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ORIGINAL RESEARCH

Virtual reality as an intervention tool for upper limbs in Parkinson's disease: a case series

Realidade virtual como ferramenta de intervenção para os membros superiores na doença de Parkinson: série de casos

Realidad virtual como herramienta de intervención para los miembros superiores en la enfermedad de Parkinson: una serie de casos

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ABSTRACT | Parkinson's disease (PD) is a neurodegenerative disorder in which dopaminergic loss occurs in the basal nuclei region. One major complaint associated with PD is upper extremity motor deficits (UE), frequently reported in difficulties to perform activities of daily living (ADL), which may negatively affect quality of life. In recent years new technologies have emerged to assist the UE rehabilitation process in PD, such as virtual reality. Therefore, this study sought to verify the effects of an intervention in the UE with semi-immersive virtual reality equipment on ADLs and quality of life of individuals with PD. Six individuals with PD were selected for intervention, and evaluated by the Mini Mental State Examination, the Hoehn & Yahr Scale, the Unified Parkinson's Disease Rating Scale (UPDRS), the Parkinson's Disease Questionnaire (PDQ-39) and the *test d'évaluation des membres supérieurs de personnes âgées* (TEMPA). The interventions lasted 27 minutes per session, twice per week, for 5 weeks, using the *Leap Motion Controller*. Individuals showed improvement in muscle strength, muscle endurance, ADLs, and quality of life, all statistically significant. In conclusion, the protocol based on virtual reality applied to the upper limbs effectively improved the activities of daily living and quality of life in individuals with PD.

Keywords | Parkinson's Disease; Upper Extremity; Virtual Reality.

RESUMO | A doença de Parkinson (DP) é uma desordem neurodegenerativa na qual ocorre a perda dopaminérgica na região dos núcleos da base. Uma das principais queixas associadas à DP são os déficits motores dos membros superiores (MMSS) frequentemente relatados em dificuldades para realizar as atividades de vida diária (AVDs), podendo interferir negativamente na qualidade de vida. Nos últimos anos novas tecnologias surgiram para auxiliar no processo de reabilitação dos MMSS na DP, sendo a realidade virtual uma delas. Portanto, este estudo teve como objetivo verificar os efeitos de uma intervenção nos MMSS com equipamento de realidade virtual semi-imersiva nas AVDs e na qualidade de vida de indivíduos com DP. Foram selecionados seis indivíduos com DP para intervenção, avaliados por meio do miniexame do estado mental, da escala de Hoehn e Yahr, da escala unificada de avaliação para a DP (UPDRS), do questionário sobre a doença de Parkinson (PDQ-39) e do *test d'évaluation des membres supérieurs de personnes âgées* (Tempa). Seis sujeitos foram submetidos à intervenção com duração de 27 minutos por sessão, duas vezes na semana, por cinco semanas, utilizando o *Leap Motion Controller*. Obteve-se melhora na força muscular, na resistência muscular, nas AVDs e na qualidade de vida, todos com significância estatística. Dessa forma, verificou-se que

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o protocolo baseado em realidade virtual aplicada nos MMSS foi eficaz para melhorar as AVDs e a qualidade de vida dos indivíduos com DP deste estudo.

Descritores | Doença de Parkinson; Extremidade Superior; Realidade Virtual.

RESUMEN | La enfermedad de Parkinson (EP) es un trastorno neurodegenerativo con pérdidas dopaminenérgicas en la región de núcleos basales. Una de las principales quejas asociadas a la EP son los déficits motores de los miembros superiores (MMSS), que muchas veces resultan en dificultades de realizar las actividades de la vida diaria (AVD), lo que impacta negativamente la calidad de vida. En los últimos años surgieron nuevas tecnologías para ayudar en el proceso de rehabilitación de los MMSS en la EP, y una de ellas es la realidad virtual. Por lo tanto, este estudio tuvo como objetivo comprobar los efectos de una intervención en los MMSS utilizando un equipo de realidad virtual semiinmersivo en las AVD y en la calidad de vida de individuos con EP. Se seleccionaron a seis individuos con EP para la intervención, que fueron sometidos a evaluación por el Miniexamen del Estado Mental, la Escala de Hoehn y Yahr, la Escala Unificada de Evaluación de la Enfermedad de Parkinson (UPDRS), el Cuestionario de la Enfermedad de Parkinson (PDQ-39) y el *test d'évaluation des membres supérieurs de personnes âgées* (Tempa). Seis sujetos se sometieron a una intervención de 27 minutos por sesión, dos veces por semana, durante cinco semanas, utilizando el *Leap Motion Controller*. Hubo una mejora en la fuerza muscular, en la resistencia muscular, en las AVD y en la calidad de vida, todos con significación estadística. Así se constató que el protocolo basado en realidad virtual aplicado a los MMSS fue eficaz en la mejora de las AVD y en la calidad de vida de los individuos con EP de este estudio.

Palabras clave | Enfermedad de Parkinson; Extremidad Superior; Realidad Virtual.

INTRODUCTION

Parkinson's disease (PD) is characterized by a slow progression, being the second most frequent neurodegenerative disease worldwide, behind only Alzheimer's disease[1]. Parkinson's disease results from the decrease in the production of idiopathic dopamine, but there are some studies that indicate a possible interaction with genetic and environmental factors. The disease prevalence increases with age, usually affecting individuals aged over 60 years and, rarely, people aged over 40 years[2]. In Brazil, there are approximately 220,000 patients with PD, figure that may double by 2030. Such data are worrisome due to the high incidence of hospitalizations, in addition to the need for medication and care for the rest of life[3].

One of the main complaints of those affected by PD are motor deficits of the upper limbs (ULs), often associated with difficulties in daily tasks such as tying shoelaces, buttoning buttons, typing on keyboards, among others. Since the initial stage of the disease, these changes appear, causing losses in speed and range of motion, with losses in manual function that directly reduce activities of daily living (ADLs) and, consequently, in the quality of life of these individuals, making them more dependent[4]. As the disease progresses, changes in upper limbs will increasingly limiting work, recreation, and ADLs[3,4].

According to the European Physiotherapy Guideline for Parkinson's Disease[5], there are no specifically effective techniques for the rehabilitation of upper limbs in PD, requiring further investigations on beneficial therapies. Among some treatments, techniques such as music therapy[6], based on repetition training in simple and double task[7], movement therapy induced by upper limbs restriction[8], mirror therapy[4], Lee Silverman voice treatment – BIG method to improve the range of motion[9], have been used to rehabilitate and to minimize motor losses in the upper limbs[5].

However, in recent years, new technologies have emerged to assist in the rehabilitation process of subjects with PD, with virtual reality (VR)[10] being one of them. VR treats balance, gait, upper limb and lower limb deficits in different populations, such as older adults, in post-stroke sequelae, in multiple sclerosis and in PD. The techniques that use VR propose an interaction between the patient and a computer system, which creates a virtual environment. Sucha environment can stimulate motor learning via repetition, feedback, and motivation to achieve the expected results[11]. Furthermore, as VR involves cognitive and motor skills stimulation, it can contribute to greater independence in ADLs when compared to training based only on motor exercises. The intervention by VR is promising in the application of upper limbs motor movements[12].

One of the tools used for the rehabilitation of upper limbs is the Leap Motion Controller (LMC)[13], which allows for the creation of a control interface for hand and finger movements, requiring no manual contact or touch with the equipment[14]. There are also other types of instruments that use VR, such as the Kinect[15] and Nintendo Wii exergames, the latter has a motion sensor called the Wiimote and a platform called the Wii Balance Board[16]. However, LMC seems to offer more precise movements as well as more detailed information on hand and finger location, speed and angles of movement[17]. Likewise, this tool is interesting for rehabilitation and can be adapted according to the needs of each individual, promoting a more playful and fun interaction through various movements of the upper limbs that can be performed in several games[18].

Due to the portability and low cost of the sensor, LMC is appropriate for exercises in therapeutic and home environments without extensive supervision. The current literature shows relevant results regarding the use of LMC in the rehabilitation of upper limbs in other pathologies, evaluating gross motor function and manual dexterity, as in stroke[19-21], cerebral palsy[22], Duchenne muscular dystrophy[23], and post-burn rehabilitation[24]. However, only one pilot study with five participants described the use of LMC with a focus on improving dexterity and unilateral and bilateral manual coordination in PD[25]. Thus, this study aimed to verify the effects of an intervention in upper limbs with immersive virtual reality equipment in ADLs and in the quality of life of individuals with Parkinson's disease.

METHODOLOGY

This is a case series with convenience and non-probabilistic sampling, which evaluated and intervened via virtual reality in six individuals with PD. As inclusion criteria, participants should have the understanding of the games on the first day of familiarization and be able to perform the tests. Individuals who had brain pacemaker implantation, who had recent lesions or limitations in the function of upper limbs due to another diagnosis were excluded from the study.

Procedures and evaluations

Two weekly meetings lasting 27 minutes per session were held in the individuals' home environment over five weeks, totaling 10 interventions. Pre- and post-treatment evaluations were performed in the 1st and 10th interventions. The Mini Mental State Examination (MMSE)[26] was used to assess cognitive function encompassing the following domains: temporal orientation, spatial orientation, immediate and recall memory, calculus, language-naming, repetition, comprehension, writing, and drawing copy. This is not a diagnostic tool, but it helps to determine which functions should be investigated. The test procedure is given by a score, in order to assign the individuals' schooling level; thus, the higher the score, the lower the cognitive deficit. Then, the classification of the motor staging of PD was performed by the Hoehn and Yahr scale[27]. Based on this tool, the individual is classified into one of five stages based mainly on signs and symptoms to assess the disability level. Individuals classified in the scale from one to three are in the stages of mild to moderate disability, while those with stages four and five, severe disability.

After this procedure, the unified scale of evaluation for Parkinson's disease (UPDRS) was applied – part III (motor examination), items from 20 to 25, in which resting tremor, postural or kinetic tremor of hands, rigidity, quick finger tapping (thumb and index fingers) with the greatest possible amplitude, opening and closing the hands with fast and wide movements, and, finally, rapid movements of pronation and supination of hands. Recently, a study[28] evaluated and compared the original version (UPDRS) and the updated version (MDS-UPDRS) and found high reliability for the use of these items specifically for the evaluation of upper limbs.

Subsequently, the Parkinson's Disease Questionnaire (PDQ-39)[29] was applied, consisting of 39 questions covering the themes mobility, activities of daily living, emotional well-being, social support, body discomfort, stigma, cognition, and communication. In this questionnaire, the individuals identify how often they found themselves in the situations mentioned in the last 30 days. The options are never (zero points), rarely (one point), sometimes (two points), often (three points) and always (four points). From 0 to 100, the lowest score corresponds to the highest quality of life.

Finally, the *test d'*évaluation *des membrer supérieurs de personnes* âgées (TEMPA)[30] was applied, an instrument that assesses the degree of disability of the upper limbs. It presents a manual on how to administer it, the necessary measures to make the box and where to dispose of the specific material of each task. The materials required for the test are: 100g coffee pot, 1,000mL water jar, coffee spoon, cup, water cup, medicine jar and 10 placebo capsules, white envelopes, seal, pencil, playing cards, coins (R$1, R$0.50, R$0.25, and R$0.10), small glass jar (7cm diameter and 5cm high), small objects (toothpick, nut, safety pin, 2.5cm diameter button and nail), piece of non-slip material and sheets for recording the scores[29]. Figure 1 illustrates the box and materials required to perform the test.

Figure 1. TEMPA Box

The test consists of performing tasks with the upper limbs, such as: (1) opening a pot and removing a spoonful of coffee; (2) unlocking a lock, picking up and opening a container of pills; (3) writing in an envelope and sticking a postage stamp; (4) shuffling and distributing playing cards; and the unilateral ones: (1) reaching and moving a pot; (2) lifting a jar and pouring water into a cup; (3) handling coins; and (4) picking up and moving some objects.

This test was translated into and adapted for Brazilian Portuguese, in addition to being validated for adults with PD. Each task should be timed from the moment the individual removes their hand from the cradle as soon as they finish the task[31]. Tasks are assessed in different ways. First by the speed of execution, and the time should be recorded and then the functional quotation, which refers to the autonomy to perform each task, should be evaluated. Then, the analysis of the tasks must be carried out, which characterizes and quantifies the difficulties faced by the examined individual, being composed of five items: active range of motion, force of execution of the movement, precision of the broad movements, grips and precision of the fine movements. All items are evaluated by a scale score. To complete the assessment, handgrip strength and relative isometric muscle endurance should be measured using a handgrip dynamometer and a stopwatch.

Intervention

Firstly, the patient was trained with the Leap Motion Controller instrument for five minutes for a presentation and interaction of virtual immersion. From the second meeting, the protocol was done in eight sessions: in the first game, lasting seven minutes; in the second and third game lasting six minutes each; and the last game lasting eight minutes, totaling 27 minutes of interaction with games. Between the games, a rest of about two minutes was adopted. The games were chosen in order to relate the movements performed with common tasks performed in the ADLs, and can be found at the Leap Motion website.

The LMC is a device with a Universal Serial Bus (USB) device capable of tracking hands and fingers via VR with high precision and performance[18]. Due to its small size, it is necessary to connect the USB device to the computer and place your hands above the LMC. The instrument has three infrared light emitters and two cameras that receive these lights. Regarding size and weight, it has respectively 8.0×3.0×1.2cm and 45g. As for the precision of the movements, it is the only device that allows interaction with objects of small thickness, from 0.01mm[32]. Figure 2a shows the device with VR interaction.

Participants were seated in a comfortable chair, without forearm support, with elbows flexed at 90°, in front of a table with the computer screen positioned horizontally to the eyes. The first game was the Playground, with three moments: first, hands must be placed under the LMC for calibration; then participants must take the squares and fit into the "bodies" that will appear, ending with the removal of petals from a flower (Figure 2b). Another game used was Takt – Rhythm, which involves hitting the notes where they appear in the space. This game has a score and is divided into difficulty-based levels (Figure 2c). The next game used was Vitrun Air, which consists of dragging a "sphere" along an obstacle course, from which the individual must dodge the obstacles until the end of each level (Figure 2d). Finally, the game Joca – The Handglider was played, which consists of moving a "plane" in order to get as many coins as possible, also dodging obstacles. The score count was restarted if collision occurred (Figure 2e).

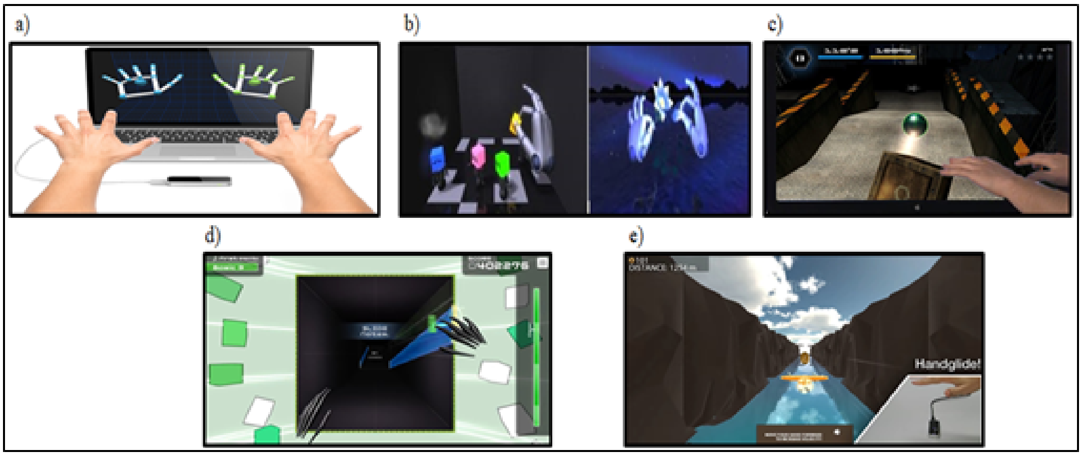

Figure 2. (a) Leap Motion Controller; (b) Playground; (c) Takt – Rhythm; (d) Vitrun Air; (e) Joca – The Handglider

At the last meeting, a satisfaction questionnaire with questions regarding the intervention, considering that most patients had never had contact with a laptop computer. The answers were objective and divided into questions, for example: "Did you feel pain at any time of therapy?", and the patient should mark among the options "a lot," "more or less," or "little."

Statistical analysis

Data were recorded in an Excel database and subsequently analyzed using the Statistical Package for the Social Sciences (SPSS) version 13.0.

In the descriptive analysis of continuous variables, the mean and standard deviation or median (interquartile range) were used. For the categorical variables, the data were expressed in n (% of all cases). The significance level adopted for all tests was 5% (α=0.05). To verify the means before and after the physical therapeutic care, paired t-test for parametric data and the Wilcoxon test for non-parametric data were used.

RESULTS

Among the six participants, two were women and four were men, with a mean age of 70.83 years. As shown in Table 1, participants were positioned from stages two to four on the Hoehn and Yahr scale.

Table 1. Sample demographics

Individual	Age	Gender	H&Y
1	59	W	2
2	76	W	3
3	47	M	3
4	72	M	2
5	86	M	2
6	85	M	4
Average	70.83	-	2.66

H&Y: Hoehn and Yahr scale; M: man; W: woman.

In the MMSE, we did not found statistically significant improvement in cognitive status, comparing pre- and post-intervention values. However, in the PDQ-39 the results showed a significant improvement in the individuals' quality of life. In the UPDRS-III scale (items 20–25), subjects showed no post-intervention improvement (Table 2).

Table 2. Comparison of pre- and post-intervention means and medians

Characteristic	Pre	Post	p
MMSE	23.333 (5.46)	25.333 (5.78)	0.08
PDQ-39	51.38 (26.85)	44.86 (22.29)	0.05*
UPDRS-III (items 20-25)			
ResTre	1.66 (1.36)	1.50 (1.04)	0.36
PostKinTre	2.00 (1.67)	1.83 (1.47)	0.36
Rig	1.50 (1.37)	1.50 (1.37)	-
FinTap	2.00 (1.00-3.00)	1.00 (1.00-3.00)	0.08
HanMov	1.00 (1.00-3.00)	1.00 (0-3.00)	0.15
ProSupM	1.66 (0.81)	1.33 (1.03)	0.17

Data on mean (standard deviation) or median (minimum and maximum). MMSE: Mini Mental State Examination; PDQ-39: questionnaire on Parkinson's disease; UPDRS-III: Unified Scale of Evaluation for Parkinson's Disease – motor examination; ResTre: resting tremor; PostKinTre: postural or kinetic tremor of hands; Rig: rigidity; FinTap: continuously finger tapping; HanMov: hand movements; ProSupM: pronation and supination movements of hands.

*: significant value in the pre- and post-intervention comparison.

Regarding TEMPA, the total result (functional quotation) showed a statistically significant improvement in questions related to ADLs (Table 3).

By analyzing each item corresponding to the tasks performed via the speed of execution, we could also observe a significant improvement in the items "pick up and move a pot – right hand," "lift a jar and pour water into a cup – right hand," "lift a jar and pour water into a cup– left hand," "handle coins – right hand," and "pick up and move small objects – right hand." Moreover, we observed significant positive outcomes in the hand grip strength of the right hand, as well as an improvement in post-intervention isometric resistance, in both hands (Table 3).

Table 3. Comparison of the means and medians of the pre- and post-intervention of TEMPA

Characteristic	Pre	Post	p
TEMPA	−25.83 (12.41)	−22.83 (12.84)	0.03*
PTP-D (sec)	4.77 (3.68-21.22)	3.70 (3.06-10.63)	0.02*
PTP-E (sec)	5.51 (3.25-16.43)	4.07 (2.68-10.20)	0.07*
APTCCC-B (seg)	21.45 (8.38)	19.57 (11.27)	0.32*
PJSA-D (sec)	18.31 (16.10-42.44)	13.82 (9.39-26.41)	0.02*
PJSA-E (sec)	18.85 (14.71-50.99)	14.43 (10.54-36.78)	0.02*
DFARCP-B (sec)	30.52 (27.12)	34.61 (10.75)	0.71*
EECS-B (sec)	40.15 (23.74)	45.39 (17.87)	0.74*
EDCJ-B (sec)	31.26 (22.76)	41.13 (15.89)	0.44*
MM-D (sec)	24.40 (12.37)	19.36 (10.16)	0.01*
MM-E (sec)	23.25 (11.15)	20.21 (5.42)	0.43*
PMPO-D (sec)	23.97 (13.53-38.07)	13.19 (9.72-35.47)	0.02*
PMPO-E (sec)	24.25 (10.72)	23.15 (13.61)	0.85*
Handgrip strength			
Right (kg)	20.97 (9.54)	28.45 (11.64)	0.02*
Left (kg)	21.11 (8.63)	25.59 (10.95)	0.08*
Isometric endurance			
Right (sec)	21.08 (13.84-62.4)	36.81 (24.66-72.45)	0.04*
Left (sec)	26.31 (17.49)	37.39 (21.53)	0.01*

Data on average (standard deviation) or median (minimum and maximum). Tempa: test d'évaluation des membres supérieurs de personnes âgées; PTP-D: pick up and move a pot – right hand; PTP-E: pick up and move a pot – left hand; APTCCC-B: open a jar and take out a spoonful of coffee – bilateral; PJSA-D: lift a jar and pour water into a cup – right hand; PJSA-E: lift a jar and pour water into a cup – left hand; DFARCP-B: unlock a lock and open a container of pills – bilateral; EECS-B: write in an envelope and stick a postage stamp – bilateral; EDCJ-B: shuffle and distribute playing cards – bilateral; MM-D: handle coins – right hand; MM-E: handle coins – left hand; PMPO-D: lift and move small objects – right hand; PMPO-E: lift and move small objects – lefthand.

*: significant value in the pre- and post-intervention comparison.

Regarding the satisfaction questionnaire applied (Table 4), we observed that all participants reported the games as "fun" and "interesting." Considering the difficulty imposed by some games, the individuals answered that the physical therapist support was essential. Some subjects reported that after playing the games, they felt tired or in pain, but nothing that prevented them from performing the intervention.

Table 4. Virtual Reality Satisfaction Questionnaire

No.	Question	IND 1	IND 2	IND 3	IND 4	IND 5	IND 6
1	Are video game sessions fun?	2	2	2	2	2	2
2	Were the games interesting to you?	1	2	2	2	2	2
3	Do games meet a real need?	2	2	2	1	2	2

(continues)

Table 4. Continuation

No.	Question	IND 1	IND 2	IND 3	IND 4	IND 5	IND 6
4	Would you keep using the games if you could?	2	2	2	1	2	2
5	Would you use the games at home?	1	2	2	0	2	2
6	Were the games clear to play and easy to understand?	2	1	1	1	1	0
7	Were you able to play without the support of the physical therapist?	1	1	1	1	0	0
8	If you did receive support, was the physical therapist's support important?	2	2	2	2	2	2
9	Was the game model adequate?	2	2	2	2	2	1
10	Are the elements used in therapy sessions adequate (laptop computer, leap motion)?	2	2	2	2	2	2
11	Were you able to perform all games successfully?	2	1	2	2	1	0
12	Were one-handed exercises simple to perform?	1	1	2	1	1	0
13	Were the exercises with both hands simple to perform?	1	1	1	2	1	0
14	Did the games require much effort?	1	1	2	0	2	2
15	In general, is the level of difficulty of the games adequate?	2	2	2	2	2	1
16	Did you feel tired after playing the games?	0	2	1	0	1	2
17	Did you feel pain at any point in therapy?	0	2	1	0	0	2

IND: individual; "0": little; "1": more or less; "2": much.

DISCUSSION

Based on this study objective, to verify the effects of an intervention in upper limbs with semi-immersive virtual reality device in ADLs and in the quality of life of individuals with Parkinson's disease, in both TEMPA and PDQ-39 tests, individuals with PD improved after intervention. These findings corroborate the study by Tomo et al.[7], who analyzed the effects of training four tasks (wearing a coat, combing hair, answering the phone, and taking a glass to the mouth). In this study, the groups were divided into simple and double task over five one-hour long training sessions and 15 minutes for each task, in which improvement was observed in the box and block test[33]. Alike, our research tasks were similar to the mentioned study, as they intended to improve the functionality of the upper limbs and were similar to the performed ADLs.

Motor limitations related to ADLs—such as mobility and communication—negatively affect quality of life, causing depression and leading to little interaction and participation in the social life of individuals with PD[33]. The study by Fontoura et al.[34] conducted an intervention with conventional physical therapy and VR, using the Microsoft Kinect X-Box console to perform the Kinect Adventures games, which consists of several adventures and sports, and Kinect Dance, which involves dancing, through a motion sensor that tracks the entire body. The intervention involved the performance of movements of the upper limbs with different amplitudes, lasting 30 minutes, for five weeks. The authors observed quality of life improvements, similar to the study by Santana et al.[35], which evaluated the effects of VR on the quality of life of patients with PD, also using the PDQ-39 as an investigation tool.

In the study by Oña et al.[25], an intervention was performed via VR with LMC in a protocol with six games, two sessions of 30 minutes per week, for six weeks, with five patients, observing an improvement in muscle strength, especially in the hand not affected by PD. Furthermore, they also observed that, despite the participants accepting the intervention, they had difficulties executing some exercises. This study showed an improvement in muscle strength and endurance, the latter possibly due to the fact that the participants remained for 27 minutes with elevated upper limbs, contracting muscles such as deltoid, supraspinatus, infraspinatus, round pronator, wrist and finger flexors, among others. According to the questionnaire applied at the end of the study, the interventions were satisfactory, fun, and interesting; however some participants experienced difficulties in performing some movements in the proposed games, sometimes requiring the therapist assistance.

Although some studies indicate that the interaction with VR can become exhaustive and cause fatigue after 20 minutes, the results of this intervention show good potential even in short- and medium-training sessions[24,25]. In the study by Soares et al.[36], the sessions lasted 30 minutes and improved the execution time of the box and block test [33]. Similarly, Wang et al.[37] with 45-minutes long sessions, found possible beneficial results in the recovery of the functioning of the upper limbs in subjects who suffered a subacute vascular accident. In the study by Iosa et al.[20] with sessions of 30 minutes, good results were also found in the recovery of manual skills, assessed via the 9-hole peg test[38] after the LMC intervention. Thus, our research is in line with the aforementioned studies regarding the protocol used—27 minutes per session—since the individuals did not present fatigue or pain that made the intervention impossible, making it possible to perform all games without dropping out during the protocol.

In the study by Santana et al.[35], they observed functional gains in all aspects of UPDRS-III after intervention with VR and functional exercises for upper limbs, lower limbs and balance, in groups that underwent game therapy. Pompeu et al.[39], who conducted a comparative research between groups of individuals with PD who underwent game therapy and balance exercises, showed improvement in motor functioning after the intervention in both groups. In this study, we did not verify significant improvement in the UPDRS-III scale (items 20–25), which is possibly related to the therapy targeting only wide movements of the upper limbs, as well as the small number of participants.

VR presents motor and cognitive demands, in which some specific skills are trained and compromised by Parkinson's disease. The games reflect important elements for motor learning, such as repetition, motivation and feedback, and enhance cognitive use due to the visual and auditory cues provided by the games[40]. Based on our outcomes, even observing the engagement and a better performance in the games during the intervention, no significant improvements were obtained in the MMSE score, which might be explained by the intervention period, stages of the disease from mild to moderate and small sample size. Finally, games can improve attention and concentration by repeating movements and, consequently, stimulate motor learning.

Our outcomes are significant, achieving the proposed objective, showing that the use of the LMC device can be an effective method for rehabilitation in Parkinson's disease. However, there were some limitations in relation to the small sample size, the heterogeneity of the patients and the low number of sessions. Therefore, we suggest to carry out further studies with VR via the Leap Motion Controller to consolidate this intervention tool, with a greater number of sessions, a more homogeneous sample, and more participants.

CONCLUSION

The intervention protocol based on VR was effective in improving the functioning of the upper limbs, thus contributing to ADLs and the quality of life of individuals with PD in this study. Notably, all games improved performance during the intervention and, based on the satisfaction questionnaire, we observed a good acceptance of the proposed protocol. Thus, the semi-immersive virtual reality with the use of the Leap Motion Controller device seems to be an effective proposal for rehabilitation of the upper extremities in Parkinson's disease.

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