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Original Research Article

Virtual Reality-Based Training on Upper Body Movement and Activities of Daily Life in Older Adults with Parkinson's Disease

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Abstract

Introduction: Parkinson's Disease (PD) is a progressive neurodegenerative disease that affects both a person's motor and non-motor functions. Adults with PD experience difficulties with walking, balance, bed mobility, and other tasks of daily living (ADL). For older adults living with PD, physical therapy has been shown to greatly improve their quality of life. In recent years, with advancements in technology, physical therapy has made leaps and bounds in the treatment of patients with neurological diseases. One rising innovation in technology that shows promise as an alternative physical therapy treatment is the use of virtual reality (VR). **Purpose:** The purpose of this study was to investigate how VR, focused specifically on the upper body, may affect upper body movement and activities of daily life in people with PD. **Methods:** Five participants with Parkinson's Disease, who ranged in age from 60 to 94 years, participated in 8 weeks of VR training using the *Nintendo Wii Sports* interactive video game. To determine whether there was an improvement in upper body movement and ADLs, the participants' upper body motor ability was assessed before and after *Wii* game training using the Arm Motor Ability Test (AMAT). **Results:** Participants' improvement in playing the *Wii* games did not necessarily show improvement in their ability to complete the AMAT tasks. Only two participants showed an improvement on their AMAT score. When examined by type of task, participants demonstrated an improvement in post-test times on gross motor AMAT tasks but not on fine motor tasks. **Conclusion:** Final results of this study demonstrated that the use of the *Nintendo Wii Sports* interactive video game with people with PD improved the participants' performance on gross motor tasks but not did not improve participants' overall AMAT performance. These results show that interactive virtual reality games may improve people with PD's upper body mobility and activities of daily life while performing gross motor movements.

Key Words: Fine Motor, Gross Motor, Intervention, Physical Therapy, Virtual Reality

Introduction

Parkinson's Disease (PD) is a progressive neurodegenerative disease that affects both a person's motor and non-motor functions[1]. PD usually begins to manifest in late adulthood. An estimated 1% of Americans over the age of 60 and 4% of the oldest Americans in the country are currently living with PD[1]. This percentage of older Americans living with PD is expected to double by the year 2030[1]. Adults with PD experience difficulties with walking, balance, bed mobility, and other tasks of daily living. In addition, adults diagnosed with PD experience upper limb muscle tremors which make it difficult to perform gross and fine motor tasks such as throwing a ball and writing, respectively.

For older adults living with PD, physical therapy has been shown to greatly improve their quality of life. Past physical therapy methods for treating PD have included general physical therapy, balance training, strength training, physiotherapy, aerobic training, and interventions based upon the Lee Silverman Voice Treatment program or LSVT BIG[1-4]. Physical therapy treatment for Parkinson's Disease has been shown to improve an individual's gait, balance, strength, and overall control of muscle movement[1-2,4-6].

Advancements in technology has allowed physical therapy to further our understanding and improve the treatment of patients with neurological diseases. One rising innovation in technology that shows promise as an alternative physical therapy treatment is the use of virtual reality. For years virtual reality, in forms such as interactive video games, has been used by the general public as a popular form of entertainment and mild exercise, but in the past few years physical therapists have begun to incorporate virtual reality into their treatment methods. In physical therapy, virtual reality offers the chance of intensive repetition of tasks with increased visual and auditory feedback to patients allowing virtual reality to be more interesting than conventional physical therapy[7]. Virtual reality, such as in common interactive video games, also allows the user to easily change the difficulty level of the task and has no limitation in terms of time or place making it continuously available for use[8].

The effects of virtual reality have been studied in improving functional balance, gait, and decreasing fall risk in older adults[9-10]. Virtual reality has also ben studied in the treatment of stroke patients and individuals with neurological diseases, such as cerebral palsy[11-12]. The use of virtual reality with patients with PD has also been studied in similar ways. Yen et al.[13] observed the use of virtual reality in balance training with patients with Parkinson's compared to conventional balance training and concluded that there were no significant differences between the outcomes of the two treatment methods. However, the participants in the virtual reality group showed increased somatosensation scores compared to the participants who only received conventional balance training. Likewise, a study was conducted on virtual reality-based *Nintendo Wii Fit* training in improving muscle strength, sensory integration ability and walking abilities of people with PD[14]. In this study participants showed significant overall improvement in strength, balance, and walking ability. The use of virtual reality-based training has also been studied in its ability to improve obstacle-crossing performance and dynamic balance in patients with PD[15]. Results showed that there were no significance differences in improved crossing stride length and velocity between the virtual reality-based training group and the traditional exercise group. More recently, a study investigated improvements in postural stability in patients with PD after they participated in home based virtual reality training with the *Nintendo Wii Fit* system. The virtual reality-based training grouped showed equivalent or higher overall improvement in postural stability compared to a traditional exercise group following the study[16]. Even virtual reality dance games have been used to determine effects on people with Parkinson's balance, activities of daily life, and depressive disorders[8]. Results for this study involving virtual reality dance games showed a significant increase in participants' balance and ability to perform Activities of Daily Living (ADLs), and a decrease in participants' depression disorders.

The majority of early research on the use of virtual reality with PD is focused on lower body movement. It seems clear that the use of virtual reality for the treatment of Parkinson's Disease can improve balance, walking ability, strength, and ability to perform ADLs. However, there are not many studies stating how virtual reality may help to improve upper body motor control in this population. Ma and colleagues[17] investigated how virtual reality training affected functional reaching movements in PD patients. The results for this study showed a decrease in PD patients' movement times as well as an increase in the patients' peak velocity compared to a non-exercise intervention group that targeted fine motor skills. Due to the lack of research on virtual reality training's effects on upper body movement of people with PD, the purpose of this study was to investigate how virtual reality, focused specifically on the upper body, may affect upper body movement and activities of daily life in people with PD.

Methods

Participants

Five participants with Parkinson's Disease, who ranged in age from 60 to 94 years, completed the study. Descriptive statistics are reported in Table 1. During the study one participant was receiving physical therapy for the lower body. The participants were recruited from a local health and rehabilitation center where each of the participants lived. Participants were chosen solely based on their diagnosis of having Parkinson's Disease and ability to participate in the training sessions. IRB approval from Radford University was obtained, and signed consent was required from each participant before testing began.

Instruments

To determine whether there was an improvement in upper body movement and ADLs, the participants' upper body motor ability was assessed before and after training using the Arm Motor Ability Test

(AMAT)[18]. The AMAT is designed to evaluate impairments in upper limb function in post-stroke patients during activities of daily life using a quantitative and a qualitative measure[18]. This battery has demonstrated evidence of test-retest, intra-rater, inter-rater, and internal consistency reliability[19]. Additionally, this test has been shown to be a valid assessment of ADL deficiency as evidence of content-, criterion-, and construct-related validity has been demonstrated[20].

Table 1. Participant information

Participant	Gender	Dominant Hand	Age	Height (inches)	Weight (pounds)
1	M	Right	86	69	185
2	M	Right	60	73	216
3	M	Right	77	74	157
4	F	Right	94	62	158
5	M	Right	88	66	150

Post-stroke symptoms are similar to the symptoms of PD and an appropriate testing battery for PD that assessed the same constructs as the AMAT was not found. For these reasons, the AMAT was selected to assess the effects the virtual reality training had on the PD participants. The AMAT consists of 13 ADL tasks that involve one to three component tasks or movement segments. We did not include the *Prop on Extended Arm* task because it is a balance movement that was not applicable to virtual reality training. Table 2 provides a list and description of 12 ADL tasks that were assessed in the current study. Tasks either require involvement of one arm or both arms. Each task was measured separately, and the participant's score was the time it took to complete the task criteria outlined in the AMAT from start to finish.

Procedures

Virtual reality training consisted of 8 weeks of *Wii* game programming. The researcher led participants in group exercise sessions with other residents of a skilled nursing health and rehabilitation center. During these exercise sessions, the participants played games against one another using the *Nintendo Wii Sports* interactive video game. This video game is designed for all ages, does not require complicated movements, and focuses mainly on the use of the participants' arms and upper torso. The participants played three games using this video game program: boxing, bowling, and golf.

Each participant's upper body mobility was assessed one week prior to beginning the virtual reality training using the AMAT. Testing using the AMAT took thirty minutes to an hour to complete for each participant. Next the participants were led through eight weeks of virtual reality-based exercise sessions using the *Nintendo Wii Sports* game. These exercise sessions were held once a week and were 45 minutes long with time equally divided between each of the three games. Following the eight weeks of exercise sessions, each participant's upper body mobility was once again assessed using the AMAT.

Table 2. AMAT tasks and descriptions of each task[18].

Task Number	Task Name	Task Description	Gross Motor or Fine Motor Movement
1	Knife and Fork Task	Participant used a knife and fork to cut a square piece of playdoh, then brought piece of playdoh to his/her mouth without touching the lips.	Fine Motor
2	Foam "Sandwich" Task	Participant picked up a foam "sandwich" and brought it to his/her mouth.	Gross Motor
3	Eat with Spoon Task	Participant used a spoon to pick-up jellybeans from a bowl and bring the beans to his/her mouth.	Fine Motor
4	Drink from Mug Task	Participant picked up a coffee mug and brought it to his/her mouth.	Gross Motor
5	Hair Combing Task	Participant picked up a comb and imitated combing his/her hair.	Gross Motor
6	Open Jar Task	Participant grasped the lid of a jar and twisted the lid until he/she opened the jar and completely removed the lid.	Gross Motor
7	Tie "Shoelace"	Participant tied the laces of a tennis shoe placed in front of them on the table.	Fine Motor
8	Use Telephone Task	Participant picked up a cordless telephone dialed a predetermined number.	Fine Motor
9	Wipe Up Spilled Water Task	Participant used a paper towel to wipe up a small amount of spilled water.	Gross Motor
10	Put on Sweater Task	Participant put on a button up sweater and buttoned the first two buttons on the sweater	Gross Motor (putting on the sweater) and Fine Motor (buttoning sweater)
11	Put on T-shirt Task	Participant pulled on a t-shirt.	Gross Motor
12	Light Switch/Door Task	Participant, while standing, flipped a light switch "on" then "off" and then opened and closed a door.	Gross Motor

Statistical analyses

Data analysis for the study was both quantitative and qualitative in nature. Percent change for each participants' pre-test and post-test scores on the AMAT was computed to determine whether there was a quantitative change in the participants' upper body motor function (total time for all tasks collectively). The pre-test was administered to the participants a week before virtual reality training began, and the post-test was administered a week after virtual reality training ended. Because the sample size for this study was small, running an inferential test did not seem prudent. All statistics and graphs were computed using *Microsoft Excel Version 16.13.1.*

To examine qualitative data for the study, participants were asked open ended questions at the end of each exercise session to assess each participants' individual experiences during the session. There was no theme analyses to these questions and participants answers were only used to make small changes during the study and enrich qualitative data.

Results

Quantitative

Figure 1 shows the percent changes in times for all five participants' pre-test and post-test AMAT scores. As seen in Figure 1, only two participants (i.e., participant 3 and 4) showed an improvement in their overall times from pre- to post-test. The remaining three participants showed no change on the post-test (i.e., participants 1, 2, and 5). These results show that while some participants improved their movements while playing the *Nintendo Wii* Sports interactive video game, this improvement did not correspond with an overall decrease in the participants' times on the AMAT tasks.

However, when AMAT tasks were split and categorized as either gross or fine motor tasks a trend began to manifest as to how participants performed on tasks. Figure 2 and Figure 3 show the participants' overall changes in time when performing gross and fine motor AMAT tasks. As observed in Figure 2, each participant demonstrated an overall decrease in time to complete gross motor tasks during the post-test. This included the only two tasks that all the participants completed in less time during the post test: the *Drink from Mug* task and the *Wipe Up Spilled Water* task. Likewise, Figure 3 shows that the majority of participants exhibited an increase in time to complete fine motor AMAT tasks during the post-test.

Qualitative

All participants showed improvement in their performance while playing the *Nintendo Wii Sports* interactive video game. At the beginning of the eight weeks of using the game the participants had difficulty with completing full range of motion (ROM) with movements and making contact using the virtual avatars. This difficulty was due to a combination of participants having to learn to use the *Wii* game console technology and learning to accurately move their arms and torso correctly during the games. Participants self-reported feelings of being tired and having muscular soreness following the first session of using the game during open ended questioning at the end of the session. As the participants continued playing the games every week, there were noticeable improvements in completing full ROM movements and making contact using the virtual avatars. The participants also reported less muscular soreness and feelings of being tired following the 45 minutes of game play as the weeks progressed.

Figure 1. Percent change in total time to complete pre- and post-test AMAT.

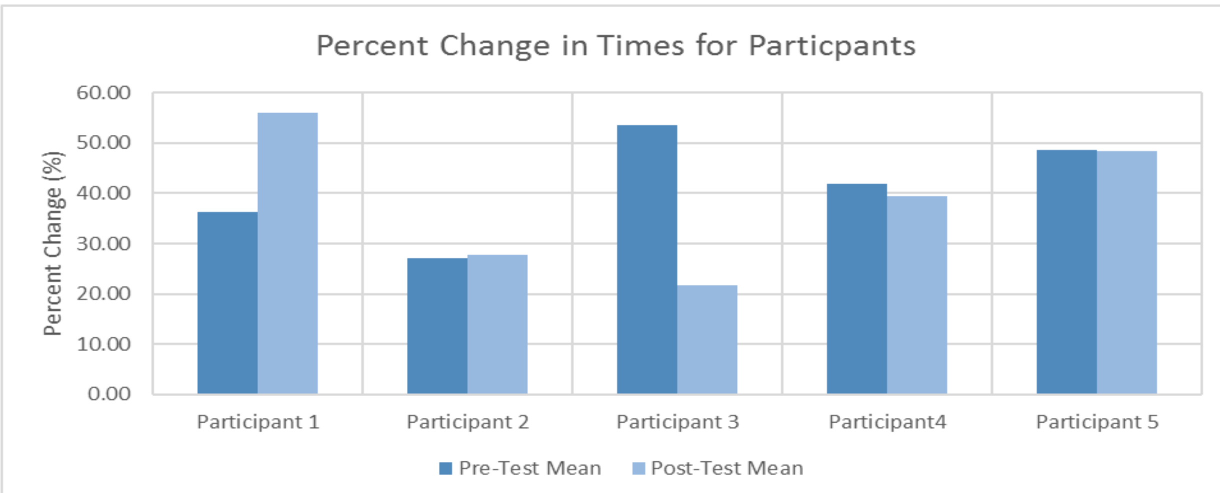


Figure 2. Overall time changes for participants on gross motor AMAT tasks.

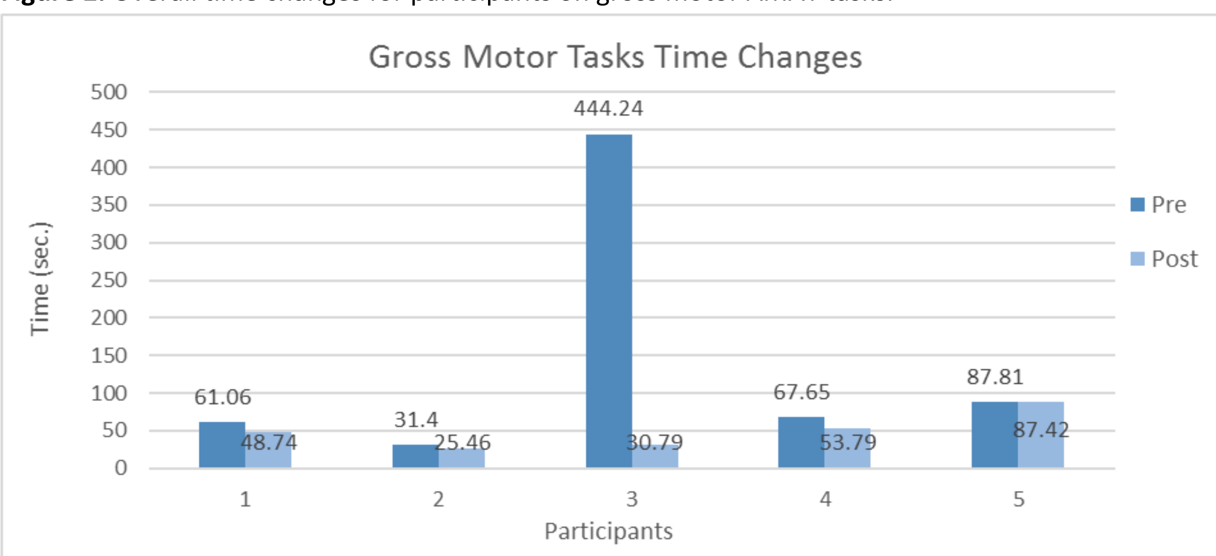
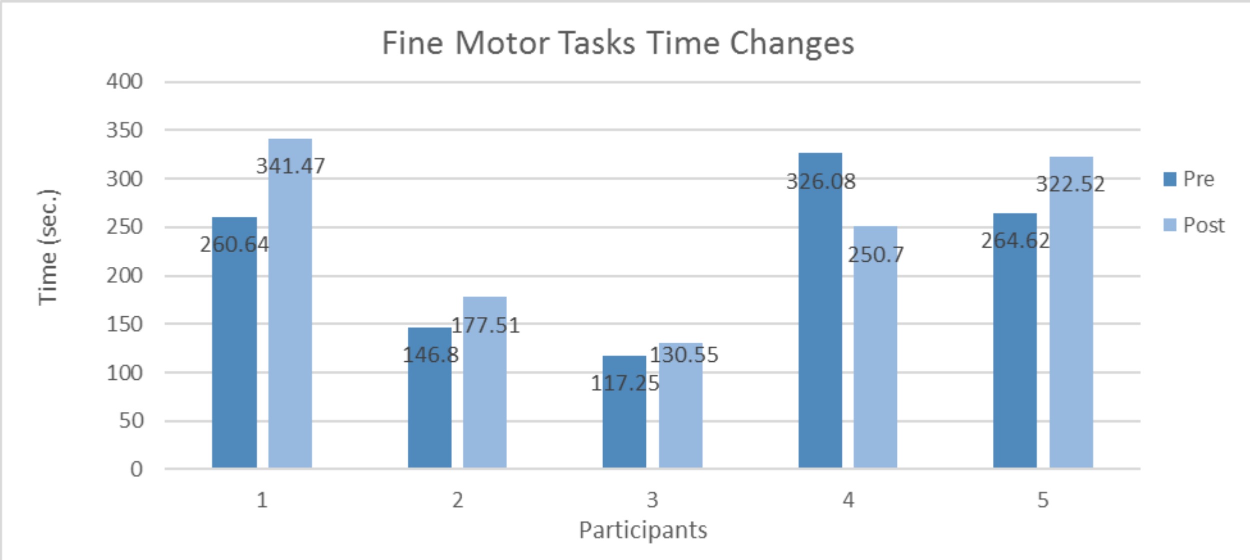


Figure 3. Overall time changes for participants on fine motor AMAT tasks.



Discussion

The key finding for this study was how playing the *Wii* games effected the participants ability to complete gross and fine motor AMAT task on the post-test. In particular, after eight weeks of playing the games, the majority of the participants showed the most improvement in completing gross motor tasks within the battery. This included the two tasks that all the participants showed improvement on: the *Drink from Mug* and the *Wipe Up Spilled Water* tasks. Other gross-motor tasks that the majority of participants improved their AMAT post-test times on included: *Foam "Sandwich"* task*, Hair Combing* task*, Open Jar* task*, and Light Switch/Door* task. This improvement on these particular tasks could be attributed to the participants' improved ROM movements while playing the *Nintendo Wii Sports* game. Participants were required to use their arms and upper torso to swing and punch during the games, all of which are gross motor movements. As the weeks progressed, the participants demonstrated greater ability to complete these movements with full ROM. This improvement in using full ROM for swinging and punching could account for the participants' ability to complete gross motor tasks on the AMAT faster during the post-test than the pre-test.

This study's finding of improved gross motor movement in PD participants correlates with findings from previous studies. Following lower body virtual reality training PD patients demonstrated improved gross motor movements in regards to balance and gait as reported by studies completed by Liao et al.[14-15]. Additionally, in the 2011 study by Ma and colleagues[17] PD participants showed improvements when performing gross motor functional reaching movements following virtual reality training. Specifically, the participants in this study demonstrated a decrease in the amount of time it took to successfully complete the reaching movements[17]. The results of these previous studies agrees with the findings of improved gross motor movement across participants in this current study.

The participants showed the least amount of improvement on completing fine motor AMAT tasks in less time on the post-test. These tasks included such fine motor movements as the *Knife and Fork* task*, Eat with Spoon* task*, and Tie "Shoelace"* task. A comparison of this study's results on fine motor movements in PD patients following virtual reality training to other similar studies was not investigated. One possible explanation for the lack of improvement on these fine motor tasks is the participants' observed difficulties with using the Wii remote controller buttons during the games. While the participants had become better at using the remote controller buttons by the end of the eight weeks, they still struggled to press the correct buttons and often required assistance during the games. Pressing these remote-control buttons exercised the participants' fine motor skills. Their trouble with being able to press the buttons may explain why they did not show as great of an improvement in fine motor AMAT tasks as they did with the gross motor tasks.

These key findings regarding the use of virtual reality training to influence gross and fine motor skills in older adults with PD adds to previous research on this technology's uses with upper body movement in this population. Upper body movement is comprised of both gross and fine motor movements in order to complete varying daily tasks. From turning a door knob to opening a door to putting on and buttoning a sweater, we use varying degrees of gross and fine muscle control every day. Adults with PD struggle with these daily task due to slowness and difficulty in controlling their gross and fine motor skills. A main reason for conducting this study was due to the lack of research on how virtual reality effected upper body movement in adults with PD. This research study demonstrates how the use of virtual reality training not only has an impact on upper body movement but how further research could lead to virtual reality training being used to specifically target gross or fine motor skills in adults with PD.

Additional factors may have had an influence on the results of this study. The most important of these factors is the small sample size of the participants. A larger sample size may have experienced different results to the intervention. The small sample size also accounted for many other influencing factors in this study, including a wide age range for the participants. The participants for this study ranged in ages from 60 to 94 years of age. This wide range could have led to age related influences on participants' performances during the study affecting their stamina, ROM, and speed both during game play and during AMAT testing. Additionally, the small sample sized led to a grossly uneven representation of gender in the study. Only one female participated in the study. This gender gap led to the data being highly influenced by the male participants performance during the exercise sessions and the AMAT testing. Also, the small number of participants in the study did not allow for there to be a control group as a comparison to the virtual reality training. The participants also each exhibited varying degrees of PD symptoms. Most notably, the participants displayed individual differences in experiencing hand tremors. Tremors are a common symptom of PD and the severity of each participant's tremors may have affected their individual performances during the study. Lastly, mood and emotional experiences could have affected participants' performance from week-to-week.

Conclusions

The final results of this study demonstrated that the use of the *Nintendo Wii Sports* interactive video game with people with PD improved the participants' performance on gross motor tasks but not did not improve participants' overall AMAT performance. Additionally, the participants did not demonstrate improved performance on fine motor tasks after completing the eight weeks of virtual reality training. These results show that the use of interactive virtual reality games had the greatest effect on improving upper body mobility and activities of daily life while performing gross motor movements in some persons with PD.

Further study is suggested to continue to investigate the effects of virtual reality interactive video games on upper body mobility and activities of daily life in older adults with PD. Future studies can extend the study period to more than eight weeks to investigate effects after further long-term use of the games. Future research should address the effects of virtual reality on specific age groups, different stages of PD, and gender differences. Also, future research should address how traditional physical therapy treatments for upper body movement and ADLs in people with PD may compare to virtual reality gaming treatment. Moreover, additional research is needed to investigate how virtual reality gaming could be tailored to specifically use and improve fine motor control in PD participants.

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