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Research Article

Virtual Reality for Upper Limbs in Patients with Parkinson's Disease: Protocol Study

Gisele de Paula Vieira[1], Márcio Nogueira de Souza[2], Marco Orsini[3], Marco Antonio Araujo Leite[4] and Clynton Lourenço Corrêa[1,5]*

[1]*Master and PhD Program in Neurology and Neuroscience, Universidade Federal Fluminense, Brazil*

[2]*Master and PhD Program in Biomedical Engineering, Universidade Federal do Rio de Janeiro, Brazil*

[3]*Master and PhD Program in Rehabilitation Sciences, UNISUAM, Brazil*

[4]*Master and PhD Program in Neurology and Neuroscience, Universidade Federal Fluminense, Brazil*

[5]*Master and PhD Program in Physical Education, Universidade Federal do Rio de Janeiro, Brazil*

***Corresponding Author**: Clynton Lourenço Correa, Laboratório de Neurobiologia Comparativa e do Desenvolvimento, Instituto de Biofísica Carlos Chagas Filho, Universidade Federal do Rio de Janeiro, Av. Carlos Chagas Filho, Bloco G2-001, CCS, Ilha do Fundão, Rio de Janeiro, RJ, Brazil.

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Abstract

Background: Parkinson's disease causes motor impairments with negative effect on activities of daily living. Nowadays, there is no training protocol specialized on functional aspects of the upper limbs in patients with Parkinson's disease. Virtual reality is considered a ludic activity offering visual and auditory feedbacks. Thus, virtual reality emerges possibly as a therapeutic tool in the neurorehabilitation area. In this paper, we describe a protocol based on non-immersive virtual reality for upper limbs of patients with Parkinson's disease.

Methods: This is a study protocol based on a randomized longitudinal clinical study. Samples will be carried out in hospitals, using the following quantitative and qualitative measures: Parkinson's Disease Questionnaire, Unified Parkinson's Disease Rating Scale, Test d'Évaluation des Membres Superieurs of Personnes Âgées and the 9-Hole Peg Test of Upper Extremity Function. To capture the frequency and amplitude of resting tremor, we will use a triaxial accelerometer. Thirty patients between 60 and 70 years old will be invited to the research according to inclusion and exclusion criteria. The samples will be divided into two groups; one will be trained with virtual reality and the other will be trained with conventional physiotherapy.

Conclusion: The protocol presented can be an alternative to assess and to treat upper limbs of patients with Parkinson's disease.

Keywords: *Parkinson's disease; Upper Limbs; Physical Therapy; Virtual Reality*

Abbreviations

ADL's: Activities of Daily Life; bpm: Heart Beats Per Minute; CP: Conventional Physiotherapy; CIMT: Constraint-Induced Movement Therapy; HR: Heart Rate; mmHg: Mercury Millimeter; GDS-15: Geriatric Depression Scale; MMSE: Mini-Mental State Examination; 9HPT: Nine Hole Peg Test; PD: Parkinson's Disease; PDQ-39: Parkinson's Disease Questionnaire; SpO2: Peripheral Oxygen Saturation Functional of Blood Hemoglobin; TEMPA: Test d'Évaluation des Membres Supérieurs des Personnes Âgées; UPDRS: Unified Parkinson's Disease Rating Scale; VR: Virtual Reality

Background

Parkinson's disease (PD) has unknown etiology and is the second most common neurodegenerative disease in the elderly. Although drug therapy is progressing, PD often leads to an expressive motor limitation and severe disability [1]. PD is clinically characterized by

bradykinesia and at least one of the following signals: resting tremor, rigidity, and postural instability. The motor symptoms presented by people with PD can develop into deficits in manual dexterity and strength modulation, affecting the standard functionality of their extremities. Limitations can be observed in activities of daily living (ADL) like writing (micrography), an inability to reach some directions and difficulties in movements that demand accurate dexterity, gripping and manipulating objects, and tasks involving self-care [2].

Among the physical rehabilitation techniques used in PD patients, the effectiveness of virtual reality (VR) has been examined as a potential therapeutic tool for these people. The VR is an interaction technique between the user and a computational system that recreates the environment in an artificial way through virtual interface. The purpose of this technique is to create and to maximize the sense of reality for the user [3,4]. The VR has been used in the rehabilitation of balance and mobility of the elderly [5] and has also been explored with patients with neurological disease [6,7]. However, studies involving the use of VR games in the rehabilitation of PD patients have been poorly reported [8]. Moreover, few studies about VR and PD have targeted benefits for lower limbs [9].

The PD patients present a progressive impairment of motor function, associated with cognitive disability and reduction of quality of life. The disabilities can be reduced with repetitive functional activities. In addition, feedback on the motor performance and motivation are important elements when learning motor ability. It is important to remember that these two elements mentioned above exist in VR.

In PD, low levels of physical activities resulting in the reduction of mobility demonstrate poor maintenance of basic daily functions involving upper limbs. Although physical activities can improve mobility, the adherence to exercises and physical activity programs represent a challenge [10]. Nowadays, there are no training protocols focused on functional recovery of upper limbs in PD patients [9,10]. Thus, the aim of this study is to describe a protocol based on non-immersive VR as a therapeutic tool to improve upper limb function in PD patients. The secondary purposes are: (1) To measure the upper limbs' global function before and after the non-immersive VR training; (2) To compare the motor and manual dexterity before and after the non-immersive VR training; (3) To evaluate the frequency and range of resting tremor in upper limbs before and after the non-immersive VR training and (4) To evaluate the quality of life before and after the non-immersive VR training. In the evaluation of the effectiveness of the non-immersive VR, the results will be compared to the conventional physiotherapy training protocol.

Methods

This study proposes conducting a random and longitudinal clinical protocol based on evaluations with qualitative and quantitative measures. All the procedures will be done on the stage "ON" of the disease with an interval of at least two hours and a maximum of four hours between the medications.

The study will be held at the Fluminense Rehabilitation Association, in Niterói - RJ, Brazil.

Data collected from human research participants will be kept under custody of researchers for varieties purposes, such as: demonstration of priority of claims of intellectual property and requests under Freedom of Information Act. After conclusion of the study, all the material will be handed over to the Institute of Neurology Deolindo Couto, UFRJ, Brazil.

During data collection, only principal investigator and neurologist will have access to interim results.

Upon request, investigators will give any information concerning this study for the Brazilian Research Ethical Committee (BREC). Investigators who are professors will make the final decision to conclude the trial.

BREC periodically reviews and evaluates the accumulated study data for participant safety, study conduct and progress, and, when appropriate, efficacy. Besides, BREC makes recommendations concerning the continuation, modification, or termination of the trial. The BREC considers study-specific data as well as relevant background knowledge about patient population under study.

Participant protection and ethics

All individuals will sign an Informed and Free Consent Form, according to Helsinki declaration, approved by the Research and Ethical Committee.

Inclusion criteria

Individuals must be between 60 and 70 years old and classified in stages 2-3 of Modified Hoehn and Yahr Scale obtaining more than 13 points on the Mini-Mental State Examination (MMSE) for illiterate, 18 points for low/medium education and 26 for education above 9 years and be able to copy the pentagon [11] and must be without physical therapy treatment for at least 3 months preceding the training program.

Exclusion criteria

The exclusion criteria will be: incapacity to obey verbal and visual commands; individuals who present with other neurological and/or associated orthopedic illness that damages their upper limbs function; unstable heart disease or cardiopulmonary insufficiency attested by the physician; resting cardiac rate above 120 bpm, systolic blood pressure in 180 mmHg and diastolic blood pressure above 100 mmHg; postural hypotension; individuals with pacemaker or other kind of biological electronic device implanted as recommended by the Nintendo Wii® equipment manufacturer or with changing drugs and/or dosage during the length of this study.

Recruiting Process

Individuals will be evaluated and selected by a neurologist who is specialized in Movement Disorders. Patients have a diagnosis of Parkinson's disease using the Queen Square Brain Bank criteria [12]. Then, patients will be passed to the Physiotherapy Ambulatory to verify if they comply to the research inclusion and exclusion criteria. The physiotherapist who will treat patients of the Control and Experimental groups will not know what the research is about. All individuals will be volunteers thus, after showing the research processes and methods, the study team will review the research agreement and terms with the research participants. Finally, the research participants will fill out an Informed and Free Consent Form to participate in the research. Unblinding is not permissible for physiotherapists treating patients from Experimental and Control Groups. Unblinding is allowed in cases where patients will be excluded of the study to identify the group which the patient belonged.

Study Population

The sample will consist of 30 individuals, considering a 0.05 sampling error rate according to the statistical calculation applied to the infinite population. The sample will furthermore be composed of both genders, between 60 and 70-years old, diagnosed with Parkinson's Disease, and be confirmed as staging between 2 and 3 of the Modified Hoehn and Yahr Scale. These individuals will be divided into two groups; one will be trained with virtual reality (VR) and the other will be trained with conventional physiotherapy (CP). The groups will be constituted randomly, through a lottery, based on envelopes named as non-immersive virtual reality group and conventional physiotherapy group. If the patient has difficulty for adapting the non-immersive virtual reality, he/she can be allocated to the other group. The physiotherapist who will apply non-immersive virtual reality and conventional physiotherapy should take note any problems and communicate to the principal investigators. Principal investigators will be responsible for the draw of the groups, analysis of the data and decision to end the research.

Evaluation Tools

All individuals will be subjected to the same evaluation to analyze the outcome on the previous and post training period. The following evaluations will be used: Geriatric Depression Scale (GDS-15), PDQ-39, UPDRS, Test d'Évaluation des Membres Supérieurs of Personnes Agées (TEMPA) and Nine Hole Peg Test of Upper Extremity Function (9HPT). An accelerometer will be used to capture the frequency and amplitude of resting tremor.

The GDS-15 is one of the most frequently used instruments for the detection of depression in the elderly. The GDS offers valid and reliable measures for the evaluation of depressive disorders [13]. In our study, GDS-15 short form version will be applied, the total score varies from a minimum of 0 to a maximum of 15. Value equal or more than 6 in the total score represents depression. We highlight that the GDS-15 will not be adopted as a exclusion criterion.

Mini-Mental State Examination (MMSE) will be used for patient selection [14]. This exam has been endorsed and adapted cross-culturally to a culturally relevant Portuguese version [11]. This tool is widely used to track cognitive disorders. It is composed of 30 questions typically grouped in seven different categories, each of them prepared with the intention to evaluate specific cognitive domains: temporal orientation (5 scores), space orientation (5 scores), registration of three words (3 scores), attention and calculation (5 scores), memory of the three words (3 scores), language (8 scores) and visual constructive capacity (1 score). Total score varies from a minimum 0 until the maximum of 30. It was observed that the maximum score on the MMSE depends on the educational level of the individuals, suggesting the following final scores: 13 for illiteracy; 18 for 1 - 7 years of study and 26 for educational level above 9 years of study [15].

Heart rate (HR) will be verified using an oximeter Onyx 9500®, with the sensor positioned on the third finger of the right hand and the reading being determined after the signal stabilization [16]. HR will be verified with the individuals standing in a resting position in order to determine the resting HR, because the individuals with a HR above 120 bpm in rest will be excluded from the sample [16]. Peripheral Oxygen Saturation Functional of Blood Hemoglobin (SpO_2) will also be carried out with the oximeter Onyx 9500®. The SpO_2 will be verified in a resting/ standing position. Individuals presenting SpO_2 in rest < 90% will be excluded from the sample [17].

The Parkinson's Disease Questionnaire (PDQ-39) will be used to evaluate the individuals' quality of life. This data is obtained by a structured questionnaire in an interview Likert scale way, which consists of 39 items that can be answered with 5 different options: "never"; "rarely"; "sometimes"; "frequently" and "always." The scores in each item varies from 0 (never) to 4 (always). The PDQ-39 is divided into eight aspects: Mobility (10 items), Activities of Daily Life (6 items), Emotional Welfare (6 items), Stigma (4 items), Social Support (3 items), Cognition (4 items), Communication (3 items) and Body Discomfort (3 items). The final score for each individual is calculated according to the following calculation formula: 100 x (sum of total scores of the patients on the 39 questions/4x39). The score can vary from 0 to 100, where 0 means the best and 100 the worst quality of life [18].

The Unified Parkinson's Disease Rating Scale - UPDRS will be used to evaluate the signs, symptoms and specific motor activities of patients' daily life through self-reporting and clinical observation. It is composed of 42 items, divided into four parts: mental activity, behavior and mood, activities of daily life (ADLs), motor exploration and drug therapy complications. The grade in each item varies from 0 to 4, the final score varies from 0 to 145. The best score is closer to 0 and the worst score is closer to 145. UPDRS is validated scale, thus making it an appropriate evaluative tool for this study [19].

Test d'Évaluation des Membres Superieurs of Personnes Âgées (TEMPA) will be applied to evaluate the upper limbs function. This test includes eight standard tasks including four unilateral tasks and four bilateral tasks, representing daily life activities. The scores are based on the execution speed, functional graduation and executed task analysis. To evaluate the execution speed, the tasks are timed from the moment the patient takes out the hands from the support (lower platform) until the moment that the patient finishes the task (observing that all tasks must be done as fast as possible). Unilateral tasks will be done twice, one for each upper limb, firstly being executed by the dominant side. The original scale proposes a negative quote, where 0 means absence of incapacity. For the purpose of statistical analysis, on the translated version, the independent values for the signals will be used. Bigger values correspond to a bigger incapacity [20]. TEMPA is a valid and reliable instrument to assess upper limbs activity limitations in PD showing good clinimetric properties and capable of detecting the influence of motor symptoms during the carrying out of daily living tasks [21].

The 9-Hole Peg Test of Upper Extremity Function - 9HPT evaluates accurate manual dexterity and is composed of nine small pegs and a plate with nine holes. The individual is asked to take a peg, one by one, and insert it in the plate holes. Finishing this task, the patient

must remove the pegs and place them back in their original place. The researcher will record the task execution time. The test will be done twice with the dominant side and the non-dominant side. Then, the time average of right and left upper limb will be calculated. The chair and table are regulated according to the patient convenience and comfort [22]. The 9HPT has the potential to serve as a tool easily administered and useful for the evaluation of the upper extremity function of different populations, and individuals with neurological conditions [23,24], including patients with PD [22].

The triaxial accelerometer (Analog Device) - A7260, developed by our team, will be used to capture the resting tremor signal. The portable acquisition system is composed of a USB Daq card of National Instruments 6009 chip, connected to a personal computer. The program loaded into LabView 8.2, using the 1000 Hz frequency sample, does acquisition and data storage. An off-line program, developed in Matlab 6.5 will be used to obtain the following target variables: essential frequency, amplitude and spectral composition, processes the signals on the three axes (anteroposterior, vertical and side-to-side) of acquired accelerometry. Synthetic descriptors can be developed for the spectral composition to summarize all types of tremors.

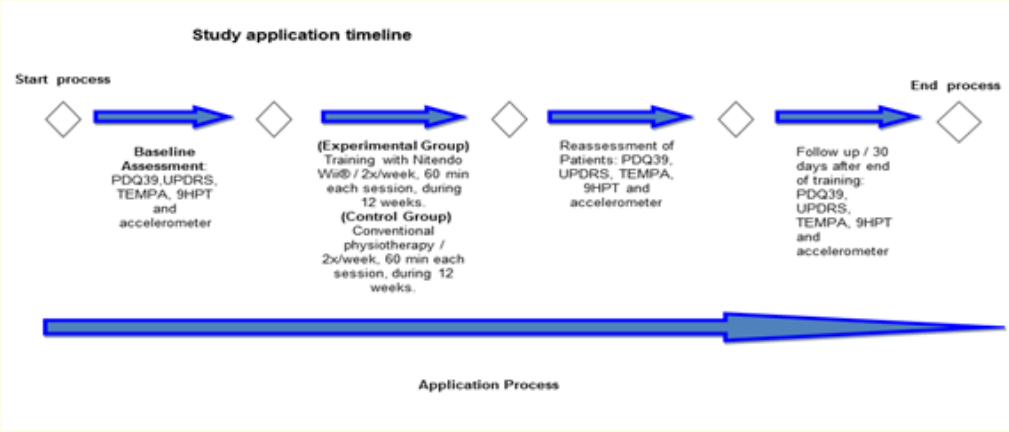

Figure 1: *Study application timeline.*

Training Protocol

Non-immersive virtual reality training (Experimental Group)

Patients will perform two sessions to familiarize themselves with the Nintendo Wii®. The training will last three months, totaling 24 sessions distributed in two weekly sessions with 60 minutes each, directed to the Nintendo Wii Sports Resort® (Canoeing, Table Tennis, Bowling and Sword Play), Super Monkey Bool®, Wii Play® (Mobile target shooting), Deca Sports® (tennis) and Sports Resort (Golf)®games practice. The volunteers will perform bilateral movements in some games and in other games they will perform unilateral movements. The participants will be asked to use their dominant upper limb alternatively with their non-dominant upper limb. The training will begin with the dominant upper limb and after seven and a half minutes using the dominant limb, volunteers will begin training with the non-dominant limb, which will also last seven and a half minutes. During the sessions, if necessary, the volunteer can rest, but the time will not be interrupted. In summary, on the first sitting of each week, four games will be used: Nintendo Wii Sports Resort® (Canoeing, Table Tennis, Bowling and Sword Play). At the second session of each week, the games will be: Super Monkey Bool®, Wii Play® (mobile target shooting), Deca Sports 2® (tennis) and Wii Sports Resort (Golf)®. Each game will last for 15 minutes. After each training period, an evaluation using clinical outcomes will be performed. After 4 weeks of the research completion, the tests will be applied again to evaluate the possible retention effect caused by the physical training with non-immersive VR.

Conventional Physiotherapy for upper limbs (Control Group)

Volunteers will perform the conventional physiotherapy training, following the protocol especially structured for them. The training will take three months, totaling 24 sessions distributed in two weekly meetings, 60-minutes per session. Each session will be directed to 3 sets of practice exercises including flexibility, mobility and functionality for upper limbs.

For the first exercise set, each exercise will be completed 5 times. The following exercises will be done: 1) rotation of the lower torso with the patient supine, knees and hips bent and feet flat; 2) patient positioned in lateral decubitus will perform trunk rotation combined with scapula standards (shoulder protraction with elevation and shoulder retraction with depression).

In the second exercise set, patients must perform the exercises based on proprioceptive neuromuscular facilitation technique for shoulder girdle, trunk and upper limbs. The following exercises will be complete: 1) patient in the lateral position, scapular diagonal: anterior elevation/ posterior depression and anterior depression/posterior elevation. The movements must be oriented by the therapist; 2) Upper limbs' exercises. Each exercise will be performed on the patients' right and left side: 2.1) arm flexion-abduction-external rotation with extended elbow and forearm supination with dorsiflexion of wrist, extension and abduction of the fingers; arm extension-adduction internal rotation with extended elbow, forearm pronation with palmar flexion of wrist, flexion and adduction of the fingers; 2.2) arm flexion-abduction-external rotation with elbow flexion, forearm supination with dorsiflexion of wrist, extension and abduction of the fingers; and arm extension-adduction-internal rotation with elbow extension, forearm pronation with palmar flexion of wrist, flexion and adduction of the fingers; 2.3) arm flexion-abduction-external rotation extending forearm supination elbow with dorsiflexion of wrist extension and abduction of the fingers; arm extension-adduction-internal rotation with elbow flexion, forearm pronation with palmar flexion of wrist flexion and adduction of the fingers; 2.4) flexion-adduction-external rotation with elbow extension, forearm supination, palmar flexion of wrist flexion and adduction of the fingers; and extension-abduction-internal rotation with elbow flexion, forearm pronation, dorsiflexion of wrist extension and adduction of fingers, 2 sets of 5 repetitions each; 3) Next, patients will do bilaterally the following movements with the upper limbs: 3.1) arm flexion-abduction-external rotation with extended elbow, forearm supination with dorsiflexion of wrist, extension and abduction of the fingers. After execution of the movements described above, patients will do bilaterally arm extension-adduction rotation with extended elbow, forearm pronation with palmar flexion of wrist flexion and adduction of the fingers; 3.2) On the right upper limb: Arm flexion-abduction-external rotation with elbow extended, forearm supination with dorsiflexion of wrist, extension and abduction of fingers and left upper limb: Arm internal extension-adduction-rotation with extended elbow, forearm pronation with palmar flexion of wrist flexion and adduction of the fingers. After movement sequences described above, the right upper limb will do arm extension-adduction-internal rotation built with extended elbow, forearm pronation with palmar flexion of wrist, flexion and adduction of the fingers and the left upper limb will do arm flexion-abduction-external rotation with elbow extended, forearm supination with dorsiflexion of wrist, extension and abduction of fingers, in 2 sets of 5 repetitions each.

In the third exercise set, patients will perform two different functional exercises, allocating seven and a half minutes for each, totaling 15 minutes of functional activities per session. The functional activities will be: a) bowling: composed of six pins located 3 meters away from the patient. The patient must take down the pins throwing a tennis ball at them. Each patient will have 3 attempts to accomplish this task. This exercise will be done separately with each upper limb; b) Patients will hold a support grip in each hand. These devices will be linked to cables holding an object. The purpose is to keep the object away by performing the following movements: shoulder abduction and flexion movements, elbow flexion and wrist in neutral position.

Revaluation will be done after the 24sessions. Then, four weeks after the end of training, tests will be applied again to evaluate possible retention effect caused by the training.

Descriptive Statistics

Quantitative data will be analyzed for standard deviation and mean. Data that is not normally distributed will be presented as a median and using interquartile intervals. Qualitative data will be reported as a distribution of frequency and percentage.

Multivariate analysis

Our main goal is to detect if the virtual reality is a training tool to maximize the upper limbs function in patients with Parkinson's Disease, comparing the motor performance between two trained groups (VRand CP). Once the study completed the evaluation of pre-training, post-training and follow up, the data will be analyzed with linear mixed models. This analysis method will also be used to describe our secondary outcome measures (TEMPA, 9HPT, accelerometer and PDQ-39).

Discussion

PD is a progressive neurodegenerative illness with motor and non-motor complications that demands a long period of treatment [25]. Motor complications include resting tremor, rigidity, bradykinesia, balance and gait disturbances, deficits in cardiorespiratory capacity and deterioration of muscle strength (including upper limbs) [26]. Non-motor complications include sensory complaints, autonomic dysfunctions, fatigue, apathy, sleep alteration, depression, cognitive dysfunction and decline in quality of life [27].

With regard to the upper limb function, movement disorders lead to progressive limitations in activities such as reaching, holding and many other motor dexterity tasks [2]. The deficits in the movement speed, strength and strength modulation can significantly affect the functional capacities in patients with PD. Beyond the difficulties of reach, grip and manipulation ability, cognitive losses are observed in the early stages of PD [2].

Considering that the motor complications of upper limbs start in the PD's early stages, it is necessary that the therapist be aware of the patients' needs. In a recent research study, authors reported that a large percentage of physiotherapists do not know specific tools to evaluate the engine capacity of upper limbs. One of the hypotheses relies on the fact that most of the patients complain more about problems with balance and gait than upper limb dysfunctions. Thus, dysfunctions that involve the upper limbs are often not considered the priority for these patients [10]. Consistent with the need for developing tools which evaluate the function of upper limbs in patients with PD, our group is validating the TEMPA (Test d'Évaluation des Membres Superieurs of Personnes Âgées) as an instrument to evaluate the function of upper limbs in patients with PD. The TEMPA evaluates the ADL involving shoulder, elbow, wrist and fingers joints. For this reason, we believe that the TEMPA can be useful as a sensitive instrument to detect functional modifications in patients with PD.

In current research, the 9-Hole Peg Test of Upper Extremity Function - 9HPT has been used as a sensitive tool to evaluate the manual dexterity in patients with PD [10], although there is not an available tool to evaluate all the upper limb movements yet.

As reported above, it is important to emphasize that the loss of functional quality of upper limbs results in the loss of quality of life in these patients [2]. Because patients have functional difficulties with their upper limbs, they are more dependent on basic care, such as: feeding, hygiene and getting dressed. Based on this, research was performed to verify the effect of constraint and induction movements' therapy (CIMT) over the hands and arms functions in patients with PD. For this purpose, the authors included 20 individuals staging between 2 and 3 according to the Hoehn and Yahr scale. Patients were divided into two groups, one was the control group and the other was the experimental group. To evaluate the possible effects of the training of upper limbs function, the authors used the Fugl-Meyer scale [28]. However, the authors used an inadequate instrument to evaluate patients with PD. The Fugl-Meyer scale has elements that evaluate patient's specific conditions with hemiparesis developed to evaluate brain injury. Conditions such as irregular flexor synergy and spasticity are evaluated on this scale, but these conditions are not present in patients with PD. Therefore, this scale is not appropriate to evaluate the upper limbs function in patients with PD.

As mentioned above, there is a gap in the PD patients' rehabilitation, which needs to be filled. Researchers need to investigate therapeutic possibilities concerning the upper limbs function in PD [9]. It is necessary to obtain new instruments that are able to evaluate the function of those limbs and verify techniques and resources in the physical rehabilitation field that offer independence and a better quality of life for these patients.

In this context, the VR emerges as a suitable instrument to be added to neurorehabilitation competencies that address the significant demands of patients with PD as it offers a tool that encompasses visual, aural and tactile feedback. Furthermore, demand focus and cognitive interaction of the patient are needed to achieve good results. In a comprehensive way, physical therapy based on VR is possible to explore not only the motor abilities, but also the cognitive ones thus, making it easier for repetition and motor learning these patients through.

The functional capacity of the patients with PD is different between patients considering the disease progression [29]. According to the scientific evidences [29,30], an important point is that games for people with PD should not be difficult in terms of rhythm or cognitive complexity. Based on this concept, in a recent pilot study [29], the authors developed a specific exergame for PD using KinectTM, focusing on the lower limbs, aiming to improve the movement execution time during tasks. In this game, patients must perform lateral leg movements to try to crush moles that arise from holes in the floor. The movements performed by the patients were captured by the console and then sent and processed on the computer. The 10-Meters-Walk (10MWT) test was used to evaluate the performance of the patients before and after training.

The training protocol was carried out during 5 weeks (4 sessions per week, totalizing 10h). Although the system provides different difficulty levels, an intermediate level was established in order to perform the exercise. The study enrolled a total of 7 subjects with idiopathic PD (4 males, 3 females). Comparing the values obtained in the 10MWT, the authors found statistically significant differences between pre- and post-training.

These findings corroborate with another study [8] where the authors aimed to assess the feasibility, safety and results of playing Microsoft Kinect Adventures™ for people with Parkinson's disease in order to guide the design of a randomized clinical trial. Seven patients (six males, one female) with Parkinson's disease were enrolled in this study (Hoehn and Yahr Stages 2 and 3). The intervention lasted fourteen sessions of 60 minutes, three times a week, playing four games of Kinect Adventures™ (Space Pop, 20,000 Leaks, Reflex Ridge and River Rush). The clinical outcomes were the 6-minute walk test, the balance assessment system, the dynamic gait index, and the PDQ-39 questionnaire. The main finding of this study was that training with Kinect™ was safe and feasible for patients with stages 2 and 3 Parkinson's disease. Patients improved their performance in all four games, suggesting the feasibility of the training. All seven participants concluded the 14 sessions with good adherence. In despite of intense visual stimulation and rapid movement of the head required by the games, none of the participants experienced dizziness, nausea or any of the adverse effects, suggesting that training with Kinect™ could be safe for people with Parkinson's disease.

In a recent study [31], a device based on immersive virtual reality was used to investigate the hypometria in upper limbs of the patients with PD. Patients were randomly assigned in two groups: 8 subjects composed the experimental group (EG); and 7 the active-controlled group (CG). The protocol evaluated the impact of 4-weeks imitation-therapy on movement hypometria in PD. For this purpose, the EG and CG used a same VR system. Patients allocated in the EG imitated full amplitude repetitive finger-tapping movements presented by the VR-avatar at three different tapping rates. Patients allocated in the CG performed a protocol matching the same features presented to the EG (both in the spatial and temporal domains). They performed full-amplitude finger tapping while watching the virtual hand. Thus, for the CG, the VR-avatar reproduced online the self-paced movements performed by the subjects who were instructed to keep a full amplitude (spatial domain) and to follow three different rates (temporal domain). Therefore, the effects of imitation-motor-practice vs. motor-practice alone were evaluated. In both cases the avatar was presented in 1st person's perspective and observed through a head mounted display. The amount of weeks/protocol, sessions/week, and practice and rest-periods/session were the same for both groups: patients trained 3 sessions per week, for 4 weeks. Each session lasted 25 min during the first two weeks and 35 min the last two weeks. The effect of the training was evaluated pre-, post-intervention and 2-weeks after the training period. Movement amplitude increased significantly after the therapy in the EG. Considering EG and CG, motor thresholds and silent periods evaluated with transcranial magnetic stimulation were differently modified by training. This pilot-study indicates that the imitation of full extension movements stimulates visuo-motor

adaptations in turn reducing hypometria. Previous results [32] endorsed the idea that imitation may cause online movement adaptations in PD. However, a study [31] showed that imitation therapy has an offline effect in movement amplitude. EG's hypometria was reduced in virtual and real environments testing. Thus, studies show that clinical validity of the VR is based on transference of trained skills to the real world [32].

In a recent review [33], commercial video games in rehabilitation were used to treat various symptoms in Parkinson's patients. Video games for patients with Parkinson's disease seem to be effective for: (1) Gross motor function - Significant improvements in motor performance were found, especifically, for some gait parameters such as stride length, gait speed, and freezing [8,34,35,36]; (2) Fine motor function - Significant improvements in fine motor skills [37,38] and dual-task activity [39] were observed. The transfer of rehabilitation goals to real-life functionality is an important aspect of neurological rehabilitation (physiotherapy and occupational therapy); the ultimate goal of rehabilitation is to increase autonomy in daily life activities [40]. Therefore, many exercises are task-oriented [41-43]. Unfortunately, video games are often not task-oriented, mainly because of the fact that commercial video games were not developed in response to specific clinical goals.

Conclusion

Research focusing on physical therapy interventions emphasizing upper limbs on patients with PD is very limited. The protocol presented here can be an alternative to evaluate and treat upper limbs of patients with PD.

Ethics and Dissemination

The ethical approval was obtained by the Ethics Committee of the Institute of Neurology Deolindo Couto - INDC/UFRJ (Brazil) - CAAE: 05166912.4.0000.5261. This Committee judged the study design, ethics, and safety rules. The study is registered in the Trial registration: Brazilian Clinical Trials Registry (RBR-4MX7JX). Throughout the study, if an individual presents any problem, the patient will be referred to public health system by the researchers.

Strengths and Limitations of this Study

Strengths

There is a scientific gap concerning physical therapy approach in upper limbs of patients with Parkinson's disease (PD). This study will explore whether videogame console based on virtual reality is capable to improve physical and functional aspects in these patients. In addition, virtual reality offers focus on task demands and requires patient cognitive interaction, important features to achieve therapeutic benefits. This study includes a control group for comparison purposes. This study presents a long-term intervention lasting three months, while other studies address immediate results with short intervention periods.

Limitations

Cardiac performance of patients submitted to non-immersive reality virtual protocol will not be controlled. Thus, authors will not discuss exercise intensity of this physical intervention.

Dissemination Policy

Findings from this research will be publicize via publication and presentation in Conferences, Seminars among others.

Financial Support

GVP is CAPES fellow; CLC is FAPERJ fellow.

Conflict of Interests

The authors declare that there is no conflict of interests.

Authors' Contributions

All the authors were involved on the conception and development of this research, they reviewed it critically and approved the final version manuscript.

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