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Effect of Virtual Reality Training Versus Otago Exercises on Balance and Functional Independence in Subjects with Stroke

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ABSTRACT

BACKGROUND AND OBJECTIVE: Balance impairment is one of the most prevalent deficits following a stroke and is a major contributor to activity limitations and reduced functional independence. Virtual Reality (VR) training provides an engaging, task-specific environment and has gained attention for its potential benefits. The objective of the study was to compare the effects of Virtual Reality training and Otago exercise programs on balance and functional independence in individuals with stroke.
METHODS: Quasi-experimental study, where Sixty subjects with a clinical diagnosis of stroke were allocated into two groups using systematic random sampling. Group A (n = 30) received Virtual Reality training along with a standard rehabilitation program, whereas Group B (n = 30) received Otago exercises along with a standard rehabilitation program. Participants underwent intervention three times a week for eight weeks. The Berg Balance Scale and Modified Barthel Index were used to assess the effectiveness of the interventions.
RESULTS: Independent t-test was used to compare the mean differences between groups, and paired t-test was used to assess pre- and post-test differences. Both groups showed significant improvements within groups, whereas between-group comparison revealed that Virtual Reality training along with standard rehabilitation showed greater improvement than Otago exercises with standard rehabilitation.
CONCLUSION: Eight weeks of intervention led to significant post-test improvements in both groups. However, Virtual Reality training with standard rehabilitation was more effective than Otago exercises. This intervention can be incorporated in post-stroke rehabilitation to enhance balance and functional independence.

Keywords: *Post stroke, virtual reality training, Otago exercise program, Berg balance scale, Modified Barthel index*

INTRODUCTION

Stroke is a clinically defined illness that is characterized by an abrupt, focused neurological impairment that is caused by vascular injury (hemorrhage or infarction) to the central nervous system.[1] According to recent data, the global yearly number of stroke victims is estimated to be 77.19 individuals moreover 80% of all stroke cases are ischemic strokes which are the most common form.[2]

The annual crude incidence of stroke is reported to fall between 108 and 172 cases per 100,000 people. Its crude prevalence varies greatly, ranging from 26 to 757 per 100,000 individuals. Furthermore, the case-fatality rate within the first month after a stroke has been noted to be between 18% and 42%.[3] After a stroke, many patients experience falls, which are considered one of the most frequent and serious complications. The risk is highest during the recovery phase, with studies reporting that as low as 7% of patients may fall within the initial week, and event can raise up to 73% within a year after hospital discharge.[4]

Sensory, motor, cognitive, and communication problems are common among people who have experienced a stroke.[5] However, fall frequency is higher in people who have had a stroke which is result from imbalance.[6] Ability of the body to maintain equilibrium is called balance and this is classified into static and dynamic balance. When the body is balancing same position without offering any movement is called static balance where as in dynamic balance, the body regain its previous position after moving the body.[7]

Combined physiological and cognitive distributions can be providing balanced and rapid synergy patterns to body and keep the body in well balanced position. However, the process is complex but the response to stimulus is rapid and accurate in order to prevent fall.[8] Social isolation, fall risk, and physical inactivity is quite common in CVA with balance impairments.[9] With balance impairments in stroke, patients may have restriction in daily living activities which lead to loss of independence and may reduce level of participation in the community.[10]

In order to improve balance, there are several rehabilitation procedures have been published in stroke. Transitioning from a seated to an upright posture, maintaining equilibrium on a single limb, engaging both the affected and unaffected extremities on stools placed at differing elevations, sustaining postural control on compliant or mobile surfaces such as foam platforms or a rocker base, moving laterally as part of mobility training, performing core-stability exercises using a therapy ball, executing forward and sideways reach tasks, holding an upright position with visual input removed, positioning the feet in a heel-to-toe alignment, advancing toward forward progression in the same alignment, shifting the body laterally, alternating limb movements in forward and backward directions, progressing along a straight pathway, carrying out repetitive downward foot taps, and participating in object-handling activities such as tossing and receiving soft balls or beanbags are commonly utilized therapeutic interventions which have been evident in balance improvement.[11] In addition, Tai Chi, Otago exercises hydrotherapy, treadmill practice, perturbation-based balance exercise, and simulation based exercises using virtual reality environment are some other rehabilitation therapies that have been found to improve balance.[12]

Virtual reality is one of the novel and booming therapy in technology-based rehabilitation for stroke patients. Virtual environment mimics human behavior that is provided by machine interface from a computer technology.[13] VR glasses are commonly used machine interface that helps in visualizing desired environment by engaging senses. In VR media, projections and flat screens are another interface which enable the perception of tactile, auditory, and motor information.[14]

VR categorized into 4 types:

- In immersive with the use of VR glasses, glove, helmet there will be no connection with real life world. However, the user will be fully immersed in the virtual environment
- In semi-immersive the person: will be in a closed space that's is surrounded with virtual images which will be provided by screens
- Semi immersive in the second person: without losing contact with reality, the user is projected virtually through a screen. An image capturing system or a digital image of the body or part of it can generate virtual avatars. Along with virtual reality system, some complementary devices can be added.
- In non-immersive training: there will be a screen or monitor that interacts the person with virtual world in 3D format.[15]

Some of the benefits in VR are the capability of increasing motor performance, functional and sequential repetition. task can be modified and varied according to the demand and recovery stage.[16] For stroke patients, virtual reality improves balance, vertical perception and decreases the risk of fall.[17]

In New Zealand, Otago exercise was initially developed and assessed. Strength balance and walking trainings are part of this program which helps to improve functional balance, lower limb strength, the balance of one leg, mobility and walking.[18] This program can improve functional independence which in-turns reduces the fall risk as well as disability progression.[19]

In Otago program, levels and repetitions are present to treat balance and strength issues. Level is indicating difficulty of exercise whereas repetition gives an idea of progression of the exercise. Hip opening activities to strengthen the sides of the pelvis, flexion and extension exercises for the knee, ankle, and toe joints make up strength training. Balance training consists of walking backwards, ambulating in a figure of eight path, heel-toe walking, single leg standing, walking on the heels, walking on the toes, walking backwards, standing up from a sitting position and walking upstairs.[20]

There are numerous studies widely available on comparison of Otago exercises to conventional balance exercises but lacks a comparison of Otago exercises and virtual reality training on improving balance and fall reduction in patients with stroke. Therefore, this study intends to compare the effectiveness of Otago exercises and virtual reality-based interventions to enhance balance and fall reduction in individuals who have had strokes.

MATERIALS & METHODS

This Quasi experimental study was approved by the Ethical committee of GSL Medical College & General Hospital. The study was conducted at Department of physiotherapy, tertiary care teaching hospital affiliated to DR.NTR University during the period of one year. A total 80 subjects were screened in that 60 subjects were recruited to participate in the study and randomized into two groups with 30 subjects in Group-A Virtual reality training along with conventional physiotherapy and 30 subjects in Group B received Otago exercises along with conventional physiotherapy.

Inclusion Criteria: Subjects with stroke ≤ 6 months were included, subjects who had an MMSE score of 24-30, Subjects who were able to communicate, Brunnstrom grading 4 and 5 in paretic lower limb, Subjects who were able to walk with support or without support, who gave consent to participate in the study.

Exclusion Criteria: Subjects who underwent recent surgeries in lower limb, Deep vein thrombosis, Recent fractures in lower limb, any neurological conditions other than stroke, Subjects with cognitive deficits were excluded.

Outcome Measures: Berg Balance Scale [21]: The Berg Balance Scale (BBS) provides a quantitative measure of balance in older adults. This 14-item assessment requires

participants to maintain specific postures and perform movements of varying difficulty. Each task is rated on a scale from 0 to 4 based on the individual's ability to achieve the required balance. A total score can be calculated, with a maximum of 56 points. Scores between 0 and 20 indicate significant balance impairment, while scores ranging from 41 to 56 reflect good balance performance.

Modified Barthel Index [22]**:** The Modified Barthel Index evaluates an individual's ability to perform daily activities independently and assesses their level of mobility. The original 10-item form of the Modified Barthel Index (MBI) consists of 10 common ADL activities. In the Modified Barthel Index (MBI), a five-point system replaced the original two or three- or four-point rating system. <15 - usually represents moderate disability and <10 - usually represents severe disability. The Modified Barthel Index (MBI) can take 20 minutes to complete by direct observation.

INTERVENTION:

The study consisted of 8 weeks of intervention which includes virtual reality training along with conventional physiotherapy (Group A) and Otago exercise program along with conventional physiotherapy (Group B). Before the commencement of treatment, the study was explained individually to the subjects to minimize the learning effect during the course of the study. Baseline measures were taken before the treatment by using Berg balance scale and Modified Barthel index and post-test measures were taken after 8 weeks of intervention by using Berg balance scale and Modified Barthel index.

GROUP A: VIRTUAL REALITY

In this group the Thirty subjects underwent balance training using the Bobo system, which integrates a Bobo balance board with mobile application-based training programs. The BOBO software allowed for the development of individualized rehabilitation exercises, which were based on deficits identified during the initial balance assessment. These exercises were performed while standing on Bobo balance board paired with VR headset to enhance visual-vestibular stimulation. The BOBOVR is a virtual reality headset equipped with a wireless controller for engaging with VR games and applications. The controller is specially designed for use with the BOBOVR Z6 headset and includes a touchpad, trigger button, and multiple other buttons to navigate and control your VR experience. After pairing the controller, we can use it to move through menus and engage with virtual elements in our VR games and experiences. The smartphone allows for scrolling and selecting. Training was conducted in a quiet room with minimal to no distractions. The Bobo balance board was connected via Bluetooth to a smartphone running the Bobo pro app. VR headset was used to enhance sensory integration. Each session lasted approximately 80 minutes and was supervised by a trained physiotherapist.[23]

FIG 1: Smartphone screen showing different selectable game options, along with BOBO Balance board for training

FIG 2: Application of VR At start, during and end of the car and skateboard Game

GROUP B: OTAGO EXERCISE PROGRAM

In this Group B, 30 subjects underwent baseline evaluation, during 8 weeks of treatment the subjects received total 24 sessions, 3 sessions per week for 80 minutes per day.

Group B received Otago exercise program along with conventional physiotherapy. Otago Exercise Program is structured into four progressive levels. Each session began with a warm-up and ended with a cool-down, and participants were also encouraged to walk regularly at a pace and distance that suited their comfort. Exercises were demonstrated prior to starting, and initial performance was documented using the Otago exercise schedule. The warm-up included 30 seconds of chair marching and arm swings, followed by five repetitions of head, neck, back, trunk, and ankle movements, along with an 8-second calf stretch. Participants started with Level 1 exercises and advanced to the next level upon completion of the previous one. Training was adapted to each participant's ability, and all levels were introduced as appropriate. The intervention spanned 8 weeks, with sessions lasting 80 minutes per day and including rest breaks. The cool-down routine involved stretching the calf and the back of the thigh, each held for 8 seconds.

FIG 3: Therapist performing calf stretching of left leg

FIG 4: Subject performing Chair marching, Arm swings, Neck movements, Trunk movements, ankle pumps, Back extension exercises under the supervision of physiotherapist

Balance Retraining Exercises: The balance exercises were structured into four progressive levels: Level A, B, C, and D. [24]

FIG 5: Subject performing Backward walking, walking and turning around, Tandem walking, one leg standing, Heel standing and Toe standing, sit to stand exercises under the supervision of physiotherapist

Statistical Analysis

All statistical analysis was done by using SPSS software version 20.0 and MS excel – 2019.

Descriptive statistical data was presented in the form of mean ± standard deviation and mean differences, percentages were calculated and presented. Intra Group Comparisons: Paired student t test was performed to assess the statistical difference within the groups for Berg Balance Scale for Balance and Modified Barthel Index for Functional Independence from pre- test and post- test values in post stroke.

Inter Group Comparisons: Independent student t test was performed to assess the statistical difference in mean value between the groups for Berg Balance Scale for Balance and Modified Barthel Index for Functional independence. Data was tabulated and graphically represented. For all statistical analysis, $p<0.05$ was considered as statistically significant.

RESULT

A total of 80 subjects were screened for eligibility; 60 subjects were included in the study trial they underwent baseline assessment and the subjects who met the inclusion criteria were randomized into two groups. In this study 30 subjects completed training in group A and 30 subjects completed training in group B. The results showed that there is a statistical significance in two groups.

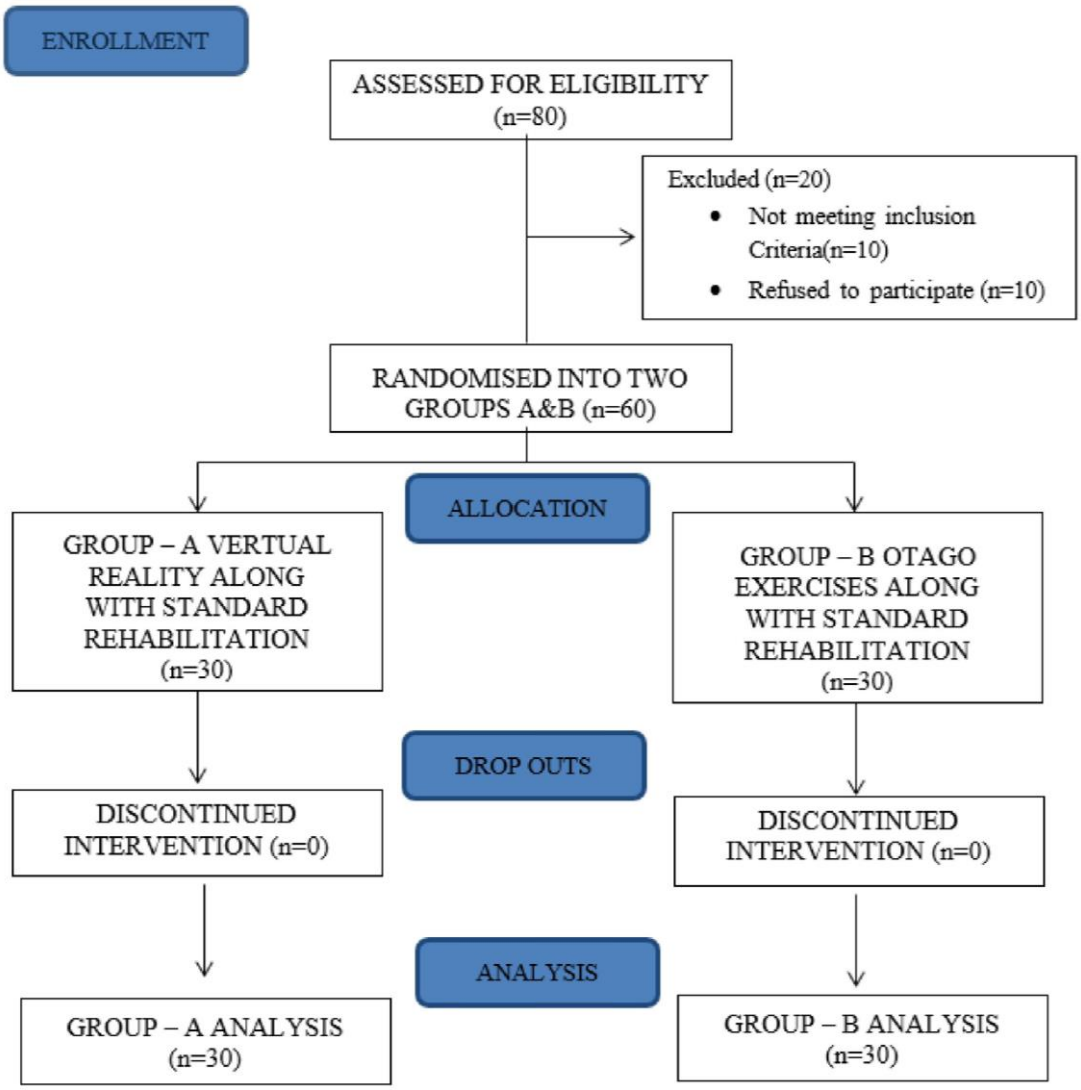

FIG 6: CONSORT FLOW CHART OF STUDY

TABLE 1: COMPARISON OF PRE-TEST MEAN SCORES OF BERG BALANCE SCALE IN BETWEEN THE GROUPS

GROUPS		MEAN	SD	P VALUE	INFERENCE
BBS	GROUP-A	39.92	2.19	0.575	Insignificant
	GROUP-B	40.33	2.38		

The above table-1 shows that the pre-test mean score of berg balance scale between group a and group b were found to be statistically insignificant ($p>0.05$). group-a pre-test had a mean score of 39.92, while group-b pre-test had a mean score of 40.33, indicating an insignificant difference of pre-test values between the groups.

TABLE 2: COMPARISON OF POST-TEST MEAN SCORES OF BERG BALANCE SCALE IN BETWEEN THE GROUPS

GROUPS		MEAN	SD	P VALUE	INFERENCE
BBS	GROUP-A	50.23	1.65	0.001	Highly significant
	GROUP-B	44.83	2.26		

The above table-2 shows that the post-test mean score of berg balance scale between group a and group b were found to be statistically significant ($p<0.05$). group-a post-test had a mean score of 50.23, while group-b post-test had a mean score of 44.83, indicating a highly significant difference of post-test values between the groups A&B.

TABLE 3: COMPARISON OF PRE-TEST MEAN SCORES OF MODIFIED BARTHEL INDEX IN BETWEEN THE GROUPS

GROUPS		MEAN	SD	PVALUE	INFERENCE
MBI	GROUP-A	58.10	2.56	0.040	Insignificant
	GROUP-B	56.96	1.44		

The above table-3 shows that the pre-test mean score Modified Barthel Index between group a and group b were found to be statistically insignificant ($p>0.05$). group-A pre-test had a mean score of 58.10, while group-B pre-test had a mean score of 56.96, indicating an insignificant difference of pre-test values between the groups.

TABLE 4: COMPARISON OF POST-TEST MEAN SCORES OF MODIFIED BARTHEL INDEX IN BETWEEN THE GROUPS

GROUPS		MEAN	SD	PVALUE	INFERENCE
MBI	GROUP-A	67.16	3.27	0.001	Highly significant
	GROUP-B	61.96	1.42		

The above table-4 shows that the post-test mean score of Modified Barthel Index between group A and group B were found to be statistically significant ($p<0.05$). group-A post-test had a mean score of 67.17, while group-B post-test had a mean score of 61.96, indicating a highly significant difference of post-test values between the groups A&B.

DISCUSSION

The aim of the study was to compare the effect of virtual reality training and Otago exercises on balance and functional independence in post stroke subjects. The following outcome measures were Berg balance scale and Modified Barthel index to assess the balance and functional independence. The results showed significant improvement in outcome measures such as berg balance and modified Barthel index. The two interventions were similarly effective in improving balance and functional independence.

Several studies have reported positive effects on virtual reality in post stroke

subjects. Subjects were assessed to improve balance and functional independence at baseline and at the end of intervention using berg balance scale and modified Barthel index.

This study supports the findings of Marta A. Montalban, who conducted a literature review on Rehabilitation through virtual reality therapy after a stroke The review included multiple studies that demonstrated significant improvements in motor function, balance, and gait when virtual reality was used alongside conventional therapy. Subjects undergoing VR-based rehabilitation showed early improvements in mobility and engagement due to the interactive and immersive nature of the therapy. This may be attributed to increased patient motivation and the ability of VR to provide real-time feedback and task-specific training, which enhances neuroplasticity and motor recovery in stroke patients. (VR + CG).[13]

In Group A (VR) there is statistically more significant improvement in BBS and MBI ($P < 0.001$). There was an earlier study by Steven Phu, Sara Vogrin, Ahmed Al Saedi, and Gustavo Duque, who conducted a study on balance training using virtual reality improves balance and physical performance in older adults at high risk of falls. The intervention was carried out over a period of 6 weeks, during which participants in the experimental group received balance training through immersive virtual reality systems, while the control group underwent conventional balance training. The results showed that subjects who received VR-based training demonstrated significantly greater improvements in balance and physical performance than those in the traditional training group. The interactive and engaging nature of virtual reality, along with real-time feedback and task-oriented challenges, may have contributed to increased motivation and adherence to therapy, leading to better rehabilitation outcomes. Our findings in this study were consistent with the above studies.[25]

Demeco demonstrated that immersive virtual reality interventions create an enriched, interactive environment that effectively engages stroke survivors in repetitive and meaningful movement practice. The review highlighted that such immersive systems deliver multisensory inputs—including visual, proprioceptive, and vestibular cues—that promote enhanced sensorimotor integration and postural control. Through real-time feedback and task-specific training, immersive VR encourages active participation and cognitive engagement, both of which are essential for motor relearning. The underlying mechanism is believed to involve the reinforcement of neural pathways and stimulation of cortical reorganization, thereby supporting neuroplastic recovery.

Furthermore, the incorporation of immersive and motivating tasks was found to significantly improve upper limb dexterity, dynamic balance, and gait performance, ultimately enhancing independence in daily activities. These findings reinforce the importance of sensory feedback, task-specific repetition, and neural adaptability in optimizing motor and functional recovery following stroke.[26]

Virtual reality thought to have clinical potential as a tool to enhance balance and gait rehabilitation. Jie Shen report that virtual reality–based exercise offers a promising approach to balance rehabilitation in stroke patients by integrating immersive, task-oriented, and feedback-driven activities. The study highlights that VR interventions significantly enhance postural stability, functional balance, and motor performance when compared to conventional therapy. The author attributes these improvements to the engaging and repetitive nature of VR tasks, which promote neuroplasticity and facilitate sensorimotor integration. Their findings support the use of VR as an effective adjunct or alternative to traditional balance training in post-stroke rehabilitation.[27]

According to Bohan Zhang, Ka-Po Wong, and Jing Qin emphasized that virtual reality–based interventions significantly contribute to improving limb motor function, balance, gait, and overall daily functional performance in stroke patients. Their systematic review supports the premise that VR provides an enriched, interactive, and task-oriented training environment that enhances motor learning through repetitive, feedback-driven practice. The authors suggest that such immersive environments facilitate neuroplastic adaptations and strengthen sensorimotor coordination, leading to better functional recovery. These findings align with the present study's outcomes, reinforcing that VR can serve as an effective adjunct to conventional therapy in promoting post-stroke balance and mobility rehabilitation.[28]

Previous research by Vishal Sana and co-authors on effects of virtual reality therapy on balance, dizziness and gait in patients with subacute stroke demonstrated that VR-based rehabilitation provides a highly engaging, task-oriented environment that stimulates visual, vestibular, and proprioceptive pathways. By offering real-time feedback and adjustable levels of challenge, VR can facilitate motor learning and motivation. Patients undergoing VR training often demonstrate greater improvements in gait speed, balance confidence, and a reduction in fear of falling when compared to traditional therapy modalities. VR often leverages augmented sensory feedback and cognitive engagement to promote neuroplasticity.[29]

In Group B (Otago exercise programme) there is statistically significant improvement in BBS and MBI. According to Pirayesh, Karmi et the interactive and functional aspects of the Otago program, along with its emphasis on task-specific training, may contribute to greater motivation and adherence, which are crucial factors in post-stroke rehabilitation.[30]

The intervention was carried out over a period of 8 weeks, during which participants in both intervention groups attended exercise sessions three times per week. Subjects were randomly assigned to either the core stability group, Otago exercise group, or a control group. The results showed that both the core stability and Otago exercise groups demonstrated significant improvements in quality of life when compared to the control group. Notably, the Otago group exhibited a greater degree of improvement in quality-of-life scores compared to the core stability group.

The effectiveness of the Otago Exercise Program may be attributed to its structured and progressive approach, which combines lower limb strengthening, balance retraining, and functional walking activities. Exercises such as knee bends, backward walking, and sideways walking target key muscle groups and postural reflexes needed for safe mobility. These exercises enhance proprioception, coordination, and neuromuscular control, which are often impaired after stroke. Additionally, the repetitive and goal-oriented nature of the program may help reestablish motor patterns and increase the patient's confidence in their movement abilities.

An independent gait increases the confidence of an individual and makes life productive. The ankle and hip strategies show an improvement with the practice of Otago exercise program. Previous research by Aishwarya Satish Valiv, Vrushali Bhore, Otago exercises and task-oriented progressive resistance strength training are believed to enhance balance and functional performance in stroke patients through mechanisms rooted in neuroplasticity and muscle re-education. The results demonstrated that both interventions led to statistically significant improvements in Berg Balance Scale (BBS) and Timed Up and Go (TUG) test scores, indicating that structured physical rehabilitation contributes positively to post-stroke recovery. However, participants in the Otago group showed more pronounced gains in both balance and

functional mobility compared to those in the task-oriented resistance training group.[24]

The progressive and repetitive nature of Otago exercises might have led to enhanced neuroplastic changes within the central nervous system, thereby contributing to functional improvements. The findings of this study are consistent with previous literature that highlights the importance of balance-specific interventions in stroke recovery. According to previous research by Huei-Ling Chiu, Ting-Ting Yeh, Yun-Ting Lo, Pei-Jung Liang, and Shu-Chun Lee reported that the Otago Exercise Programme (OEP) is highly effective in improving both actual and perceived balance in older adults. Their meta-analysis indicates that structured, progressive strength and balance exercises can significantly reduce fall risk and enhance confidence in daily activities.

The study highlights that regular engagement in OEP promotes postural control, lower-limb strength, and functional stability, which are critical for maintaining independence in older populations. These findings support the use of targeted exercise interventions like OEP as a practical strategy for fall prevention and balance enhancement, aligning with the present study's focus on improving balance and functional mobility in vulnerable populations.[31]

Yi Yang and his co-authors reported that the Otago Exercise Programme (OEP) effectively reduces fall risk in older adults by improving lower-limb strength, dynamic and static balance, and gait stability. The authors explain that the mechanism underlying these benefits involves enhanced neuromuscular coordination and postural control, which support stability during daily activities. Additionally, OEP contributes to increased confidence and reduced fear of falling, promoting greater engagement in physical activity. These findings support the present study's focus on structured exercise interventions to enhance balance and functional mobility in older populations.[32]

The current study indicated that after 8 weeks of intervention with virtual reality showed more significant effect in BBS and MBI than Otago Exercise program on balance and functional independence. This study concluded that virtual reality is useful for the treatment of post stroke subjects.

Despite the favorable outcomes observed in the present study, certain limitations were identified like: a) Small sample size, b) absence of blinding, c) lack of follow up period. Consequently, future research was recommended to employ more rigorous randomization procedures and recruit larger cohorts to enhance statistical power and strengthen the robustness of results. The incorporation of assessor blinding or objective outcome measures was suggested to minimize bias, and the inclusion of longitudinal follow-up assessments was advised to evaluate the long-term effectiveness of the intervention.

CONCLUSION

The present study concludes both virtual reality along with conventional physiotherapy and Otago exercises along with conventional physiotherapy showed significant improvement in Balance and Functional independence in post stroke subjects. However Virtual reality along with conventional was more effective when compared to Otago exercises along with Conventional physiotherapy. Hence treatment intervention may be incorporated in post stroke subjects.

Declaration by Authors

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