CASE REPORT

The combined effects of virtual reality with motor imagery techniques in patients with Parkinson's disease

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Abstract

A 60-year-old man and a 63-year-old woman, diagnosed with Parkinson's disease received virtual reality (VR) and motor imagery (MI) with routine physical therapy (PT) treatment to improve balance, motor function and activities of daily living for a total of 60 minutes each session, three visits per week for 12 weeks and follow-up on week 16. This case report revealed 15 and 18 points improvement in motor function on Unified Parkinson's Disease Rating Scale part III (UPDRS) in male and female patients and in Activities of daily living on UPDRS-part II for 9 and 8 points for male and female patients respectively. The Berg Balance Score (BBS) score also improved with a clinically significant change of 9 and 11 points in male and female patients, respectively. The male and female patients reported a significant improvement in their balance, confidence on the Activities-specific balance confidence scale (ABC) scale as 14% and 16% were observed, respectively. VR in combination with MI in addition to routine Physical Therapy showed improvement in outcomes for the 2 patients presented in this case report.

Keywords: Balance, Parkinson's disease, Motor imagery, Motor function, Physical therapy, Virtual reality.

DOI: https://doi.org/10.47391/JPMA.4856

Introduction

Parkinson's disease (PD) is a movement condition that affects an estimated 4 to 6 million people globally.[1] Movement initiation and the execution of voluntary tasks are commonly affected in patients with PD, which is a progressive degenerative neurological disorder that affects the Activities of daily living (ADLs) and quality of life.[2] The majority of the people affected with PD are 50-70 years of age, with peak incidence in the 60s with slight predominance in men, though juvenile and early-onset PD have also been reported in the literature.[3]

A multidisciplinary approach is encouraged for the rehabilitation of PD, and as part of this approach, exercise programmes have been shown to relieve both motor and non-motor symptoms.[4] This is especially important, as according to statistics often cited in the literature states that approximately 20-50% of adults who start an exercise programme withdraw within the first 6 months.[5]

The use of modern technologies has shown promising results so far. Still, their widespread adoption is limited.[6] Virtual Reality (VR) and Motor imagery (MI) are two advanced non-conventional therapeutic techniques that improve movement, particularly the balance and mobility of individuals with PD.[7] VR is capable of generating an environment and accomplishing motor and cognitive tasks in a safe setting. VR can be patient-specific or task-specific depending on individual needs. Interventions based on VR are known to promote implicit motor learning and reorganization of neural channels.[8] VR is superior to regular exercise protocols in terms of encouraging and motivational therapy environments for an individualized exercise plan.[4]

MI is a variant of mental stimulation where an individual imagines the performance of an action without making use of body musculature.[9] Strong relation between motor performance and MI has been reported with evidence that time taken to perform an imagined task correlates with activity execution time.[10] MI is also capable of promoting neuroplasticity in the damaged brain. The literature provides substantial evidence of the beneficial impact created by a combination of MI and action observation therapy among stroke patients, but there is not much research about the PD population.[11] PD patients can engage in MI, therefore improving their functional output by use of compensatory mechanisms such as using visual inputs.[12]

Although research has contributed to our understanding of the implications of VR and MI as clinical rehabilitation tools, overall evidence of the usefulness of the two innovative technologies in improving symptoms in PD remains limited. The purpose of this case report, therefore, is to examine the effects of VR and MI with routine PT training programme on motor function, balance, and ADLs in a clinical population of individuals with PD.

Case Report

Case I: A male patient, 60-years of age was referred by a

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Table-1: Characteristic of the patients.

Characteristics		Patient #1	Patient #2
Demographics	Age	60-Years	63- Years
	Gender	Male	Female
	Marital Status	Married	Married
	Hand Dominance	Right	
	Duration of PD	6-Years	8-Years
	Age at diagnosis PD	54 Years	55 Years
Family History	Family History of PD	No	No
Symptom History	Motor Symptom	Tremors	Rigidity, Tremors
Medication History	Medication Therapy	Yes	Yes
Disease Stage	Modified H&Y	1	2.5
Cognitive Function	MMSE Score	27/30	25/30

PD-Parkinson's disease, MMSE- Mini-Mental State Examination Score, Modified H&Y-Modified Hoehn and Yahr Stage.

neurologist to the Department of Physical Therapy, Safi Hospital, Faisalabad on 3rd July 2020 for the management of bothersome tremors, predominantly on the right side. The diagnosis of PD was established by the referring neurologist six years ago. He was labeled as a stage-I PD patient according to the modified Hoehn-Yahr (H&Y) staging.[13] The tremors were followed by bradykinesia and speech abnormalities in the following years. His cognitive function was intact with a mini mental status examination (MMSE) score of 27 out of 30. The patient was taking carbidopa/levodopa for the management of the motor symptoms, and at the time of observation, the patient did not report any exacerbation of the symptoms. His neurological system was functioning well with no apparent deficit. The patient had never taken part in any physical rehabilitation programme (Table-1).

Case II: A 63-year-old female patient was referred to the Department of Physical Therapy, Safi Hospital, Faisalabad on 16th August 2020 by a neurologist with an established diagnosis of PD, eight years ago. As described by the patient in March 2011, she started noticing a flickering in her right hand that was barely noticeable but progressed over the years. After a few months, she developed difficulty in moving her body and initiating movements. When she consulted her physician, she was referred to the neurologist where her diagnosis was made at the age of 55. There was no family history, and on the H&Y staging, she was stage 2.5 with mild bilateral presentation. Her score was 25 out of 30 on mini mental status examination (MMSE), representing good cognition. She had right hand dominance, and she reported mild drooling at night with occasional choking incidents. She was currently on levodopa-based medication twice a day for symptom management, including both motor and non-motor symptoms, and was responding well to the pharmacological therapy, with limited numbers of "off events" reported in her medical history. Off events refer to the non-response of the patients with PD to pharmacological treatment.[14] Her neurological examination, cranial nerve function, superficial and deep sensations, and cerebellar functions were found intact (Table-1).

A comprehensive evaluation was performed as the next step of the management system. Both patients were assessed for motor function, balance, and ADLs by the use of Unified Parkinson's Disease Rating Scale (UPDRS) part-II and III, Berg Balance Scale (BBS), Activities-Specific Balance Confidence Scale (ABCS).

In patient # 1, the assessment of the motor function on UPDRS-III (Item #18-31) revealed that the most common physical symptoms were resting tremors, speech was mildly affected, finger taps were quite evident on the left side of the body, and bradykinesia was limiting the movement to a noticeable level in the neck and left side. The aggregate score obtained by this patient was 22/108. Balance was assessed on the BBS (14-item scale), and the obtained score was 45/56 depicting moderate deficits of the balance system. Standing on one leg, reaching forward with outstretched arm while standing, and standing unsupported with one foot in front of the other were the activities affected to a greater extent on balance assessment. Self-perceived balance confidence was measured on ABCS. Administered through interviews, ABCS contains 16 task-related questions to be asked of the patient.[15] The initial score obtained by patient #1 was 78%. The patient considered himself least confident with activities like reaching for a small can on a shelf at eye level, getting into or out of a car, and walking in a crowded mall where people rapidly walked past. The patient reported being confident enough in the performance of ADLs, but evaluation on the UPDRS-II revealed few deficiencies. This subsection of the UPDRS contains a maximum score of 52 (item #5-7). Patient obtained 13 out of 52.

Patient #2 was also assessed for the same outcomes. Tremor at rest, action or postural tremor of hands, rigidity, posture, gait, postural stability, body bradykinesia, and hypokinesia were found to be profoundly affected motor components. The score obtained by the patient in the motor section was 37/108, signifying a moderate level of affected function. Balance evaluation also revealed significant findings. Securing 40/56 on BBS, except for a few tasks including sitting to standing, standing unsupported, and sitting with back unsupported but feet supported on the floor or on a stool were noticeably affected. In relevance to the findings on the motor sub-

component and balance, the ABCS score reported similar discrepancies. She obtained a 60% score indicating a moderate level of functioning and confidence in her performance. She demonstrated limited confidence in activities like walking outside on icy sidewalks, walking up or down stairs, bending over, picking up a slipper from the front of a closet floor, reaching for a small can off a shelf at eye level and getting into or out of a car, walking across a parking lot to the mall, and walking up or down a ramp.

Both patients were treated with routine PT augmented with VR and MI as per protocol previously published for the treatment of Parkinson's disease.[7]

Each session started with routine PT and lasted for a total of 40 minutes. Initially, the patients were guided through warm-up exercises. Warm-up exercises were performed for five minutes of five repetitions each. Patients were guided by performing proper breathing, avoiding shallow breathing and straining and holding of breath at all times during the session. They were asked to practice lying on their back on the bed and under the supervision of the principal examiner. Stretching exercises were performed for 15 minutes per session and the stretches were held for 10-30 seconds with four repetitions in each of the following areas: upper chest and neck flexors, shoulder flexors and adductors, elbow and wrist flexors, knee flexors, calves and lower back. Strengthening exercises were also performed for 15 minutes during each session, repeating each exercise 10-15 times. The following muscles were trained for this training: core muscles (abdominal muscles), hip, knee, back and elbow extensors. To cool down, slow continuous stretches of the shoulder flexors, adductors, hip and knee flexors were performed for five minutes.[16]

Virtual reality rehabilitation protocol: The VR system consisted of a wall-mounted display, a Wii box, a Wii remote, and a Wii Fit board that the patient should stand on while interacting with the VR system and playing the selected games. A panel of three experienced physical therapists selected the games for three areas: motor functionality, balance and ADLs. As part of the treatment protocol, two sessions were given as practice sessions to familiarise them with the environment and the VR system and to build a relationship between therapist and patient. Patients were given an explanation of the games, the importance of therapy, and the rating of each game. For the units in the first three weeks, the selected games to improve motor skills and balance were at an easy level. Motor function enhancement games included tennis, boxing, bowling, and table football, while balance training games included soccer, table tilt, penguin slide, Tilt City, one-leg extension, and torso rotation.[16]

Each training session included two games for dynamic balance and one for targeted static balance. Exercises were selected based on the level of difficulty and the level of difficulty was gradually increased according to the patient's performance. Starting with the "Penguin Slide", it went on to the Table Tilt, then Tilt City and finally football was played. Initially, each game was played for 2-3 minutes per session.

With the progression of performance, 3-4 minutes of Table Tilt was added. While playing this game, a typical mobility pattern was initiated, and weight shifts improved with the activity. In the same week, subjects performed single-leg extensions for 1-2 minutes. In the coming weeks, Tilt City, soccer, and torso twists were added to the plan. The subjects performed these activities for 1-5 minutes per session. Treatment sessions then progressed to motor function games, including bowling, tennis, kicking, and boxing (least challenging to most challenging), with most treatment sessions ending with boxing. The subjects were able to perform most of the games with minimum guidance. Boxing was performed in the last three weeks of therapy because of the increased balance and coordination demands.[16] Each session lasted for 10-15 minutes.

Motor imagery rehabilitation protocol: The last 5-10 minutes of the session comprised the MI, and a three-step process was used to incorporate the technique.

In Step I: The patients were instructed to watch the videos recorded by the principal investigator. Two types of videos were available: one with the normal movements and the other containing the recordings of the patients performing the movements. The patients were instructed to watch and analyze the differences in both videos.[16]

Step II: The patients were instructed to relax and focus on their breathing patterns. Clear instructions were given to relax by sitting comfortably in the chair, backs supported properly, with arms in their lap, eyes closed, and breathing in and out slowly through the nose. This was repeated 10 times.

Step III: The patients were asked to perform the activities, and verbal commands were given whenever needed. The activities involved recalling the movements and the points they had previously analyzed. The focus was on feeling the "movement" while being comfortably seated in the chair with eyes closed. The difficulty level of the activities was increased gradually by the principal investigator.[16]

Table-2: Clinical outcome measures (Patient No.1).

	Outcomes	Outcome Measures	Baseline	6th Week	12th Week	Follow-Up	Difference
Case-I	Motor Function	UPDRS-III*	22	15	7	9	15
	Balance	BBS*	45/56	48/56	54/56	52/56	9
	Balance Confidence	ABCS*	78%	88%	92%	92%	14%
	ADLs*	UDRS-II*	13	8	5	8	8

UPDRS-III*- Unified Parkinson's Disease Rating Scale-Part III BBS*-Berg Balance Scale ABCS*-Activity Specific Balance Confidence Scale UPDRS-II*- Unified Parkinson's Disease Rating Scale-Part II-ADLs*-Activities of daily living.

Table-3: Clinical outcome measures (Patient No.2).

	Outcomes	Outcome Measures	Baseline	6th Week	12th Week	Follow-Up	Difference
Case-2	Motor Function	UPDRS-III*	37	28	19	22	18
	Balance	BBS*	40/56	45/56	51/56	48/56	11
	Balance Confidence	ABCS*	60%	80%	86%	86%	16%
	ADLs	UDRS-II*	21	17	12	16	9

UPDRS-III*- Unified Parkinson's Disease Rating Scale-Part III BBS*-Berg Balance Scale ABCS*-Activity Specific Balance Confidence Scale UPDRS-II*- Unified Parkinson's Disease Rating Scale-Part II; ADLs*-Activities of daily living.

Outcomes: During the 12-week intervention period, of the possible 36 sessions, Patient #1 and 2 was able to participate in 33 and 30 sessions, respectively over the course of the intervention period and had to cancel six sessions due to conveyance and health-related issues. Both patients returned four weeks after the end of the interventions for a follow-up assessment. Routine PT was inconsistently performed by the patients during this one-month period. The results of the clinical outcome measures are summarized in Table-2 and 3.

Both patients improved on many components of different outcomes, and these improvements were maintained even after the therapy concluded, on both subjective and objective measures. Subjective perfections (both short- and long-term) were also reported in the form of safe ambulation and comfort levels in the performance of ADLs. The patients did not expect this improvement, and both subjects displayed emotional reactions to their improvements. The components of UPDRS-II depicted many improvements. Patient #1 improved overall with a decrease in score from 13 to 5 points, and Patient #2's score decreased from 21 to 12. In both cases, the change was more than the minimal detectable change for this section. Further evaluation in the post-therapy period indicated some items of maximal improvement. For Patient #1, turning in bed and adjusting bed clothes, handwriting, and freezing when walking were the components with major positive changes, while Patient #2 showed improvements in cutting food and handling utensils, dressing, tremors, and walking. On UPDRS-III, Patient #1 revealed improvements in rigidity, finger taps, leg agility, postural stability, and bradykinesia with a total decrease of score from 22 to 7. For Patient #2, major improvements were observed in both resting and action tremors, gait performance, stability in posture, body bradykinesia, and hypokinesia mostly on the right side of the body, with a total improvement in this section of 37 to 19 points. Again, the change exceeded the required minimal detectable change for this section of the scale. The combined change in both sections for Patient #1 was 13.5% (from 35 to 12 points out of 160) and for Patient #2 it was 17% (from 58 to 31 points out of 160). The effects of the therapy were not completely carried over to the post-therapy period, as was revealed in the post-therapy follow-up session which was recorded after one month of the discontinuation of the treatment. A decline in score was observed in the subsection of motor function of rigidity, bradykinesia, and arising from a chair and performing gait appropriately.

The BBS score also improved with a clinically significant change, improving by 9 and 11 points in Patients #1 and #2, respectively. In each successive assessment, an increase in the score and thus improvements in the functions were observed. The improvements were maintained at the one-month follow-up, and Patient #1 maintained improvements in sit to stand, reaching forward, and turning. There was a decline in the performance of placing alternate steps on the floor while standing unsupported. This might be due to the fact that this activity was not part of the patient's routine life. In Patient #2, sitting to stand, standing to sitting, transfer activities, and reaching were the activities that retained the effects of the therapy.

The patients also reported improvements in their balance

confidence, as demonstrated by the change in the ABCS score, and a change of 14% and 16% was observed, respectively. It has been reported in the literature that this should be considered a minimal detectable change.[17]

Discussion

To date, no study has been reported in the literature that has examined the combined effects of VR and MI combined with routine PT in PD. A well-designed protocol[16] was used for these patients based on the clinical manifestations of PD in different clinical stages. An interesting aspect of the VR and MI-based interventions used in this case report was the cognitive demands during training that were reported by the clients.

Numerous dimensions of motor function improved in the patients. Their weight-bearing abilities improved by playing games like Penguin Slide and Tilt City. According to the previous studies available in the literature, PD patients are known to have deficits in lateral weight shifting;[18] therefore, the purpose of selecting these games was to improve this area. Another impairment that is quite prevalent in this population is limited trunk rotation. To improve rotation, torso twists helped as well as promoting static balance. Table Tilt was helpful in promoting weight shifting in all directions; therefore, the motor activities and postures requiring balance in multiple directions were greatly improved. Single-leg extension was added in the initial half of the intervention period. Tilt City and soccer interventions were employed later on because of the increased functional demands posed by these games. Both patients achieved high scores on Penguin Slide and Torso Twist. The literature has reported that patients with PD have a tendency to improve function through the use of interventions that incorporate external cues. Therefore, it can be stated that the patients showed improvements because the external cues were balanced in the intervention programme.[19]

The transfer skills of the patients were also improved by this comprehensive exercise protocol. This research has revealed that limited transfer abilities of PD patients increase the incidence of falls, mainly referred to as the intrinsic fall factor.[20] Decreased postural control has been shown to increase the risk of falls, and the torso twist had the added benefit of improving the subject's overall strength.

Although no previously published study has looked at the combined effects of VR and MI therapy in individuals with PD, the techniques have been used separately for other neurological deficits. Several studies have reported improvements in patients with other neurological disorders; However, the "results in these individuals with different training approaches" seem to be greater.[21] In the case of these patients presented in this report, this effect can be explained by increased demands on the implicit and explicit memory system. An added benefit of this training protocol was the performance of the original movement pattern compared to other technological advances.

VR and MI primarily help it to normalize the pattern of movement initiation and Completeness. Patients with Parkinson's disease have a limited ability to learn new tasks and use new movement patterns in daily life. These innovative techniques also support the patient in modifying ineffective movements and actively avoiding them if necessary.

In the presented case report, the reason the improved function may be due to the fact that PD patients tend to learn and acquire new skill patterns based on repetition and recall, and the protocol was based on these. Even if the exact mechanism is not well understood, there is a possibility that the exercise protocol has improved external feedback, resulting in an improvement in motor skills and balance function. Overall, a positive effect of the treatment protocol was witnessed in the present case report, which far exceeded the therapeutic results reported in previous studies.

Conclusion

The present case study found that combining MI and VR with routine PT seemed to have a better impact on improving motor function, balance and activities of daily living in people with PD.

Limitations

The cases were not compared to a placebo, which is a limitation of this case report. In addition, further studies are needed to determine a quality randomised controlled trial to find the combined effects of VR and MI compared to other physiotherapy techniques or protocols for the management of patients with PD.

Statement of Ethics: The Institutional Review Board of Institute of Physical Therapy, Lahore has approved the case report and the data was collected according to the rules of the Helsinki Declarationn. The participants agreed in writing for publication of the data.

Disclaimer: The manuscript is part of PhD project of the Primary Author.

Conflict of Interest: None.

Funding Disclosure: None.

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