ageing is associated with a progressive decline in gait speed, functional mobility, and increased concern about falling, which collectively compromise independence and quality of life in older adults. Conventional physiotherapy has been shown to improve mobility but may be limited in addressing dynamic, task-specific gait challenges. Virtual Reality (VR) based training offers an immersive and engaging approach that may enhance functional outcomes beyond traditional therapy.

Aim: To compare the effects of physiotherapy-based training and VR-based training on functional mobility, gait speed and fall-related confidence in older adults.

Materials and Methods: A single, quasi-experimental, pre–post-test study with two non randomised parallel groups was conducted at the Department of Physiotherapy, Sharda Hospital, Sharda University, Greater Noida, Uttar Pradesh, India, from January 2025 to March 2025. One hundred community-dwelling older adults (60–85 years) were allocated to a physiotherapy comparison group (n=50) or VR intervention group (n=50). Outcomes included the Timed Up and Go test (TUG), Four-Metre Walk Test (4MWT) and Falls Efficacy Scale-International (FES-I). Within-group changes were analysed using paired t-tests, while between-group differences in change scores were examined using an Independent sample t-tests.

Results: Both groups showed significant pre-post improvements across all outcomes (p-value <0.001). However, the VR group demonstrated significantly greater improvement than physiotherapy for TUG (Δ=5.48±1.13 vs 1.46±1.13 s; t=-17.80, (p-value <0.001), 4MWT (t=-2.58, (p-value=0.011), and FES-I (Δ=21.60±7.60 vs 13.34±4.85; t=-6.48, (p-value <0.001). Effect sizes were large for TUG and FES-I.

Conclusion: VR-based training produced superior improvements in functional mobility, gait speed, and fall-related confidence compared with physiotherapy supporting its role as an effective rehabilitation approach for older adults.

Keywords: Ageing, Conventional physiotherapy, Fall risk

INTRODUCTION

The world's population is ageing at an accelerated rate. It is estimated that by 2050, adults aged over 60 years will have a population more than 2.1 billion worldwide, putting major strains on healthcare systems to maintain mobility, prevent falls and ensure independence of function. Among the age-related functional impairments, deterioration in gait and mobility is one of the most prevalent and clinically significant concerns [1], given the direct influence on autonomy, the risk of falls, Institutionalisation and mortality [2,3].

Gait is a complicated motor function which requires the interaction between the muscles, the skeleton, sensory input, postural control mechanisms and motor planning [4]. Age-related changes, such as muscular weakness, reduced joint motion, impaired proprioception, vestibular decline and loss of neuromotor compensation, are arguably associated with a decrease in gait velocity, loss of postural balance and are associated with difficulty in the performance of transitional tasks such as turning and sit-to-stand movements [2,5]. The changes significantly increase the risk of falls, which continue to be a predominant contributor of injury-related morbidity and consequent functional deterioration in the elderly population [6,7].

Gait speed has developed into a strong marker of overall functional health in older people and has even been described as the "sixth vital sign", due to its strong correlation with disability, hospitalisation and mortality. Functional mobility testing with gait, turning and postural transitions, represented by, for example, the TUG test, provides clinically relevant estimates of impairment of mobility and risk of falling [8,9]. Beyond measurable deficits in mobility, the perceived fear of falling affects the sheer participation in activities and deviations in gait patterns are strong, all of which contribute to the increased risk of falling and heightened constraints in functioning [10].

Conventional physiotherapy plays a central role in improving the muscular strength, the stability of the postures and the ambulatory functional capacities of seniors [11]. Nevertheless, conventional methodologies may be limited in their ability to imitate dynamic real-world locomotor environments and complex gait challenges, particularly those that include aspects of flow of sensations, negotiation of obstacles, and rapid postural changes [12,13]. These limitations have led to interest by academic researchers in other or complementary training methods that more closely replicate the needs of functional mobility.

The VR-based training provides immersive, interactive training environments that include real-world gait challenges [14]. VR-based gait tasks require continuous weight shifting, directional movement, speed modulation and postural control [13,14]. By engaging multiple sensory systems, VR training may enhance the adaptability in functional mobility tasks [14].

Prior empirical investigations have demonstrated that VR-based interventions can improve gait parameters, balance performance and functional mobility among older adults and clinical populations [14]. Preliminary investigations reported on the favourable effects of VR on gait biomechanics and dynamic balance [14]. Subsequent evidence has shown improved gait velocity and mobility results after VR or exergaming-based training [15,16]. A recent systematic review and meta-analyses support the use of immersive VR training as a modality to induce statistically significant improvements in gait, balance and general mobility in older adult populations and communities [17].

The evaluation of VR-based gait interventions requires the application of standardised and clinically demonstrated assessment tools. Measures such as the 4MWT and the TUG test are widely suggested for the assessment of gait speed, functional mobility and risk of falls in older populations because of their reliability, sensitivity to change and clinical relevance [9,18,19]. The FES-International supplements these objective measures by quantifying an individual's perception of apprehension in performing mobility-related activities, which are recognised as an important determinant of both the risk of falling and mobility behaviours [7,10].

Despite increasing evidence supporting VR-based gait training, direct comparisons between VR-based interventions and conventional physiotherapy using standardised gait and fall-risk measures remain limited [20,21]. Variability in intervention protocols and outcome selection further constrains the interpretation of existing findings. Therefore, there is a need for structured comparative studies that specifically examine whether VR-based training provides superior improvements in gait speed, functional mobility, and fall-related outcomes when compared with traditional physiotherapy approaches.

To compare the effects of physiotherapy-based training and VR-based training on gait speed, functional mobility, and fall-related confidence in older adults, and to evaluate within-group pre-post changes and between-group differences following intervention. The objectives of the study were to examine the pre-post effects of physiotherapy-based training and VR-based training,

to compare the magnitude of improvement between the VR intervention group and the physiotherapy-based comparison group and to determine the strength of association between pre- and post-intervention scores within the physiotherapy and VR groups.

Hypotheses :

- **H1:** There may be a significant pre–post improvement within each group.
- **H2:** The VR group may show greater improvement than physiotherapy (between-group comparison)
- **H3:** There may be a significant pre-post correlation within groups.

MATERIALS AND METHODS

The study was conducted in the Department of Physiotherapy, Sharda Hospital, Sharda University, Uttar Pradesh, India. Data collection took place over three months from January to March 2025. Ethical approval was obtained from the Institutional Ethics Committee of Sharda University (Approval No.: SU/SMS&R/76-A/2025/258). All participants were given detailed information about the aims and procedural protocols of the study and gave written informed consent to participate in the research activities.

The present investigation employed a quasi-experimental pre-post-test design with two non randomised parallel groups. One group received conventional physiotherapy and served as a physiotherapy-based comparison group, while the second group received VR-based training as the intervention group. Random allocation was not undertaken due to clinical and logistical constraints; therefore, the physiotherapy group functioned as a non randomised comparison group rather than a true experimental comparison group. This design was selected to allow evaluation of intervention-related changes while maintaining feasibility in a clinical setting. The investigation followed established ethical guidelines set for research that involved human subjects.

Sampling: A total of 100 community-dwelling older adults aged 60-85 years were recruited using purposive sampling among the persons attending the physiotherapy outpatient department. Participants were assigned to either the physiotherapy-based comparison group (n=50) or an intervention group in the VR-based platform (n=50) using the method of non random assignment based on participant availability and feasibility.

The sample size was based on feasibility issues and was consistent with previous quasi-experimental studies [22-24],that investigated gait speed, functional mobility and fall-related outcomes in older people. Previous studies [25,26] using outcome measures such as the TUG test and short-distance gait speed assessments have commonly included 30-60 participants per group [27], which were sufficient to detect clinically meaningful changes in mobility. Accordingly, a total sample of 100 participants (50 per group) was considered adequate to permit reliable within-group and between-group comparisons.

Inclusion criteria:

- Ability to ambulate independently without assistive devices;
- Ability to understand and follow verbal instructions;
- No documented cognitive impairment;
- No major visual or auditory deficits affecting test performance.

Exclusion criteria:

- Diagnosed neurological disorders (e.g., Parkinson's disease, stroke within the past six months);
- Acute musculoskeletal injuries;
- Severe cardiopulmonary conditions limiting mobility;
- Routine use of assistive devices for ambulation.

Study Procedure

All outcome measures were selected based on their clinical relevance, validity, and widespread use in geriatric mobility and fall-risk assessment.

Timed Up and Go Test (TUG)

Functional mobility and dynamic balance were assessed using the TUG test. Participants rose from a standard-height chair, walked three metres, turned, returned to the chair, and sat down. Timing commenced on the verbal command "go" and ended when the participant was fully seated. Two trials were performed, and the mean value was used for analysis. In line with the threshold proposed by Shumway-Cook A et al., (2000), a TUG time >13.5 s was interpreted as indicating an increased risk of falls [28].

Four-Metre Walk Test (4MWT)

Gait speed was measured using the standard 4MWT Test, following established short-distance gait assessment protocols originally described in geriatric mobility research. Participants walked along a straight four-metre path at their usual pace. Timing began when the leading foot crossed the start line and ended when the leading foot crossed the finish line. Two trials were conducted, and the mean gait speed was calculated in metres per second (m/s). Short-distance gait speed testing has demonstrated strong validity and reliability and is a recognised indicator of functional mobility and fall risk in older populations [3].

Falls Efficacy Scale-International (FES-I)

Fall-related confidence during mobility-related activities was assessed using the 16-item Falls Efficacy Scale–International

(FES-I). Total scores range from 16 to 64, with higher scores indicating greater concern about falling. In the present study, the FES-I was utilised as a fall risk–related functional outcome measure, rather than as a general psychological assessment [10].

Intervention Protocol

Physiotherapy-based comparison group: Participants in the physiotherapy-based comparison group received conventional physiotherapy interventions aimed at improving lower-limb strength, balance, and functional mobility. The programme included strengthening exercises, balance training, and gait practice consistent with routine clinical protocols used in geriatric rehabilitation.

Virtual Reality (VR)- Based Intervention Group

Participants in the VR- based intervention cohort were trained specifically to improve gait- related and mobility - specific tasks. The activities VR-furnished (Meta Quest 2 standalone VR headset (Meta Platforms, Inc., Menlo Park, California, USA) included weight shifting, directional walking, obstacle negotiation, and postural comparison exercises all requiring constant motor adaptation of individuals while being aided by real-time visual feedback [29].

Virtual Reality (VR) Engagement Assessment

Engagement with VR was assessed descriptively using a study-specific self-report questionnaire and using device usage logs. The questionnaire involved five statements where the frequency, duration and nature of VR activity were recorded and was developed by the investigators based on engagement dimensions that are commonly reported in immersive health application research. The instrument was only used for descriptive classification of engagement type (low, moderate, high) and was not exposed to formal testing for validity and reliability. Engagement type was defined a priori based on intervention adherence (session attendance). Participants who attended ≤33% of scheduled sessions were classified as low engagement, those attending 34-66% as moderate engagement, and those attending ≥67% as high engagement. Accordingly, the VR engagement questionnaire was not used for inferential purposes and thus was not exposed to psychometric validations.

Study Procedure

Participants were requested to come to a single and approximately 30-35 minutes data collection session. Upon arrival at the research centre, individuals were briefed on the objectives and procedures of the investigation and informed consent was obtained prior to the commencement of data acquisition. The session began by having the respondents complete standardised demographic questionnaires, which included age, sex, medical history, and history of falls.

Afterwards, participants were asked to complete three functional assessments: the 4MWT, the TUG test and the FES-I. All assessments were conducted under a relatively quiet, temperature-controlled setting, in order to gain that methodological consistency and minimise extraneous environmental confounders. A licensed physiotherapist did the evaluations to help maintain the protocol's fidelity and to improve inter-rater reliability [8,30]. Both groups received supervised interventions for four weeks (three sessions per week, 30 minutes per session), delivered by licensed physiotherapists, and post-test assessments were conducted within 48-72 hours after the final session. All physical tests were administered using standardised verbal instructions and demonstrations. Participants were allowed to rest intervals between assessments to prevent fatigue-related bias. Safety measures, including the availability of gait belts, standby assistance, and the use of participants' habitual mobility aids, were implemented throughout all procedures [31]. All testing adhered to international recommendations for physical performance assessments in older adults and followed ethical standards for safety, comfort, and procedural integrity [6].

STATISTICAL ANALYSIS

Data were analysed using IBM Statistical Package for Social Sciences (SPSS) version 27.0. Descriptive statistics, including means and standard deviations, were calculated to summarise demographic characteristics and outcome measures. Before conducting inferential analyses, the assumptions of normality were assessed for all primary variables and computed change scores (ΔTUG, Δ4MWT, and ΔFES-I) using the Shapiro-Wilk test. The Shapiro-Wilk test showed statistically significant deviations from normality for several variables, especially ΔTUG and Δ4MWT (p-value <0.05). However, skewness and kurtosis values for these measures remained within acceptable ranges, and graphical inspection indicated approximately symmetric distributions without extreme outliers.

Given the equal group sizes (n=50 per group) and the robustness of parametric tests to moderate violations of normality, parametric statistical methods were deemed appropriate. Paired-sample t-tests were used to examine within-group pre-to post-intervention changes in TUG, 4MWT, and FES-I scores for both physiotherapy and VR groups. Independent-sample t-tests were conducted to evaluate between-group differences, including comparisons of improvement scores. Pearson's correlation coefficients assessed associations between pre- and post-intervention measures. All tests were two-tailed, with statistical significance at p-value <0.05.

RESULTS

The physiotherapy and VR groups were presented in [Table/Fig-1]. Both groups were equally distributed by gender, with 25 males and 25 females each. The mean age was comparable between the physiotherapy group (73.04±5.97 years) and the VR group (71.44±5.56 years), with no statistically significant difference (t=1.43, p-value=0.156). Mean height (p-value=0.71) and weight (p-value=0.98) were also similar across groups, indicating baseline homogeneity. These findings suggest that the two groups were demographically well matched prior to intervention.

Variables	Physiotherapy group	VR group
Gender (n=25)	1:1	1:1
Age (in years) (n=50)	73.04±5.969	71.44±5.56285
Height (cm) (n=50)	Mean162.03±8.86889	162.62±9.33042
Weight (kg) (n=50)	63.40±5.70356	63.38±6.93965

[Table/Fig-1]: Demographic characteristics of participants.

Engagement level within the VR intervention group was categorised into low, moderate, and high engagement types. Among participants in the VR group, 17 (17.0%) were classified as low engagement, 24 (24.0%) as moderate engagement, and 9 (9.0%) as high engagement [Table/Fig-2].

Classification	n (%)
Low	17 (34.0%)
Moderate	24 (48.0%)
High	9 (18.0%)
Total	50 (100.0%)

[Table/Fig-2]: VR engagement classification.

Gender-based analyses showed no significant differences in outcomes (p-value >0.05), indicating similar intervention responses among male and female participants [Table/Fig-3].

Significant within-group improvements in functional mobility, gait speed, and fall-related confidence following both physiotherapy and VR-based training were demonstrated in [Table/Fig-4]. However, the magnitude of improvement was consistently greater in the VR group across all outcome measures, indicating superior functional gains compared with physiotherapy.

Comparison		Physiotherapy group: Before training	Physiotherapy group: After training	VR group: Before training	VR group: After training
		Mean±SD	Mean±SD	Mean±SD	Mean±SD
Timed Up and Go test (sec) (TUG)	Male	18.56±6.35	17.20±6.57	15.48±3.41	10.12±3.60
	Female	18.24±6.62	16.68±6.68	16.24±2.91	10.64±2.89
	t	0.174	0.277	-.845	-0.562
	Sig	0.862	0.783	.402	0.577
4-Meter Walk Test(m/s)	Male	0.40±0.24	0.73±0.30	0.48±0.22	0.76±0.23
	Female	0.46±0.24	0.82±0.25	0.44±0.25	0.74±0.27
	t	-0.986	-1.102	0.586	0.385
	Sig	0.329	0.276	0.561	0.702
Falls Efficacy Scale - International (FES-I)	Male	43.88±3.68	31.44±4.06	50.52±5.93	28.64±5.31
	Female	45.04±3.83	30.80±4.19	50.76±5.56	29.44±5.69
	t	-1.09	0.548	-0.148	-0.518
	Sig	0.281	0.586	0.883	0.610

[Table/Fig-3]: Pre and post-training comparison.

Groups		Mean±SD	t	p-value
Comparison group	Timed Up and Go test (Sec) (TUG) (Pre)	18.4000±6.42698	9.147	<0.001
	Timed Up and Go test (Sec) (TUG) (Post)	16.9400±6.56649		
	4-Meter Walk Test (M/S)-Pre	0.4340±0.24379	-21.677	<0.001
	4-Meter Walk Test (M/S)-Post	0.7800±0.28284		
	Falls Efficacy Scale - International (FES-I)-Pre	44.4600±3.76997	19.461	<0.001
	Falls Efficacy Scale - International (FES-I)-Post	31.1200±4.09898		
Experimental	Timed Up and Go test (Sec) (TUG)(Pre)	15.8600±3.16879	34.316	<0.001
	Timed Up and Go test (Sec) (TUG)(Post)	10.3800±3.25068		
	4-Meter Walk Test(M/S)-Pre	0.4600±0.23990	-23.982	<0.001
	4-Meter Walk Test(M/S)-Post	0.7540±0.25492		
	Falls Efficacy Scale -International (FES-I)-Pre	50.6400±5.69196	20.098	<0.001
	Falls Efficacy Scale - International (FES-I)-Post	29.0400±5.46589		

[Table/Fig-4]: Paired comparison of pre and post-training functional performance in comparison physiotherapy and VR groups (n=50).

The VR group achieved significantly greater improvements than the physiotherapy group in functional mobility and fall-related confidence, with large effect sizes, while gait speed gains were comparable between groups, are shown in [Table/Fig-5]. Overall, VR-based intervention demonstrated superior efficacy for mobility and fear-of-falling outcomes.

Outcomes	Physiotherapy group (Mean±SD)	VR group (Mean±SD)	t	p	Effect Size (Cohen's d)
ΔTUG (s)	1.46±1.13	5.48±1.13	–17.80	<0.001	3.56
Δ4MWT (m/s)	0.35±0.11	0.29±0.09	–2.58	0.011	0.52
ΔFES-I	13.34±4.85	21.60±7.60	–6.48	<0.001	1.30

[Table/Fig-5]: Independent samples t-test comparing change scores between the intervention groups.

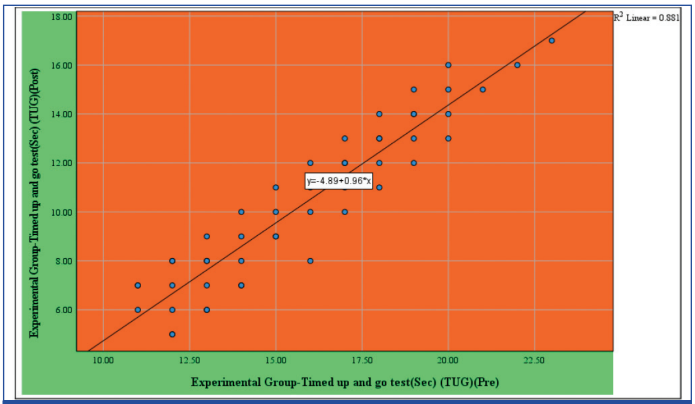
The physiotherapy group showed strong and statistically significant pre–post correlations for mobility and gait performance [Table/Fig-6]. Similarly, in the VR group, TUG scores display a high correlation pre and post (r=0.938, (p-value <0.001), indicating consistent improvement among participants. Similarly, 4MWT scores show a strong pre-post correlation (r=0.940, (p-value <0.001), reflecting stable gains in walking speed. However, FES scores demonstrate a very weak and non-significant correlation (r=0.073, (p-value=0.616), suggesting varied individual responses in fear-of-falling reduction within the VR group [Table/Fig-7-9].

Between	Pearson's correlation	Sig. (2-tailed)
A and B	0.985**	<0.001
C and D	0.919**	<0.001
E and F	0.289	0.089

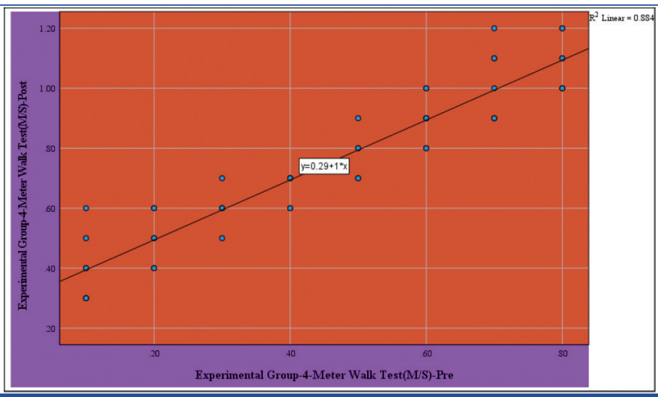
[Table/Fig-6]: Pearson's correlation between pre- and post-training measures in the physiotherapy group.
**. Correlation is significant at the 0.01 level (2-tailed); A:Timed Up and Go test(Sec)(TUG)(Pre); B:Timed Up and Go test(Sec) (TUG)(Post); C:4-Meter Walk Test(M/S)(Pre); D:4-Meter Walk Test(M/S)(Post); E:FES(Pre); F:FES(Post).

Between	Pearson's correlation	Sig. (2-tailed)
A & B	0.938**	<0.001
C & D	0.940**	<0.001
E & F	0.073	0.616

[Table/Fig-7]: Pearson's correlation between pre- and post-training measures in the experimental (VR) group.
**. Correlation is significant at the 0.01 level (2-tailed); A:Timed Up and Go test(Sec)(TUG)(Pre); B: Timed Up and Go test(Sec) (TUG)(Post); C: 4-Meter Walk Test(M/S)(Pre); D: 4-Meter Walk Test(M/S)(Post); E: FES(Pre); F:FES(Post).



[Table/Fig-8]: Scatter plot showing the relationship between pre- and post-intervention Timed Up and Go (TUG) performance in the experimental (VR) group.



[Table/Fig-9]: Scatter plot showing the relationship between pre- and post-intervention 4-Metre Walk Test (4MWT) gait speed in the experimental (VR) group.
The strong linear trend reflects stability in individual gait performance rankings across the intervention period.

DISCUSSION

The present study demonstrated that both physiotherapy-based training and VR–based intervention significantly improved functional mobility, gait speed, and fall-related confidence in older adults; however, the magnitude of improvement was consistently greater in the VR group. The strong pre–post correlations observed for TUG and 4MWT in both groups indicate consistency in individual mobility performance improvements. In contrast, the weak and non significant correlation for FES-I in the VR group suggests greater inter-individual variability in fall-related confidence, possibly influenced by psychological and experiential factors beyond physical performance alone.These findings were broadly consistent with previous systematic reviews and meta-analyses reporting superior or comparable benefits of VR-based rehabilitation compared with conventional exercise in older adults [12,17,32-34].

The greater reduction in TUG time observed in the VR group aligns with randomised and quasi-experimental studies showing that task-oriented and visually enriched VR gait training enhances dynamic mobility and turning performance more effectively than traditional physiotherapy alone [14,24,35]. Similarly, the significant improvement in 4MWT gait speed is consistent with earlier evidence that VR-based interventions are effective in improving short-distance walking speed, a clinically meaningful marker of functional independence and survival in older adults [3,15,17].

The larger reduction in FES-I scores in the VR group is consistent with studies reporting enhanced confidence during mobility-related tasks following immersive and feedback-driven training [27,32]. While some meta-analyses report variable effects of VR on fear of falling [17], the present findings suggest that improvements in functional performance may indirectly contribute to reduced fall-related concern.

Despite these benefits, previous literature highlights several challenges associated with VR use among older adults, including unfamiliarity with digital interfaces, initial anxiety, visual strain, cybersickness, and balance apprehension [12,36,37]. Consistent with these reports, the present study required supervised sessions, gradual task progression, and simplified VR tasks to ensure safety and adherence. These observations reinforce recommendations that VR-based gait rehabilitation for older adults should be clinically supervised and carefully individualised to maximise benefit while minimising adverse effects. Overall, the present findings extend existing evidence by demonstrating that VR-based gait training produces superior improvements in clinically validated mobility and fall-risk measures compared with physiotherapy within a structured quasi-experimental framework.

Limitation(s)

The limitations of the present study include its quasi-experimental design and non-randomised group allocation. Additional limitations include recruitment from a single clinical setting and a short intervention duration. The lack of objective biomechanical outcome measures should also be acknowledged. These limitations may have restricted interpretation of gait adaptations following VR training.

Future studies should use randomised controlled trials with larger and more diverse samples to strengthen the methodology. Longitudinal follow-up assessments are recommended to help point out the durability of VR-related improvement in gait and mobility. Moreover, comparative studies examining different intensities of training using VR and task complexity are warranted to optimally define intervention protocols for older adults of different levels of functional capacity.

CONCLUSION(S)

Both physiotherapy-based and VR-based interventions conclusion were effective in improving functional mobility, walking speed, and fall-related parameters in older adults. However, the results presented by VR-based training produced significantly higher gains in all the measured outcomes compared with traditional physiotherapy. These findings support the use of VR-based gait training as a strong and clinically relevant type of modality to augment mobility and reduce fall risk in the elderly population.

REFERENCES

[1] Friedman SM, Munoz B, West SK, Rubin GS, Fried LP. Falls and fear of falling: Which comes first? A longitudinal prediction model suggests strategies for primary and secondary prevention. J Am Geriatr Soc. 2002;50(8):1329-35.

[2] Prince F, Corriveau H, Hébert R, Winter DA. Gait in the elderly. Gait Posture. 1997;5(2):128-35.

[3] Studenski S, Perera S, Patel K. Gait speed and survival in older adults. JAMA. 2011;305(1):50-60.

[4] Li F, Fisher KJ, Harmer P, McAuley E, Wilson NL. Fear of falling in elderly persons: Association with falls, functional ability, and quality of life. J Gerontol B Psychol Sci Soc Sci. 2003;58(5):P283-90.

[5] Rosso AL, Studenski SA, Chen WG, Aizenstein HJ, Alexander NB, Bennett DA, et al. Aging, the central nervous system, and mobility. J Gerontol A Biol Sci Med Sci. 2013;68(11):1379-86.

[6] Muir SW, Berg K, Chesworth B, Klar N, Speechley M. Balance Impairment as a risk factor for falls in community-dwelling older adults who are high functioning: A prospective study. Phys Ther. 2010;90(3):338-47.

[7] Tinetti ME, Richman D, Powell L. Falls efficacy as a measure of fear of falling. J Gerontol Psychol Sci. 1990;45(6):239-43.

[8] Peel NM, Kuys SS, Klein K. Gait speed as a measure in geriatric assessment in clinical settings: A systematic review. J Gerontol A Biol Sci Med Sci. 2013;68(1):39-46.

[9] Podsiadlo D, Richardson S. The timed "Up &; Go": A test of basic functional mobility for frail elderly persons. J Am Geriatr Soc. 1991;39(2):142-48.

[10] Yardley L, Beyer N, Hauer K, Kempen G, Piot-Ziegler C, Todd C. Development and initial validation of the Falls Efficacy Scale-International (FES-I). Age Ageing. 2005;34(6):614-19.

[11] Mo N, Feng JY, Liu HX, Chen XY, Zhang H, Zeng H. Effects of Exergaming on musculoskeletal pain in older adults: Systematic review and meta-analysis. JMIR Serious Games. 2023;11:e42944.

[12] Howard MC. A meta-analysis and systematic literature review of virtual reality rehabilitation programs. Comput Human Behav. 2017;70:317-27.

[13] Maillot P, Perrot A, Hartley A. Effects of interactive physical-activity video-game training on physical and cognitive function in older adults. Psychol Aging. 2012;27(3):589-600.

[14] Mirelman A, Patritti BL, Bonato P, Deutsch JE. Effects of virtual reality training on gait biomechanics of individuals post-stroke. Gait Posture. 2010;31(4):433-37.

[15] Mao Y, Chen P, Li L, Huang D. Virtual reality training improves balance function. Neural Regen Res. 2014;9(17):1628-34.

[16] Park EC, Kim SG, Lee CW. The effects of virtual reality game exercise on balance and gait of the elderly. J Phys Ther Sci. 2015;27(4):1157-59.

[17] Lee J, Phu S, Lord S, Okubo Y. Effects of immersive virtual reality training on balance, gait and mobility in older adults: A systematic review and meta-analysis. Gait Posture. 2024;110:129-37.

[18] Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: Association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol. 1994;49(2):M85-M94.

[19] Roush J, Bay RC. Percentile ranks for walking speed in subjects 70-79 years: A meta-analysis. Int J Allied Heal Sci Pract. 2014;12(1):Article 5.

[20] Del Din S, Galna B, Godfrey A, Bekkers EMJ, Pelosin E, Nieuwhof F, et al. Analysis of free-living gait in older adults with and without Parkinson's disease and with and without a history of falls: Identifying generic and disease-specific characteristics. J Gerontol A Biol Sci Med Sci. 2019;74(4):500-06.

[21] Haber N El, Erbas B, Hill KD, Wark JD. Relationship between age and measures of balance, strength and gait: Linear and non-linear analyses. Clin Sci. 2008;114(12):719-27.

[22] Dierick F, Bouché AF, Guérin S, Steinmetz JP, Federspiel C, Barvaux V, et al. Quasi-experimental pilot study to improve mobility and balance in recurrently falling nursing home residents by voluntary non-targeted side-stepping exercise intervention. BMC Geriatr. 2022;22(1):1006.

[23] Kaewjoho C, Mato L, Thaweewannakij T, Nakmareong S, Phadungkit S, Gaogasigam C, et al. Thai dance exercises benefited functional mobility and fall rates among community-dwelling older individuals. Hong Kong Physiother J. 2020;40(1):19-27. Doi: 10.1142/S1013702520500031. Epub 2019 Dec 16. PMID: 32489237; PMCID: PMC7136526.

[24] Mohamed Zein El-AbdeenMohamed D, Noshy Abd EL-Aziz Mohamed H, Hassan Abd Elhameed S. Effect of a home-based physical rehabilitation program via virtual reality on the functional outcomes of frail older adults: A quasi-experimental study. Sci Rep. 2025;15(1):4180.

[25] Mohammadian Z, Alimoradi M, Ramirez-Campillo R. Effects of shuttle balance exercises on gait speed, postural control, and quality of life in older males: A randomized controlled trial. Physiother Res Int. 2024;29(4):e2135.

[26] Ponti M, Bet P, Oliveira CL, Castro PC. Better than counting seconds: Identifying fallers among healthy elderly using fusion of accelerometer features and dual-task Timed Up and Go. Barkley J, editor. PLoS One. 2017;12(4):e0175559.

[27] Parmak D, Angın E, Iyigun G. Effects of immersive virtual reality on physical function, fall-related outcomes, fatigue, and quality of life in older adults: A randomized controlled trial. Healthcare. 2025;13(15):1800.

[28] Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the timed up & go test. Phys Ther. 2000;80(9):896-903.

[29] Cho GH, Hwangbo G, Shin HS. The effects of virtual reality-based balance training on balance of the elderly. J Phys Ther Sci. 2014;26(4):615-17.

[30] Tyson S, Connell L. The psychometric properties and clinical utility of measures of walking and mobility in neurological conditions: A systematic review. Clin Rehabil. 2009;23(11):1018-33.

[31] van Schooten KS, Pijnappels M, Rispens SM, Elders PJM, Lips P, Daffertshofer A, et al. Daily-life gait quality as predictor of falls in older people: A 1-year prospective cohort study. Glasauer S, editor. PLoS One. 2016;11(7):e0158623.

[32] Azimi Sanavi B, Talebpour M, Saatchian V, Oveysi Sani F, Mirakhori F. Effects of virtual reality-based exercise training on risk of falling, walking capacity, and quality of life in healthy older adults: A systematic review and meta-analysis research. J Appl Gerontol. 2025;7334648251362512.

[33] Rodríguez-Almagro D, Achalandabaso-Ochoa A, Ibáñez-Vera AJ, Góngora-Rodríguez J, Rodríguez-Huguet M. Effectiveness of virtual reality therapy on balance and gait in the elderly: A systematic review. Healthcare (Basel). 2024;12(2):158. Doi: 10.3390/healthcare12020158. PMID: 38255047; PMCID: PMC10815791.
[34] Han Y, Kim S, Park S. Effects of virtual reality intervention on motor function in community-dwelling older adults: A systematic review and meta-analysis. Medicine (Baltimore). 2025;104(30):e43488.
[35] Lee K. Virtual reality gait training to promote balance and gait among older people: A randomized clinical trial. Geriatrics. 2021;6(1):01-11.
[36] Rohor PE., Frizera A, Zimerer C, Franchine ME, Loureiro M, Machado F, et al. Effects of smart walker-assisted gait in real-world vs. virtual reality on heart rate variability and blood pressure in elderly: A randomized cross-over study. J Bodyw Mov Ther. 2025;45:319-31.
[37] Skurla MD, Rahman AT, Salcone S, Mathias L, Shah B, Forester BP, et al. Virtual reality and mental health in older adults: A systematic review. Int Psychogeriatrics. 2022;34(2):143-55.

PARTICULARS OF CONTRIBUTORS:
1. Research Scholar, Department of Physiotherapy, Sharda School of Allied Health Sciences, Greater Noida, Uttar Pradesh, India.
2. Distinguished Professor, Dean of Research, Sharda University, Greater Noida, Uttar Pradesh, India.
3. Associate Professor, Department of Physiotherapy, STA's Nashik College of Physiotherapy, Nashik, Maharashtra, India.
4. Associate Professor, Department of Physiotherapy, Mahalaxmi College of Physiotherapy and Rehabilitation Centre, Satara, Maharashtra, India.
5. Professor, Department of Physiotherapy, NIMS College of Physiotherapy and Occupational Therapy, Jaipur, Rajasthan, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Neha Chauhan,
Research Scholar, Department of Physiotherapy, Sharda School of Allied Health Sciences, Sharda University, Greater Noida-201310, Uttar Pradesh, India.
E-mail: nehachauhanbpt@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Nov 02, 2025
- Manual Googling: Jan 08, 2026
- iThenticate Software: Jan 10, 2026 (3%)

ETYMOLOGY: Author Origin

EMENDATIONS: 8

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Oct 24, 2025**
Date of Peer Review: **Nov 17, 2025**
Date of Acceptance: **Jan 13, 2026**
Date of Publishing: **Apr 01, 2026**