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EFFECT OF VIRTUAL REALITY-ASSISTED NEUROLOGICAL REHABILITATION ON MOTOR AND COGNITIVE OUTCOMES: A COMPARATIVE STUDY

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KEYWORDS

Virtual Reality; Neurological Rehabilitation; Motor Function; Cognitive Function; Fugl-Meyer Assessment; Montreal Cognitive Assessment; Physiotherapy.

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Abstract

Background

Neurological disorders may result in motor impairment and cognitive dysfunction, which can affect functional recovery and participation in rehabilitation. Conventional neurological rehabilitation commonly involves strengthening, balance training, gait training, coordination exercises and functional task practice. Virtual Reality (VR) has emerged as an adjunctive rehabilitation approach that provides an interactive environment for repetitive and task-oriented practice.

Objective

To compare the effects of Virtual Reality-assisted rehabilitation combined with conventional physiotherapy with conventional neurological rehabilitation alone on motor and cognitive outcomes.

Methods

A total of 60 participants undergoing neurological rehabilitation were included in the study and divided into two groups of 30 participants each. Group A received Virtual Reality-assisted neurological rehabilitation in addition to conventional physiotherapy, whereas Group B received conventional neurological rehabilitation alone. Motor function was assessed using the Fugl-Meyer Assessment (FMA), while cognitive status was assessed using the Montreal Cognitive Assessment (MoCA).

Results

The mean FMA score increased from 63.93 ± 4.98 to 72.60 ± 6.27 in Group A, with a mean change of 8.67 ± 1.42 points, whereas Group B increased from 64.13 ± 4.71 to 64.63 ± 5.74, with a mean change of 0.50 ± 1.96 points. The MoCA score increased from 22.57 ± 1.38 to 24.47 ± 2.15 in Group A, representing a mean change of 1.90 ± 0.88 points, compared with an increase from 22.60 ± 1.33 to 23.07 ± 2.30 in Group B, representing a mean change of 0.47 ± 1.63 points.

Conclusion

Participants receiving Virtual Reality-assisted rehabilitation combined with conventional physiotherapy demonstrated greater improvement in motor and cognitive outcomes than those receiving conventional neurological rehabilitation alone. The findings suggest that Virtual Reality may be a useful adjunct to conventional neurological rehabilitation.

Introduction

Neurological disorders can result in a combination of motor, sensory, cognitive and functional impairments. Motor impairment may affect voluntary movement, coordination and functional task performance, while cognitive impairment may influence attention, planning, learning and participation in rehabilitation. These impairments can collectively reduce an individual's ability to perform functional activities and participate independently in daily life.

Neurological rehabilitation aims to improve physical and functional abilities through structured therapeutic interventions. Conventional neurological rehabilitation commonly incorporates strengthening exercises, balance training, gait training, coordination exercises and functional task training. In the study, conventional rehabilitation consisted of these components and was provided to both groups.

Virtual Reality (VR) has increasingly been incorporated into rehabilitation as an adjunct to conventional physiotherapy. VR provides an interactive environment in which patients can perform purposeful movements and functional tasks. The ability to provide repetitive, task-oriented and visually guided activities may make VR useful for individuals requiring neurological rehabilitation.

The VR intervention used in the study incorporated reaching, grasping, stepping, upper-limb exercises, balance training and interactive rehabilitation games. These activities were provided in addition to conventional neurological rehabilitation.

Motor recovery is an important component of neurological rehabilitation. Improvement in voluntary movement and motor control may contribute to improved functional performance. The Fugl-Meyer Assessment is commonly used to assess motor impairment and recovery, particularly in individuals following stroke. It evaluates motor performance through standardized movement tasks.

Cognitive function is also relevant to neurological rehabilitation. Attention, orientation, memory, language and executive functioning may influence a patient's ability to participate in therapy and perform functional tasks. The Montreal Cognitive Assessment is a screening instrument that assesses multiple cognitive domains and can be used to evaluate global cognitive status.

Interactive rehabilitation through VR may provide simultaneous motor and cognitive demands. Patients may be required to respond to visual targets, follow instructions, perform movements accurately and adjust their performance according to task feedback. These characteristics may provide an additional form of task-oriented rehabilitation.

Previous clinical research has investigated VR-based rehabilitation for motor and cognitive outcomes, particularly in stroke rehabilitation. However, the effects of VR may vary ac cording to the neurological condition, treatment protocol, duration of intervention and outcome measure used.

The present study therefore compared Virtual Reality-assisted neurological rehabilitation combined with conventional physiotherapy with conventional neurological rehabilitation alone, with particular emphasis on motor and cognitive outcomes.

MATERIALS AND METHODS

Study Design

This comparative experimental study included 60 participants who were allocated into two groups. Participants were divided into two groups of 30 participants each.

Group A received Virtual Reality-assisted rehabilitation in addition to conventional physiotherapy, whereas Group B received conventional neurological rehabilitation alone.

Study Setting

The study was conducted in the **Department of Physiotherapy at Pacific Hospital, Udaipur.**

Participants

A total of **60 participants** undergoing neurological rehabilitation were included.

- **Group A:** 30 participants
- **Group B:** 30 participants

Inclusion Criteria

- Participants diagnosed with a neurological condition requiring physiotherapy/neurological rehabilitation.
- Adults aged 18-65 years.
- Participants who are medically stable and able to participate in the rehabilitation programme.
- Participants able to understand and follow

simple verbal instructions.
- Participants with sufficient visual and auditory ability to interact with the virtual reality system, with or without appropriate correction.
- Participants able to maintain sitting or standing safely as required for the selected virtual reality activities.
- Participants willing to participate voluntarily and provide written informed consent.

Exclusion Criteria
- Severe cognitive impairment that prevents understanding or following instructions.
- Severe visual, auditory, or vestibular impairment that prevents safe use of the virtual reality system.
- Uncontrolled epilepsy or a history of photosensitive seizures, where relevant to the VR equipment.
- Severe musculoskeletal pain or deformity that prevents participation in the intervention.
- Unstable cardiovascular or medical conditions contraindicating exercise or rehabilitation.
- Severe behavioural or psychiatric problems that interfere with participation.
- Previous significant adverse reactions to virtual reality, such as severe cybersickness.
- Inability to complete the assessment or intervention protocol.
- Participants unwilling to continue or who withdraw informed consent.

INTERVENTION

Virtual Reality-Assisted Rehabilitation

Participants in Group A received Virtual Reality-assisted neurological rehabilitation in addition to conventional physiotherapy.

The VR programme included:
- reaching activities,
- grasping activities,
- stepping activities,
- upper-limb exercises,
- balance training, and
- interactive rehabilitation games.

Conventional Neurological Rehabilitation

Participants in Group B received conventional neurological rehabilitation.

The programme consisted of:
- strengthening exercises,
- balance training,
- gait training,
- coordination exercises, and
- functional task training.

OUTCOME MEASURES

1. **Fugl-Meyer Assessment**

The **Fugl-Meyer Assessment (FMA)** was used to assess motor function.

The FMA is a standardized clinical assessment commonly used to evaluate motor impairment and recovery following neurological injury, particularly stroke.

2. **Montreal Cognitive Assessment**

The **Montreal Cognitive Assessment (MoCA)** was used to assess global cognitive status.

The MoCA is a cognitive screening tool that evaluates multiple cognitive domains and provides an overall measure of cognitive performance.

STATISTICAL ANALYSIS

Data were expressed as mean and standard deviation.

Pre-intervention and post-intervention values were assessed for both groups, and mean changes were calculated for the FMA and MoCA.

The primary comparison was based on the change observed between the two groups.

The available study data provide descriptive values and mean changes. Complete between-group inferential statistics should be reported from the original statistical analysis before final journal submission.

RESULTS

Motor Function

Table 1. Fugl-Meyer Assessment Scores Before and After Intervention

Group	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	Mean Change
Group A	63.93 ± 4.98	72.60 ± 6.27	**8.67 ± 1.42**

Group	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	Mean Change
Group B	64.13 ± 4.71	64.63 ± 5.74	**0.50 ± 1.96**

Group A demonstrated a greater improvement in FMA compared with Group B.
The observed difference in mean change between groups was approximately **8.17 points**.

Cognitive Function

Table 2. Montreal Cognitive Assessment Scores Before and After Intervention

Group	Pre-intervention Mean ± SD	Post-intervention Mean ± SD	Mean Change
Group A	22.57 ± 1.38	24.47 ± 2.15	**1.90 ± 0.88**
Group B	22.60 ± 1.33	23.07 ± 2.30	**0.47 ± 1.63**

Group A demonstrated a greater improvement in MoCA compared with Group B.
The observed difference in mean change between groups was approximately **1.43 points**.

DISCUSSION

Principal Findings

The present study demonstrated greater improvement in both motor and cognitive outcomes in participants who received Virtual Reality-assisted rehabilitation in addition to conventional physiotherapy compared with participants who received conventional neurological rehabilitation alone.
The improvement was observed in both FMA and MoCA.
The larger change was observed in the motor outcome, with an 8.67-point improvement in FMA in Group A compared with a 0.50-point improvement in Group B.
Similarly, Group A demonstrated a 1.90-point improvement in MoCA, compared with a 0.47-point improvement in Group B.
These findings suggest that the addition of VR may provide additional benefits when incorporated into conventional neurological rehabilitation.

Motor Function

The greater improvement in FMA observed in Group A may be related to the task-oriented nature of the VR intervention.
The VR programme included reaching, grasping, stepping and upper-limb activities.
These activities provide opportunities for repeated practice of purposeful movements.
Repeated task practice is an important component of neurological rehabilitation because patients require opportunities to practice movement in a meaningful and goal-directed manner.
The improvement observed in the present study is also consistent with previous research investigating VR-assisted motor rehabilitation, particularly in individuals with stroke.
However, the magnitude of improvement should be interpreted in relation to the baseline characteristics, neurological diagnosis, treatment duration and specific VR protocol used in each study.

Cognitive Function

The VR group also demonstrated greater improvement in MoCA.
The mean MoCA change was **1.90 ± 0.88 points** in Group A compared with **0.47 ± 1.63 points** in Group B.
VR-based rehabilitation may provide an interactive environment requiring patients to respond to visual information, follow instructions and perform purposeful movements.
These activities may provide additional cognitive engagement during rehabilitation.
However, MoCA is a global cognitive screening measure. Therefore, the present results should be interpreted as improvement in **global cognitive performance**, rather than specific improvement in individual cognitive domains such as memory, attention or executive function.

Motor and Cognitive Interaction

One potential advantage of VR-based rehabilitation is that motor tasks can be performed together with cognitive demands.
For example, an interactive reaching activity may require the patient to:

- identify a visual target,
- attend to the task,

- plan the movement,
- execute the movement, and
- adjust performance according to feedback.

Thus, VR may provide an environment in which motor and cognitive processes are engaged simultaneously.

The present study did not separately measure cognitive workload during the VR activities. Therefore, this interaction should be considered as a possible explanation for the observed findings rather than a directly measured mechanism.

Conventional Rehabilitation

The conventional rehabilitation group also demonstrated improvement in both outcomes.

FMA increased by **0.50 points**, while MoCA increased by **0.47 points**.

This demonstrates that conventional neurological rehabilitation remains an important component of treatment.

The greater change observed in Group A therefore indicates a potential additional contribution from incorporating VR into conventional rehabilitation rather than suggesting that conventional physiotherapy is ineffective.

Role of Repetitive Task Practice

The VR intervention provided repeated opportunities for reaching, grasping, stepping and balance-related activities.

Such repetitive task practice may facilitate improved movement performance through motor learning.

However, the number of repetitions and exact active practice time were not reported as separate variables in the present analysis.

Therefore, the contribution of repetition cannot be quantified independently.

Neuroplasticity

Neuroplasticity is frequently discussed as a possible mechanism underlying recovery following neurological rehabilitation.

The combination of repeated movement practice, sensory input and task-oriented activity may theoretically contribute to experience-dependent changes.

However, neuroplasticity was not directly measured in the present study.

Therefore, the results demonstrate clinical changes in motor and cognitive outcomes, rather than direct evidence of neuroplastic changes.

CLINICAL IMPLICATIONS

The findings suggest that VR can be incorporated into conventional neurological rehabilitation as an adjunctive treatment approach.

VR may be particularly useful for:

- reaching practice,
- grasping activities,
- stepping activities,
- upper-limb training,
- balance activities, and
- interactive functional exercises.

The intervention should be selected according to the patient's neurological condition, functional ability, cognitive status, safety and rehabilitation goals.

STRENGTHS

The present study has several strengths:

1. It compares VR-assisted rehabilitation with conventional rehabilitation.
2. Both motor and cognitive outcomes were assessed.
3. The VR programme incorporated clinically relevant movement activities.
4. The study included 60 participants.
5. The direction of change was greater in the VR group for both selected outcomes.

LIMITATIONS

The study has several limitations.

First, the sample size was limited to 60 participants, with 30 participants in each group.

Second, the study describes the participants broadly as individuals undergoing neurological rehabilitation. Different neurological conditions may have different patterns of motor and cognitive impairment and may respond differently to rehabilitation.

Third, the FMA is most commonly used for assessment of motor recovery following stroke. Therefore, its interpretation requires consideration of the neurological diagnoses represented in the sample.

Fourth, MoCA is a global cognitive screening measure and does not provide a comprehensive assessment of individual cognitive domains.

Fifth, the study did not directly measure

neuroplasticity, cortical activity, motivation, cognitive workload or treatment adherence.
Finally, long-term retention of the observed improvements was not assessed.

CONCLUSION

Virtual Reality-assisted rehabilitation combined with conventional physiotherapy resulted in greater improvement in motor and cognitive outcomes compared with conventional neurological rehabilitation alone.
The VR-assisted group demonstrated a mean improvement of 8.67 ± 1.42 points in FMA compared with 0.50 ± 1.96 points in the conventional group. Similarly, the mean improvement in MoCA was 1.90 ± 0.88 points in the VR group compared with 0.47 ± 1.63 points in the conventional group.
The findings indicate that VR may serve as a useful adjunct to conventional neurological rehabilitation for improving motor performance and global cognitive function.
Further studies with larger samples, diagnosis-specific populations, standardized VR protocols and longer follow-up are required to establish the long-term effectiveness of VR-assisted neurological rehabilitation.

Author Contributions

Suyog Shinde: Study conception, methodology, data collection, data analysis and manuscript preparation.
Dr. Dipika Balala: Supervision, methodological guidance and critical review of the manuscript.
Dr. Jafar Khan: Academic and institutional supervision and critical review of the manuscript.

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