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The effect of rehabilitation in a virtual reality environment on improving balance in older adults with Parkinson's disease: A systematic review

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Abstract

Parkinson's disease (PD) is the most common form of Parkinsonism, a group of neurological disorders, and the second most common neurodegenerative disorder. More than six million people worldwide are affected by PD. Over the past two decades, Virtual Reality (VR) technology and commercial gaming devices are used as intervention tools for rehabilitation. The aim of this systematic review is to study the efficacy of rehabilitation in VR environments in improving balance in older adults with PD. Method: The Google Scholar, Pub-Med, and PEDro databases were searched in March 2022. Different Boolean operators were used in the search with the following keywords: Parkinson OR Parkinson's disease AND balance AND virtual reality OR vr AND older adults OR elderly. The search was filtered for clinical studies published in the last 10 years. Results: Eight clinical studies were found to meet the inclusion criteria and were included in the review. The total sample was 259 older adults with PD. The intervention means for rehabilitation were VR environments, which were compared with conventional therapy. Discussion – Conclusions: The results of the review show that rehabilitation in VR environments positively affects balance in older adults with PD, equally or more than conventional therapy. Further research on the subject would help form a more complete picture.

Keywords: Parkinson's disease, virtual environment, VR, older adults, physiotherapy

Introduction

Parkinson's disease (PD) is the most common form of Parkinsonism, a group of neurological disorders, and the second most common neurodegenerative disorder after Alzheimer's disease. It is largely treatable despite its severe symptoms^[1, 2], which are classified as motor and non-motor. Some of the most common motor ones are tremors, rigidity, bradykinesia, dystonia, and postural instability. Non-motor include loss of taste and smell, sleep disturbances, gastrointestinal complications, constipation, swallowing problems, anxiety, pain, fatigue, depression, sexual dysfunction, hallucinations, psychosis, impulse control disorders, cognitive impairment, and dementia^[2, 3].

More than six million people worldwide are affected by PD^[1]. The prevalence of PD increases with age and, consequently, due to the aging global population, it is expected to double in the next two decades, escalating the social and economical burden of the disease. PD affects 1% of the population over the age of 60. In 5-10% of patients some genetic factor can be identified^[4, 5]. It is rare before the age of 50 and increasingly common with each subsequent decade^[6].

Dynamic balance training has a positive effect on postural control, motor function, and ability to perform daily activities in PD patients^[7, 8]. Over the past two decades, Virtual Reality (VR) technology and commercial gaming devices have been used as intervention tools for rehabilitation^[9]. VR technology provides a high-intensity, task-oriented, and multi-sensory feedback training. Consequently, the senses of touch, sight, and hearing, as well as the interest of the patients in rehabilitation are promoted^[10]. Due to its low cost and ease of use, VR technology is now often used in the rehabilitation of neurological disorders^[11].

The purpose of this work is to study the efficacy of rehabilitation in VR environments in improving balance in older adults with PD.

Method

The Google Scholar, Pub-Med, and PEDro databases were searched in March 2022. Different Boolean operators were used in the search with the following keywords: Parkinson OR Parkinson's disease AND balance AND virtual reality OR vr AND older adults OR elderly. The search was filtered for clinical studies published in the last 10 years.

Results

The titles and abstracts of the articles that resulted from our search were initially screened and afterwards their full-text was thorough evaluated. Eight clinical studies met the inclusion criteria and were included in the review. The total sample was 259 older adults with PD. The intervention means for rehabilitation were VR environments, which were compared with conventional therapy. Below are the characteristics of the sources included in our review. Their main findings are summarized in table 1.

Table 1: Main characteristics of included studies

Author Year	Number of participants	Intervention duration	Intervention	Outcome measures	Conclusions
Lee <i>et al.</i> (2015)	20	6 weeks	30 minutes of neurodevelopmental exercises, 15 minutes of functional electrical stimulation Intervention group: additional 30 minutes of dance exercises in VR	<ul style="list-style-type: none"> • BBS • MBI • BDI 	Dance exercises in a VR environment have a positive effect on balance, activities of daily living, and depression in older adult patients.
Feng <i>et al.</i> (2019)	28	12 weeks	Intervention group: VR exercise, 5 min warm-up, 10 min VR ball exercise with legs and arms, 10 min VR boating, 10 min VR maze 10 min stretch recovery Control group: conventional physical therapy, 5 min warm-up with stretching, 10 min balance exercises, 10 min fitness exercises, 10 min coordination exercises, 10 min stretch recovery	<ul style="list-style-type: none"> • BBS • TUG • UPDRS3 • FGA 	The intervention group had significantly better results than the control group.
Gandolfi <i>et al.</i> (2017)	76	7 weeks	Group 1: graded exergames on Nintendo Wii Fit Group 2: exercises to improve postural stability	<ul style="list-style-type: none"> • BBS • ABC • 10-MWT • MCID • DGI • PDQ-8 	VR therapy is a powerful alternative to in-clinic sensory integration balance training (SIBT) for patients with PD.
Yang <i>et al.</i> (2016)	23	6 weeks	Intervention group: trained in a personalized VR balance system Control group: trained by a physical therapist	<ul style="list-style-type: none"> • BBS • DGI • TUG • PDQ-8 • UPDRS 	Both techniques are equally effective in improving balance, gait, and quality of life in older adult patients with PD.
Pazzaglia <i>et al.</i> (2020)	51	6 weeks	Group 1: rehabilitation in VR environment Group 2: conventional rehabilitation program	<ul style="list-style-type: none"> • BBS • DGI • DASH • SF-36 	Rehabilitation of older adult PD patients in VR environments had better results than conventional treatment.
Liao <i>et al.</i> (2015)	36	6 weeks	VRWii group: exercises in a VR environment on the Wii Fit system TE group: conventional physical therapy	<ul style="list-style-type: none"> • LOS • SOT • PDQ39 • FES-I • TUG 	The intervention in VR environments had positive results and statistically significant differences that remained a month after the end of the intervention. Relevant treatment may improve the parameters measured in older adult PD patients.
Albiol-Pérez (2017)	10	15 sessions	Exercises with the Active Balance Rehabilitation system (ABAR) based on weight transfers, about 5 minutes of break, and 30 minutes of conventional therapy, with weight transfers from a sitting position	<ul style="list-style-type: none"> • UPDRS 	Older adult PD patients can maintain or even improve their postural control through rehabilitation intervention in a VR environment.
Gu (2012)	15	12 weeks	Therapeutic rehabilitation program in a VR environment with the Nintendo Wii system	<ul style="list-style-type: none"> • UPDRS3 	Rehabilitation in VR environments via the Nintendo Wii is proposed as a cost-effective treatment alternative that may yield positive results.

Literature review

The study of Lee *et al.* [12] evaluated the effect of dance exercises in VR on balance, daily activities, and depression in 20 PD patients. Participants were equally divided into two groups (intervention group mean age 68.4±2.9 years; control group mean age 70.1±3.3 years). All participants performed 30 minutes of neurodevelopmental exercises and 15 minutes of functional electrical stimulation five times a week for six weeks.

The intervention group did an additional 30 minutes of dance exercises in VR. Parameters were measured before and after six weeks of treatment using the Berg Balance Scale (BBS) for balance, the Modified Barthel Index (MBI) for daily activities, and the Beck Depression Inventory (BDI) for depression. Paired t-test was used for pre- and post-treatment differences and independent t-test was used to find differences between groups. The values for the three factors measured had significant

differences before and after treatment in the intervention group. Specifically, the improvement rates were: BBS: 4.5%, MBI: 3.64%, BDI: 10.7%. Significant differences were found between the two groups. The control group had no significant differences in any factor measured: BBS: 0.8%, MBI: 0.91%, BDI: 2.83%. The researchers concluded that dance exercises in a VR environment have a positive effect on balance, activities of daily living, and depression in older adult PD patients [12].

In another study by Feng *et al.* [13], the effect of VR technology on balance and gait in PD patients was investigated. The study involved 28 patients with PD, who were divided into two groups, the intervention group (n = 14) and the control group (n = 14). The participants of the first group (mean age 67.47±4.79) did VR exercise, namely five minutes of warm-up, 10 minutes of catching a ball in the VR environment with feet and hands, 10 minutes of VR boating, 10 minutes of VR maze, and finally 10 minutes recovery with stretching. The participants of the second group (mean age 66.93±4.64) did conventional physical therapy, specifically five minutes of warm-up with stretching, 10 minutes of balance exercises, 10 minutes of fitness exercises, 10 minutes of coordination exercises, and finally 10 minutes of recovery with stretching. Sessions took place for 45 minutes, five times a week for 12 weeks. Measures before and after the intervention included the BBS, the Timed Up-and-Go (TUG) test, the Third Part of Unified Parkinson's Disease Rating Scale (UPDRS3), and the Functional Gait Assessment (FGA). After the treatments the results in BBS, TUG, and FGA were significantly improved in both groups ($p < 0.05$). In the intervention group, the scores improved by 19.81%, 9.58%, and 44.18% respectively, whereas in the control group by 6.41%, 7.18%, and 13.69%. However, UPDRS3 did not have a significant improvement in the control group (13.55%, while in the intervention group 14.47%). Between the two groups, the intervention group had significantly better outcomes than the control group [13].

Moreover, Gandolfi *et al.* [14] compared improvements in postural stability and balance in PD patients between telerehabilitation at home with balance training in a VR environment and in-clinic sensory integration balance training (SIBT). Participants were 76 patients randomly allocated to the TeleWii group (n = 38) and the SIBT group (n = 38). In total each group did three sessions of 50 minutes per week for seven weeks. The first group performed graded exergames on Nintendo Wii Fit, while the second group did exercises to improve postural stability. Measurements were taken before, after, and one month after the intervention. For the BBS there were significant differences between the two groups, while both improved. At the post-intervention measurement the TeleWii group showed an improvement of 7.69%, when the corresponding improvement in the SIBT group was 9.23%. In the measurement after one month, the first group had an improvement compared to baseline of 6.6%, while the second 8.87%. In secondary outcomes measured (Activities-Specific Balance Confidence (ABC), 10-Meter Walking Test (10-MWT), minimal clinically important difference (MCID), Dynamic Gait Index (DGI), Parkinson's Disease Quality of Life questionnaire (PDQ-8), number of falls), both groups showed differences, except for the fall rate. Additionally, in terms of cost, it was higher in the SIBT group. The authors concluded that VR therapy is a viable alternative to in-clinic SIBT in patients with PD [14].

In their study, Yang *et al.* [15] investigated whether home-based VR balance training is more effective than conventional home-based balance training in improving balance, gait, and quality of life in PD patients. Participants were 23 older adults with PD

divided into two groups, the intervention group (n = 11, mean age 72.5 ± 8.4), who were trained in a personalized VR balance system, and the control group (n = 12, mean age 75.4 ± 6.3), who were trained by a physical therapist. Training period was six weeks with 12 50-minute sessions. Measurements were taken before the intervention, after six weeks, and after eight weeks. Primary outcome was the BBS and secondary outcomes consisted of the DGI, the TUG test, the PDQ-8, and the Unified Parkinson's Disease Rating Scale (UPDRS) score. Both groups scored similarly before the intervention. In the measurements of the sixth and eighth week, there was a similar statistically significant improvement of both groups in the BBS, DGI, TUG, and PDQ-8 scores. For BBS the intervention group showed an improvement of 7.24% from the first to the second measurement and 5.75% from the first to the third. In comparison, the control group showed an improvement of 8.96% from the first measurement to the second and 6.18% from the first to the third. The researchers concluded that both techniques are equally effective in improving balance, gait, and quality of life in older adults with PD. [15].

Another study by Pazzaglia *et al.* [16] compared a rehabilitation program in a VR environment with a conventional rehabilitation program in 51 older adult patients with PD (mean age 71). Participants were randomly assigned to a VR rehabilitation group and a conventional rehabilitation group. The programs of both groups lasted 40 minutes per session with three sessions per week for six weeks. Balance was the primary outcome measured with the BBS. Secondary outcomes included the DGI to assess gait adaptations, the Disabilities of the Arm, Shoulder and Hand (DASH) scale to evaluate upper limb performance, and the Short Form 36 questionnaire (SF-36) for quality of life. In the VR group there was an improvement in the BBS 7.89%, in the DGI 8.02%, in the SF-36 15.38%, and in the DASH scale as it decreased by 27.02%. In contrast, in the conventional treatment group statistically significant changes were found only in the DASH scale as it decreased by 17.16%. The researchers concluded that the rehabilitation of older adult PD patients in VR environments had better results than conventional treatment [16].

In another study by Liao *et al.* [17], the effect of intervention in VR environments on dynamic balance and obstacle overcoming in older adult PD patients was investigated. The study included 36 patients diagnosed with PD, who were randomly allocated into three groups. In the VRWii group (n = 12, age 67.3 ± 7.1) participants performed exercises in a VR environment on the Wii Fit system and in the TE group (n = 12, age 65.1 ± 6.7) they did conventional physical therapy. They each performed their program for 45 minutes and then ran for 15 minutes each session. They attended two sessions per week for six weeks. The last group was the control group (n = 12, age 64.6 ± 8.6) whose participants only received training to avoid falls. The primary outcomes measured were obstacle overcoming performance (measured by crossing speed, stride length, and leg vertical distance from obstacles) and dynamic balance (measured by maximum distance, speed of movement, and direction control calculated with the Limits of Stability (LOS) test). Secondary outcomes consisted of the Sensory Organization Test (SOT), the PDQ39, the Falls Efficacy Scale (FES-I), and the TUG test. The measurements were taken before the intervention, at the end of the intervention, and one month after the end of the intervention. The VRWii group showed greater improvement in crossing speed and length, dynamic balance as well as in the SOT, TUG, FES-I, and PDQ39 compared to the control group. Furthermore, they had better results in the LOS test than the TE group. In

conclusion, the intervention in VR environments had positive effects and statistically significant differences that remained one month after the end of the intervention. A relevant treatment may improve the parameters measured in older adult PD patients [17].

The aim of Albiol-Pérez [18] was to determine whether there would be changes in the postural control of older adult PD patients after a Virtual Motor Rehabilitation System (VMR) intervention. Study participants were 10 patients with PD (mean age 79.60±5.80), who did a total of 15 sessions, consisting of 30 minutes using the Active Balance Rehabilitation system (ABAR) based on weight transfers, approximately five minutes of break, and 30 minutes of conventional therapy with weight transfers from a sitting position. Measurements of postural control were made via the ABAR system in each session. The UPDRS was used to evaluate and measure the results, which showed that there was a statistically significant improvement in the control of the posture in all directions, which implies a reduced risk of falling. Comparing the measurements before and after the intervention, the improvement in left postural control was 3.95%, right 8.24%, and center postural control 2.91%. In conclusion, although older adult patients have PD, through rehabilitation intervention in a VR environment they can maintain or even improve their postural control [18].

Lastly, Gu [19] wanted to evaluate whether a therapeutic rehabilitation program in a VR environment with the Nintendo Wii system would improve balance and balance self-confidence, as well as exercise adherence, in older adult patients with PD. The sample was 15 patients (aged 58-75) with PD who did three 30-minute sessions per week for 12 weeks. Balance was assessed using a ground dynamometer in four different difficulty conditions (EOFA: eyes open – feet apart, EOFT: eyes open – feet together, ECFA: eyes closed – feet apart, ECFT: eyes closed – feet together) before the intervention and at the six-week and 12-week points. Participants completed a balance self-confidence questionnaire each week. The results showed a statistically significant improvement in balance. Specifically, from the first measurement to the second the improvement was: EOFA: 20.58%, EOFT: 19.55%, ECFA: 19.92%, ECFT: 17.32%. From the first measurement to the third (last measurement) the improvement was: EOFA: 14.45%, EOFT: 10.31%, ECFA: 13.72%, ECFT: 9.36%. Furthermore, an improvement was also seen in the self-confidence of the balance, as well as in the adherence to the exercises. In conclusion, rehabilitation in VR environments with the Nintendo Wii is proposed as a cost-effective alternative treatment that can bring positive results. The author suggests the need for further research on the subject [19].

Discussion - Results

The results of our review show that rehabilitation in VR environments could have a positive effect on the balance of older adults with PD. In all included studies an improvement in balance was found, while in some there was also a positive effect on the quality of life [15, 16], gait [13, 15, 16], depression [12], and posture control [17, 18]. Moreover, two studies found it a more economical alternative treatment compared to conventional treatment [14, 19]. The findings of our review are consistent with those of a similar systematic review and meta-analysis [9], which reports that VR rehabilitation can improve balance, motor function, gait, and ability to perform daily activities in older adults with PD. In contrast, yet another similar systematic review and meta-analysis [11] despite arguing that rehabilitation in VR environments can be applied as an alternative treatment to

improve balance, did not find any statistically significant differences. Measurements were made with the BBS, DGI, and FGA scales and indices similar to several studies in our review [12-16]. Regarding studies that compared rehabilitation in VR environments with conventional treatment, four of them showed that the VR intervention group had better results [12, 13, 16, 20] and two found equal results [14, 15].

Conclusions

The results of the studies included in our review show that rehabilitation of older adult PD patients using VR technology positively affects their balance, on par or even better than conventional treatment. The subject requires further investigation to paint a clearer picture.

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