ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 12| Issue: 4| April 2026|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2026: 8.753 || ISI Value: 1.188

EFFECTIVENESS OF VIRTUAL REALITY ON FUNCTIONAL BALANCE, FALL RISK PREVENTION AND QUALITY OF LIFE IN A POST-OPERATIVE MENINGIOMA INDUCED HEMIPARESIS PATIENT: A SINGLE CASE STUDY

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Article DOI: https://doi.org/10.36713/epra26967
DOI No: 10.36713/epra26967

INTRODUCTION

Meningiomas are prevalent brain tumours and are commonly found at the skull base. These are commonly occurring non-cancerous brain tumors, typically classified as extra-axial and often lacking a clear cause. This type of tumor is the most frequently diagnosed intracranial tumor, accounting for approximately 20–36% of all such tumors globally. The annual incidence is around 1.8 to 13 per 100,000 individuals worldwide.[1,2]

Various external factors, including exposure to ionizing radiation, hormonal changes, breast cancer, head injuries, use of mobile phones, family medical history, along with occupational risks, dietary habits, and allergies, have been associated with a heightened likelihood of developing intracranial meningiomas. A considerable proportion of meningiomas are known to arise in the supratentorial areas, particularly near the dura venous sinuses of the cerebral convexity, parasagittal region, and the sphenoid wing.[3]

One of the notable characteristics of meningiomas located in the parasagittal area is their tendency to invade the superior sagittal sinus (SSS) and lead to the enlargement of collateral veins, which then connect with larger venous structures in the sinus vicinity. Research findings suggest that parasagittal meningiomas often follow specific growth and vascular patterns. The impact largely depends on the tumor's precise location and its interaction with nearby structures. Because of the aggressive behavior of such growths, vital structures like the internal carotid artery (ICA) may be affected, resulting in reduced cerebral blood circulation.[4]

Intracranial meningiomas usually present with symptoms such as raised intracranial pressure (ICP), seizures, focal neurological problems, or cranial nerve palsies, but they often develop slowly and may go unnoticed. Some meningiomas are found incidentally during investigations for other issues. Rarely, they may present with sudden bleeding inside the tumor (about 2% of cases) or with transient ischemic attacks (TIA).[5.]

Presentation as an acute ischemic stroke due to meningioma is very uncommon. Only seven cases have been reported in the literature so far. Komotar et al. (2003) described two such cases, and in a study of 1617 meningiomas, three strokes due to internal carotid artery (ICA) compression were reported (0.19%).[6]

Meningiomas are usually slow-growing and non-invasive. Large arteries such as the ICA, MCA, and ACA are less likely to be affected compared to cortical veins and dural sinuses. When strokes occur in patients with skull base meningiomas, they are thought to be caused either by direct compression of vessels, tumor invasion, or clotting disorders.[7,8,9,10,11.12]

Conventional rehabilitation of meningioma induced hemiparesis mainly depends on repetitive and task-based exercises which often raise debates about patient adherence and the cost-effectiveness of these methods. In addition, limitations of time and space reduce their overall impact. The outcome of rehabilitation is also strongly influenced by the expertise of the therapists, and traditional methods alone are often insufficient to fully address patients' needs.[13]

Virtual reality (VR) is implemented using computer hardware and software, where digital simulations generated by a computer allow participants to experience environments resembling real-life objects and situations. Research by Matt et al. also showed that VR programs were considered more effective tools for rehabilitation than traditional approaches.[14.15]

It presents a hopeful and dynamic avenue for recovery by offering interactive and engaging therapy sessions. VR can significantly support functional improvements, especially for those with upper limb limitations, and enhance the performance of daily living activities. This approach is often found to be more stimulating compared to traditional therapy methods, leading to higher levels of patient involvement and increased exercise intensity and frequency.[16] Lloréns et al. examined VR use for lower limb rehabilitation in stroke survivors and found that participants benefitted considerably, also noting the usability of the method.[17]

Different studies have investigated the effectiveness of VR in rehabilitation in multiple sclerosis, Parkinson disease, chronic stroke, balance and mobility in the elderly, and cerebral palsy and Down syndrome or learning purposes but no studies have been reported as per evidences to find out the effectiveness of

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virtual reality on functional balance, fall risk assessment and quality of life in meningioma induced hemiparesis patients.

Whether the effect of virtual reality is same on functional balance, fall risk and quality of life like other neurological conditions or it has different effects in meningioma induced hemiparesis, this single case study was conducted.

AIM

To find out the effectiveness of virtual reality on functional balance, fall risk prevention and quality of life in a post-operative meningioma induced hemiparesis patient.

OBJECTIVES

1. To assess and compare the pretest and posttest level of functional balance
2. To assess and compare the pretest and posttest level of fall risk assessment
3. To assess and compare the pretest and posttest level of quality of life
4. To find out any correlation between functional balance, fall risk assessment and quality of life

VARIABLES

Independent Variables: Virtual Reality along with Conventional Therapy
Dependent Variables: Functional Balance, Fall risk and Quality of life
Outcome variables: Berg Balance Scale, Falls Risk Assessment Tool (FRAT) and SF-36

SETTING OF STUDY

The patient who attended Occupational Therapy Section after getting referral from PMR department, JIPMER.

Inclusion Criteria

- Patient with history of meningioma induced hemiparesis
- Able to communicate in any language
- Patient who is medically stable
- Good cognitive status (>24 on Mini-Mental State Examination)

Exclusion Criteria

- Patient who is not medically stable and depressed
- Poor cognitive status (<24 on Mini-Mental State Examination)

Methodology

A 52 years old male patient, who attended Occupational Therapy section to the clinic with a referral from physician after craniotomy. The patient had past history of left lower limb, upper limb weakness and slurring of speech for the last 1 year and complained of a diffuse headache which was severe in intensity. The patient had history of multiple falls and depression as informed by family members. There was no history of vomiting, no history of LOC or altered mental status, no history of blurring of vision. He was a known case of DM for 2 years and CAD for 6 months and on metformin. Routine biochemical and haematological investigations were normal. MRI was suggestive of right parasagittal meningioma. The right parasagittal craniotomy and excision of lesion was done.

As per reports, the patient was haemodynamically stable and muscle power of left upper limb and lower limb was 2+/5 during discharge. The patient completed and signed an informed consent and information release form to be used as a subject in a case study. He was a driver by profession.

He attended Occupational Therapy by walk being fully assisted by caretaker. Pretest evaluation was done by using Berg Balance Scale, falls risk assessment tool or SF-36 to test functional balance, fall risk assessment and quality of life respectively after demographic assessment. The patient was given virtual reality training for 6 days/week for 45 days along with conventional therapy. The duration for virtual reality training was 45 minutes to one hour. The patient's psychological status was taken into consideration during training. In case patient showed any exhaustion or not motivated enough, adequate rest and psychological counselling was being given. Every 2 or 3 days, the level of task on virtual reality was changed to make the task interesting and challenging for the patient.
At the end of 45 days, posttest evaluation was done and data were collected for statistical analysis.

RESULTS

TABLE NO: 1
Berg Balance Scale

Score	Mean	Std. Deviation	Mean Difference	t-value (paired t-test)	df	p-value
Pre-test	0.8571	1.3506	2.2143	9.282	13	0.001** HS
Post-test	3.0714	0.8287				

-p < 0.001 highly significant

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Graph -1

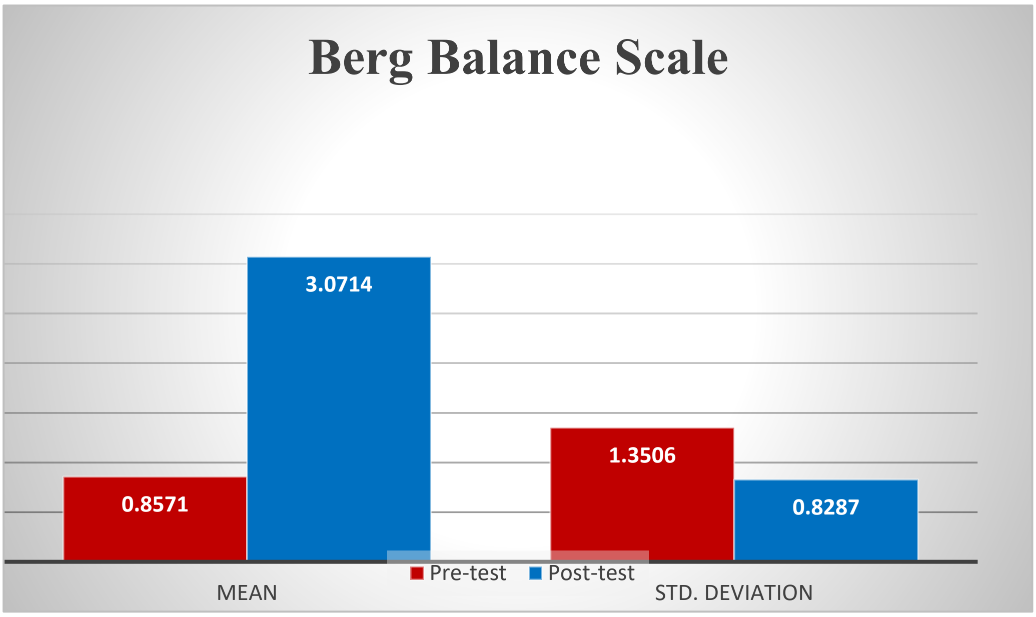

TABLE NO: 2
Fall Risk Assessment

Score	Mean	Std. Deviation	Mean Difference	t-value (paired t-test)	df	p-value
Pre-test	0.9286	2.2002	0.2857	1.472	13	0.165 **NS**
Post-test	0.6429	1.5984				

NS-Non Significant

Graph-2

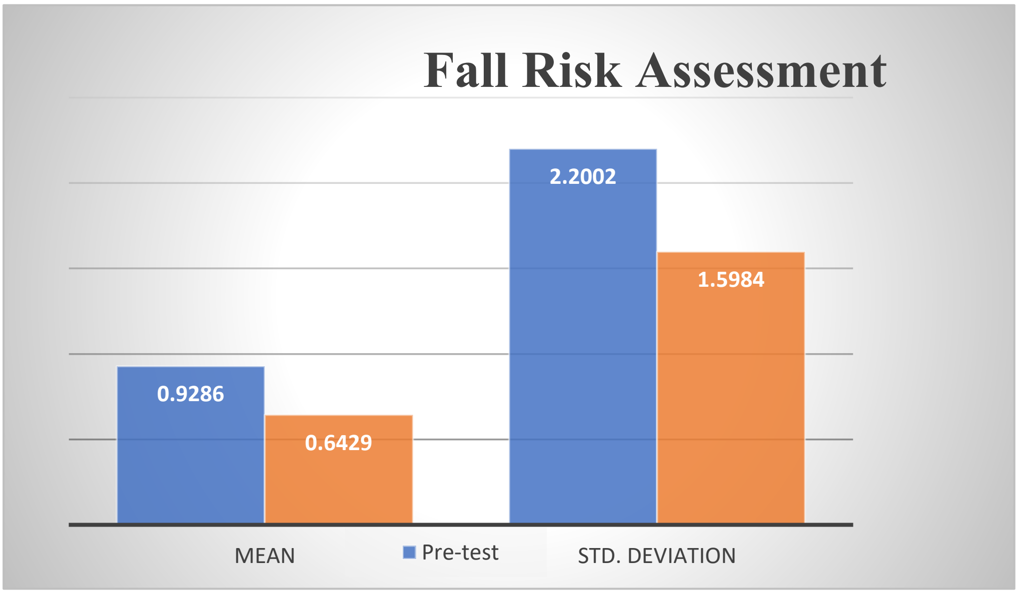

TABLE NO: 3
SF-36 Scale

Score	Mean	Std. Deviation	Mean Difference	t-value (paired t-test)	df	p-value
Pre-test	11.5278	22.1624	58.3333	11.390	35	0.000*** HS
Post-test	69.8611	28.1193				

***-p < 0.001 highly significant*

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Graph-3

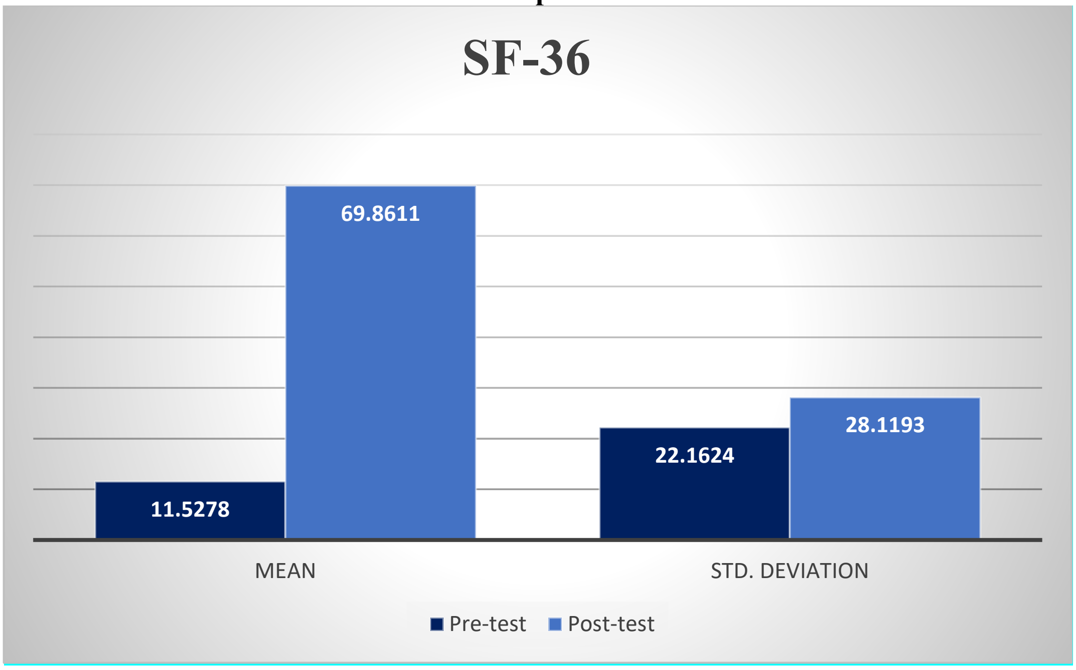

TABLE NO: 4
Correlation between Berg Balance, Fall Risk Assessment, and SF-36 Score

Test Phase	Variables Correlation	Mean (Variable 1)	SD (Variable 1)	Mean (Variable 2)	SD (Variable 2)	Pearson correlation r value	p-value
Pre	Berg Balance vs Fall Risk Status	0.8571	1.35062	0.9286	2.20015	-0.240	0.429 NS
Pre	Fall Risk Status vs SF Score	0.9286	2.20015	11.5278	22.16237	-0.121	0.679 NS
Pre	SF Score vs Berg Balance	11.5278	22.16237	0.8571	1.35062	-0.183	0.532 NS
Post	Berg Balance vs Fall Risk Status	3.0714	0.82874	0.6429	1.59842	-0.285	0.079 NS
Post	Fall Risk Status vs SF Score	0.6429	1.59842	69.8611	28.11929	-0.226	0.438 NS
Post	SF Score vs Berg Balance	69.8611	28.11929	3.0714	0.82874	-0.234	0.421 NS

*S: * Significant at $p < 0.05$, NS: Non-significant*

DISCUSSION

The aim of this single case study was to evaluate the benefit of virtual reality-based rehabilitation on Functional Balance, Fall Risk Assessment and Quality of Life in a Post-operative meningioma induced hemiparesis Patient. Table 1, 2 and 3 show statistically significant improvement in Berg Balance Scale, Fall Risk Assessment and Quality of Life scale respectively.

The scores of various challenging tasks in Berg Balance Scale improved significantly suggesting enhanced confidence and postural control of the patient. The improvements across all tasks highlight the effectiveness of the VR intervention in improving participants' functional balance.

Table No: 2 illustrates the various fall risk factors measured before and after the intervention. The mean scores indicated a reduction in fall incidents of the participant. Psychological risk factors also showed a decline, with affected individual. Overall, these findings demonstrate a positive trend in reducing some key risk factors for falls, particularly recent falls and psychological contributors.

Table No: 3 – SF-36 Scale scores reveal a substantial and statistically significant increase in health status scores. This suggests that participant experienced a marked enhancement in perceived health and quality of life following the intervention.

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Virtual reality (VR) simulates real environments through a computer, enabling users to engage in individualized, repetitive yet interesting training that stimulates both motor and cognitive skills. VR's immersive and interactive features can enhance enjoyment, motivation, and participation in therapy.

Research on VR's effectiveness in post-stroke rehabilitation shows mixed results. While VR can improve motor function, quality of life, and daily activity performance—especially when combined with conventional therapy—statistical differences from standard therapy are often limited.

A study was conducted by Jisun et al. on the benefit of virtual reality-based rehabilitation on upper-extremity function in patients with brain tumor. The intervention group performed the virtual reality program, whereas the control group received conventional occupational therapy. The participants in intervention group showed greater improvements in Box and Block test, the Fugl-Meyer scale, and the Manual Function test in shoulder/elbow/forearm functions than control group.[18]

Phu et al. conducted a pre–post intervention study with 195 older adults at high risk of falls, comparing exercise (n = 82) and virtual reality training (n = 63) to a control group (n = 50). Both intervention groups showed similar adherence (71% vs 72%) and significant improvements in balance and physical performance compared with control group.[19]

A randomized controlled trial study conducted by Sadeghi H et al. involving 51 participants compared immersive virtual reality (IVRG) and conventional balance training (BTG) over an eight-week period. Both interventions yielded significant gains in postural stability, mobility, and fatigue reduction, with no statistically significant differences between the two, whereas the control group exhibited increased postural sway and no notable functional improvements. Collectively, these findings suggest that virtual reality training may be as effective as traditional balance training in enhancing postural control and physical function.[20]

Zhang, B et al. evaluated 26 systematic reviews on VR's effectiveness in stroke rehabilitation. Findings suggest VR can improve limb function, balance, gait, and daily activities, though evidence quality is low due to issues like heterogeneity, lack of blinding, and inconsistent assessment. VR offers real-time multisensory feedback and tracks performance, enhancing neuroplasticity and motivation through enriched, task-specific activities and game-based therapy. It benefits functional recovery—reducing pain, improving muscle strength, balance, and sensation. However, strong evidence is limited.[21]

Dąbrowská M et al. conducted a study to evaluate the impact of conventional rehabilitation combined with VR on self-care and domains of HRQoL in patients ≤6 months post-stroke. There were no statistically significant differences between the groups in WHODAS 2, self-sufficiency, and balance scores ($p > 0.05$). In the experimental group, there was a statistically significant difference in WHODAS 2, assessment of self-sufficiency, and balance scores before and after therapy ($p < 0.05$). VR appears to be a suitable tool to supplement and modify rehabilitation in patients after stroke.[22]

Total numbers of 14 RCTs, involving 524 participants with Parkinson's disease, were included in the meta-analysis study conducted by Kwon SH et al. The results indicated that VR-based rehabilitation significantly improved balance function, as measured using the Berg balance scale (BBS) and activities-specific balance confidence. However, no statistically significant differences in gait ability, activities of daily living, motor function, and quality of life were observed between the experimental and control groups. Subgroup analysis revealed that combination therapy affected heterogeneity in the BBS analysis. Meta-regression analysis demonstrated a significant positive relationship, indicating that more recent studies have shown greater improvements in balance function.[23]

Table 4 shows the negative correlation between all scales suggesting no significant relationship between these scales in the pre-test and posttest phase. A retrospective review of 132 individuals with stroke (90 males, 42 females) undergoing inpatient rehabilitation across three hospitals was conducted. No significant correlation was found between the total scores of BBS and POMA ($r = 0.167$), but a significant correlation was observed between their fall risk scores ($r = 0.268$). These findings suggest that both BBS and POMA are reliable for assessing fall risk in individuals with stroke, though further research should include factors such as sex, age, balance, and gait components to strengthen predictive value.[24]

CONCLUSION

Virtual Reality proved efficient in improving functional balance, assessing fall risk, increasing self-confidence and enhancing the quality of life of a patient suffering from meningioma induced hemiparesis.

LIMITATIONS

- A single case study can't validate the efficiency of VR in meningioma induced hemiparesis condition.
- The investigator could not control the extraneous variables of getting other therapies.
- RCT should be done in order to find out the accurate effectiveness of VR based intervention.

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