ABSTRACT

THE EFFECTS OF A MULTIMODAL EXERCISE PROGRAM
WITH DUAL TASK TRAINING ON GAIT PARAMETERS
FOR INDIVIDUALS WITH PARKINSON'S DISEASE

Purpose: Parkinson's Disease (PD) affects spatiotemporal parameters of gait, which is compounded when there is a dual task. The purpose of the current study is to address the multifaceted motor and dual task deficits in PD with a multimodal intervention program in a group setting.

Materials and Methods: Twelve participants (ages 58-82) with Hoehn and Yahr (H&Y) Scale 1-4. Participants completed 60 minutes, 2 times per week of a multimodal program including: limb agility with dual tasking, Computerized Balance Training, overground gait and obstacle training, and dual task gait training and yoga one time a week for 45 minutes. Objective measures included cognitive TUG and spatiotemporal gait parameters.

Results: A repeated measures ANOVA with Bonferroni post hoc test revealed significant results between T_1 and T_3 in Cognitive TUG times for the whole group (P=.008) and for individuals stage H&Y 2 (P=.002). Additionally, significant results were found between T_1 and T_3 in gait velocity during the cognitive TUG (P=.024).

Conclusions: Participants had significant improvements in Cognitive TUG time and gait velocity during the Cognitive TUG. The current study demonstrated benefits in some gait parameters following a 5-week, 3 times per week multimodal program for people with PD.

Jessica Chellsen
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THE EFFECTS OF A MULTIMODAL EXERCISE PROGRAM WITH DUAL TASK TRAINING ON GAIT PARAMETERS FOR INDIVIDUALS WITH PARKINSON'S DISEASE

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BACKGROUND

Introduction

Parkinson's Disease (PD) is the second most common neurodegenerative disease, affecting 1-2 out of 1000 individuals in the US population, and 1 out of 100 individuals over the age of 60.[1,2] It is expected that one million individuals will be living with PD by 2020.[3] PD costs the US $25 billion per year when combining treatment and lost wages secondary to disease processes.[3] Annually, 70% of individuals with PD fall, and 67.7% of those individuals will have an injury, most commonly a femoral neck fracture.[4,5] This increases the risk of dependency in individuals with PD, fear of falling restricting activity, and mortality rate.[5,6]

PD is a progressive and multi-faceted disease, eliciting significant motor and non-motor signs due to the lack of dopamine transmission in the basal ganglia (BG).[7] The BG has four parallel channels: the motor, oculomotor, prefrontal, and limbic which all contribute to the motor and non-motor signs.[7] The most common motor signs observed in PD that contribute to falls include gait deviations, resting tremor, rigidity, motor coordination deficits, and bradykinesia.[2] Bradykinesia is the hallmark of PD, reducing the speed of motor activity, thus reducing force production.[7] As a result, individuals with PD's postural reactions are ineffective, causing more falls and potentially more injuries.[8] Additionally, those with PD can have changes in implicit motor function, resulting in freezing of gait, and loss of postural reflexes causing falls.[2] Individuals with PD have decreased voluntary eye saccades, it has shown to play a role with increased falls.[9,10] Non-motor signs include neuropsychiatric effects such as depression, dementia, and cognitive impairment.[7] It is imperative to identify that PD is heterogeneous in both its presentation and progression.[11] As PD significantly affects so many motor and non-motor areas of life, it has shown to decrease social participation and quality of life.[12,13]

PD significantly affects spatiotemporal parameters of gait, which is compounded when there is a cognitive overlay or dual task.[14-16] Examples of affected spatiotemporal parameters include decreased gait velocity, increased double support time, and increased bradykinesia or stride velocity.[14-16] Gait alterations increase during a dual motor and cognitive task as individuals are forced to rely more heavily on automatic movements because they cannot explicitly think about gait performance.[17] There is significant evidence that physical therapy interventions can improve spatiotemporal parameters of gait during dual tasking.[14,18] An ideal outcome measure to measure changes in performance is the Cognitive Timed Up and Go (TUGc).[19] Recently, the TUGc has been established as a valid and reliable measure for fall prediction in patients with PD, due to the susceptibility of these patients to increase gait deviations while dual tasking.[19]

It is difficult to define traditional physical therapy for PD because there is no consensus on best practice.[20,21] Common practice includes treadmill, gait, balance, strength, dance, Lee Silverman Voice Treatment (LSVT) BIG, boxing, and aerobic training.[21-29] Interspersed with these practices are methods to improve gait rhythm, which is provided by auditory or visual cues.[21] It seems, however, there could be interventions that interact with several of the key facets of the BG providing a “multimodal” program of vision, agility and speed, cognition and postural control.[7,8]

As there are such a wide variety of physical therapy common practices as well as time frames for treatment of those with PD, there is a need for an evidenced based program simultaneously addressing various aspects of the disease. The purpose of the current study will address this heterogeneous disease by creating a 5-week multimodal program to address the four parallel channels of the BG affected in PD: the motor, oculomotor, prefrontal, and limbic.[7] This will contribute to the field of research on PD, to explore the effects of a multimodal group exercise program on spatiotemporal gait parameters and dual tasking.

Pathophysiology of PD

The BG, located in the midbrain, is the anatomic structure involved with PD.[2] The BG has multiple components including the caudate nucleus, putamen, globus pallidus, subthalamic nucleus, and substantia nigra (SN) which contribute to regulation of movement.[2] In PD, the dopamine containing neurons in the SN degenerate, which causes the motor and non-motor signs.[7]

There are two different pathways within the BG, the direct and indirect, which constantly regulate muscle contraction and force, multijoint movements, and sequencing of movements.[7] Excitatory information is transmitted from the cortex to the BG, with SN providing dopamine within the direct pathway which excites the thalamus, transmitting information back to the cortex, initiating movement.[7] Excitation within the indirect pathway via the SN sends an inhibitory influence to the thalamus, thus inhibiting movements.[7] The lack of dopamine transmission within the SN, causes an imbalance in the BG, creating increased inhibition, thus causing the bradykinesia and akinesia observed in PD.[7,30] The BG has parallel channels including the motor, oculomotor, prefrontal, and limbic.[7] These channels play a role in automatic or implicit motor movements, eye movement regulation, cognitive processing, and regulation of emotions and motivation.[7] This concept was used to create the conceptual framework for the current intervention program. The primary motor cortex is also affected in PD, and can contribute to the bradykinesia or low amplitude and velocity of movements seen.[31] Additionally, evidence suggests the lack of motor coordination and involvement of the prefrontal channel cause the disruptions seen in dual tasking or performing a motor and cognitive task simultaneously.[32] The BG significantly affects gait and posture because of its role in implicit motor movements, postural transitions, sequencing motor activities, changing motor programs, and proprioception.[8]

Pathophysiological Effects of PD

Gait Impairments

Gait impairments are the primary motor deficit seen in PD and are directly associated with decreased quality of life and increased patient distress.[33] Gait abnormalities are compounded by bradykinesia, rigidity, and postural instability.[33] At first there are subtle changes in gait such as reduced gait velocity and increased double support time, over time the changes become more apparent including decreased limb velocity, reduced stride length, increased step length variability, stooped posture, and asymmetrical arm swing.[14-16] Individuals with minimal gait deviations in early stages of PD display increased gait deviations during dual tasking including decreased gait velocity, swing time, and left to right lower extremity asymmetry.[16] Lee,[34] an observational study of individuals with PD, determined that increased double support time is related to decreased gait velocity.

Cognitive Impairments

The impaired cognitive processing in PD has shown to cause impaired executive function, thus decreasing the ability to motor plan, which is observed as

3 distinct components; preparation, initiation, and execution of a movement, where execution is the most difficult for those with PD.[30,35] Due to the decrease in executive function, those with PD have been shown to have overestimations of motor ability and perform tasks that may be unsafe, causing more falls.[35] A specific gait challenge that stems from motor planning is difficulty in changing direction and performing serial tasks.[14,35] Individuals with PD also have difficulty with dual tasking due to the decrease in execution of movement and cognition, which correlates with increased risk for falls and decreased quality of life.[15,36] In the more involved stages of PD, they may have freezing of gait during dual tasking, which has also been shown to increase the risk for falls.[9,15]

Pathophysiological Effects of PD

Since PD is multifaceted, heterogeneous, and a degenerative disease, individuals with PD are classified on the Hoehn and Yahr (H&Y) scale, which categorizes individuals by motor function.[37] This scale is classified from 1 to 5 based upon limb involvement, balance, and gait.[37] Stage I patients have unilateral signs and minimal functional impairment.[37] Stage II has bilateral involvement, but no balance deficits.[37] Stage III has decreased righting reflexes and has some functional limitations, only mild to moderate disability.[37] Stage IV the patient is still able to ambulate and stand alone, though very disabled.[37] Stage V the individual is confined to a bed or wheelchair.[37] It is imperative to understand the significant differences between H&Y stages for creating a physical therapy plan of care. Previous research has shown gait speed of individuals with H&Y 3-4 is 24% lower than individuals with H&Y 1 and 2.[33] Additionally, severity of bradykinesia is correlated to higher classification of PD.[38]

Pathophysiological Effects of PD

As PD is a very heterogeneous and multi-faceted disease, there are many approaches to physical therapy and treatment today. Current medical treatments for PD include pharmacologic treatment, surgical treatment, and physical therapy. The pharmacologic treatment is dopaminergic replacement, Levodopa, which generally improves motor symptoms, though side effects include hallucinations, impulsivity and dyskinesia.[39] Postural instability does not respond to Levodopa, thus physical therapy in conjunction with Levodopa has the greatest effect on improved motor function.[8,20] After taking Levodopa long term, there are reductions of the drug's effectiveness with an increase in unpredictable changes in motor output.[2] Additionally, Levodopa can decrease proprioceptive and kinesthesia.[8] Deep Brain Stimulation (DBS) has been shown to be effective for individuals that begin to experience the on-off effect with pharmacologic treatment, and has shown to improve motor signs, function, and quality of life.[2,40]

While primary medical and pharmaceutical interventions have shown improvements, there is significant evidence demonstrating improvements in gait and dual tasking with PT interventions.[14,18,39] Tomlinson et al.[21], a systematic review of 43 randomized clinical trials including gait training, exercise, cuing dance, and martial arts, found an overall improvement in gait and balance parameters as well as a decrease in falls from any physical therapy treatment ranging from 2 weeks to 24 months. This is significant, as patients report that walking improvements determine their satisfaction with a physical therapy plan of care.[33] However, this review emphasized the wide range of treatment times and differences in treatment techniques, and therefore no quantitative analysis could be performed to determine if one treatment technique was better than others.[21] In spite of these findings, there are benefits in group exercise programs as it creates a sense of support, camaraderie, and communication with others.[41] Furthermore, animal models of PD have suggested that aerobic exercise can create neuroplasticity and potentially be neuroprotective from degeneration.[8]

The relevance of this study for rehabilitation is critical. While research is forging ahead, the clinical importance of providing interventions that address broad aspects of gait, motor planning, and serial tasks with cognitive loads have not been addressed. Tomlinson et al.[21] demonstrated that physical therapy treatment can decrease falls which is the biggest cause of mortality.[5] This is important as it will benefit patients, caregivers, and payers due to hospital costs from injuries secondary to falls, and additionally will improve quality of life of individuals with PD.[4,5] Furthermore, physical therapy can improve gait speed which can improve someone from a “limited household walker” to “unlimited household walker” or to a “most-limited community walker.”[21]

Postural Control

Postural control is significantly impaired in those with PD, and postural instability responds poorly to pharmacological management.[42] Specifically these individuals have decreased stability limits, creating a smaller base of support, and are more likely to fall.[6] Rossi-Izquierdo[6] used computerized dynamic posturography (CDP) training which showed improvements in postural control as evidenced by improvements on sensory organization test, rhythmic weight shift, and limits of stability. Additionally, CDP training improved TUG times post treatment and one year follow up.[6] Rivera & Trueblood,[43] a pilot study using a CDP system called the Bertec Balance Advantage used multi-sensory training activities to train aspects of the postural system including somatosensory and vision. This pilot study had significant changes in limit of stability, forward movement velocity, reaction time, end range excursion, gait velocity, and stride length.[43]

Dual Task Training

Recent studies by Grobbelaar et al.[14] and Wong et al.[44] used dual task training during gait for individuals with PD improved gait parameters and dual tasking. Grobbelaar et al.[14] implemented an 8-week randomized control trial using gait parameters during backwards versus forwards gait as an outcome measure. Treatment included dual tasking during gait, as well as serial task obstacle courses, and negotiating objects during gait.[14] Significant changes were made during backwards gait from a dual task program on bradykinesia, gait speed, and stride length.[14] Wong et al.[44] was an 8-week randomized control trial with eighty participants that used a group exercise multimodal program with dual task training. This program was task specific including postural reeducation, flexibility, strength training with functional tasks (opening doors, escalators, speed walking), dance, Wing Chun, and square stepping both indoors and outdoors on unlevel surfaces.[44] This program yielded significant improvements in gait speed with an average improvement of 0.09 m/s ($p<.001$) and TUGc times with an average improvement of 3.5 s ($p<.001$).[44] Dual task training can improve individuals' with PD step length, as well decrease stance percentage and increase swing percentage.[14,15] Wang et al.[45] conducted a meta-analysis whose purpose was to determine if dual task training improves gait and balance in those with PD; the result found that combined motor intervention with a cognitive load does significantly improve these functions in those with PD. These studies indicate the potential for task specific practice with a cognitive load in improving dual task ability and reducing gait abnormalities when performing a dual task, as they likely challenge the oculomotor, pre-frontal, and motor channels.[14,18,45] Strouwen et al.[46] found that greater increases in dual task gait velocity after any dual task training were related to lower initial dual task gait velocity and greater scores of executive function. They also found dual task training is safe, with no increase in fall risk compared to traditional physical therapy.[46]

Gait Training

Gait training is a successful treatment seen in many physical therapy treatment programs to address the gait abnormalities in PD.[14] Gait training programs have included treadmill training, overground training, and training with auditory and visual cues.[14,36,47,48] Overground gait training has shown to improve preferred walking speed, which is related to a decreased fall risk and improved community ambulation.[14,33,49] A gait velocity of 1.2 m/s is required to safely cross the street.[14] Research in overground training shows variation in study methods ranging from 3 weeks to 8 weeks, with a duration of 30 to 60 minutes per week.[14,49,50] Outcome measures included TUGc, TUG, spatiotemporal gait parameters, and posturography.[14,49,50] Overall overground training showed strong statistical significance in Grobbelaar et al.[14] and Schabrun et al.[50] but not Bello et al., where Bello et al. considered overground walking to be on a flat indoor surface for 10 meter distances at a time.[49] These studies emphasized task specific practice, which included gait training overground and dual tasking rather than a treadmill or other controlled environment.[14,49,50] Vitorio et al.[18] instituted a 24-week long pilot study with focus on balance, coordination and strengthening activities in effort to improve motor and cognitive function, posture, and gait. The study found significant improvements in stride velocity, stride length, and stride duration or stance time.[18]

Agility Training

Agility training has been seen to improve bradykinesia, power, mobility, and standing stability in individuals with PD.[51,52] Animal models of PD have shown that task specific agility exercise including obstacle courses is superior to generalized aerobic training in improving motor skills.[53] Landers et al.[54] found that an 8-week high intensity multimodal program that included agility training increased balance, motor activity, strength, and decreased fatigue compared to a low intensity traditional program. King and Horak[8] proposed a 60-minute long agility program with 3 different levels of progression in each facet of the program to address specific sensorimotor impairments seen in PD, with emphasis on speed, use of vision, and different surfaces. This program proposal included an agility obstacle course and various activities forcing trunk rotation.[8] In a similar program of agility, Gunjan et al.[55] showed that a 2-week program of 135 minutes per week of obstacle negotiation during agility training significantly improves stride length, cadence and walking speed. This program not only addressed specific impairments of those with PD, but it also was task specific practice of adding a cognitive overlay as well as serial tasks with agility training, thus likely challenging the motor, oculomotor, and prefrontal channels.[55]

Currently there are a significant number of studies addressing task based interventions that directly intervene on one functional activity. However, there are very few studies addressing the multifaceted impairments in PD with multiple interventions.[18,47] Additionally, few studies using dual task training to address cognitive deficits are multifaceted, and most are very specific to one task such as gait or balance.[47,48] Therefore, there is a gap in the literature, showing minimal studies on multimodal impairments focusing on the distinct pathology of PD: the motor, oculomotor, prefrontal, and limbic channels.[7] Furthermore, all of these studies vary in treatment duration. Currently, there is no evidenced based best practice and duration of treatment for those with PD. As each individual presents with different primary deficits and H&Y classification, these programs should be able to be individualized. Furthermore, there have only been descriptive studies thus far stratifying the H&Y classification in relation to gait spatiotemporal parameters.[33] This review will address the need for an intervention program to address the interaction with both cognitive and motor interventions for PD, with assessment of H&Y classifications.

Purpose and Hypothesis

The purpose of the current study is to address the multifaceted motor and dual task deficits in PD by applying limb agility with cognitive tasks, postural control, overground and obstacle training, and dual task gait training in a group setting. This program is in effort to address the four parallel channels of the BG: motor, oculomotor, prefrontal, and limbic.[7] Yoga is in effort to challenge the prefrontal, motor, and limbic channels; limb agility and overground and gait training to address the motor, oculomotor and prefrontal channels; dual task gait training to address oculomotor and motor channels, and the group setting to challenge the limbic channel.[7] Additionally, the study will add to the literature with the incorporation of visual tracking training and comparison of straight line gait versus a dual serial task. Further, this study will address if individuals with PD classified as H&Y 2 and 3 can improve in dual tasking.

Based on the current literature, the present study was designed to assess the efficacy of a multimodal program in improving stride velocity, TUGc, gait velocity, and double support time in individuals with PD. The null hypothesis states that there will not be a significant difference in individuals with PD in a 5 week program of cognitive and motor intervention using limb agility, postural control, overground and obstacle training, dual task gait training, and yoga between pre testing and post testing gait velocity, double support time, and TUGc scores. The alternative hypothesis states that there will not be a significant difference in individuals with PD in a 5-week program of cognitive and motor intervention using limb agility, postural control, overground and obstacle training, dual task gait training, and yoga between pre testing and post testing gait velocity, stride velocity, double support time, and TUGc scores.

METHODS

Recruitment

Subjects were recruited from the Greater Fresno Parkinson's Disease Support Group via meetings and flyers. Subjects who were interested were contacted via email or phone given a date and time for assessment if they were still interested and met the inclusion and exclusion criteria. On the initial assessment day, all participants signed consent forms and were given a copy of the form for their records. All demographic information was kept in separate locked cabinet from the study's examination findings.

Study Design

This study was a study of convenience with a within group repeated measures design. The design was a 6-week control with a 5-week intervention period, with pre (T_1) mid (T_2) and post (T_3) testing performed prior to the control, after the control, and end of the intervention.

Selection Criteria

All participants recruited had a diagnosis of idiopathic PD. Inclusion criteria was as follows: ages 40-85, H&Y 1-4, ambulatory with or without device, with a stable medical regiment for over one month and be able to follow an exercise program. Exclusion criteria: hospitalized within the last 3 months, a second neurologic diagnosis with resulting motor diagnosis, drug induced psychosis, or poorly or uncontrolled hypertension or cardiopulmonary pathology that precludes person from participating in exercise. Other exclusion criteria were pregnancy, acute thrombosis (acute vascular constriction), artificial joints, acute inflammation of the locomotor system active arthrosis or arthropathy e.g. acute inflammation or swelling of joints, acute tendinopathy in trained regions of the body (acute tendon inflammation), acute hernia (soft tissue prolapse), acute discopathy (acute problems at the intervertebral disc), gallstones or stones in the urinary tract collection system, rheumatoid arthritis and epilepsy due to secondary risk of injury.

Assessment

After signing consent forms, the participants filled out a demographic information form and were given a participant ID number. Testing of all individuals occurred at California State University, Fresno in McLane Hall 1031,104 and 111. Graduate students from the Doctor of Physical Therapy (DPT) Program performed the assessments. All individuals involved in assessments received training in outcome measures. Assessment took approximately one hour and thirty minutes.

Gait assessments were performed on the Zeno Walkway, a computerized mat for gait kinematics. The gait analysis system contains a 16 level sensing pad for collecting and analyzing temporal, spatial and pressure data. The data is analyzed with the Protokinetics software which collects and analyzes data from the walkway. The Zenomat has excellent reliability for measuring gait velocity in individuals with PD.[56] Intraclass correlation coefficient (ICC) for gait velocity and double support time is 0.93-0.99.[56] Gait assessment on the Zenomat included 20 foot walk in a straight line, 20 foot walk with a 180 degree turn, TUG, TUGc, and walking over two obstacles placed ten feet apart. The TUGc has a cut off score of 14.7 seconds for determining fallers from non-fallers in individuals with PD, with a sensitivity of 76.5% and specificity of 73.7%.[19] The TUGc has a positive predictive value of 71% for falls in older adults.[57] Additionally, the American

Physical Therapy Association PD Evidence Database to Guide Effectiveness recommends the use of the TUGc for predicting falls.[58] Spatiotemporal parameters analyzed were gait velocity, stride velocity, and double support time. Other functional outcome measures including posture, functional mobility assessments, balance, saccades, and limb velocity were assessed on test day, but will not be discussed in this paper. The order of these measures were as follows: posture, balance, functional mobility assessments, limb velocity, and saccades and took 1 hour and 30 minutes with break times interspersed.

Interventions

Participants attended 3 sessions per week for 5 weeks. On Mondays and Wednesdays participants attended one of three 60-minute time slots and rotated through four stations including limb agility, balance training, dual task gait training, and overground gait and obstacle training. There were one to two participants at each station at a time. Rest breaks were included within the session. Four individuals supervised each exercise session: the primary investigator and 3 students. On Fridays, the participants attended a group yoga class for 45 minutes, instructed by a doctor of physical therapy yoga instructor. All individuals were mandated to wear a gait belt for safety during all activities. See Table 1 for intervention schedule.

During the intervention, 1 investigator led the computerized balance training, 1 investigator assisted in the limb agility drills, one assisted in gait and step training, while the other investigator assisted in dual task gait training. Specific exercises are described below.

Limb Agility with Cognitive Tasks

Individuals participated in groups of 2. One investigator had one participant at a time participate in several dynamic activities focusing on attention, speed and dynamic balance. Participants stood in front of a 4’x8’ board with various pictures and letters. The investigator called out the name of an object or letter and the participant was instructed to move and touch the picture as quickly as possible with either their left or right hand. This activity focused on forward stepping, side-stepping, upper extremity agility, forward and sideways reaching, and trunk rotation. Throughout the intervention, cognitive difficulty of the task was increased by giving multiple commands at one time. The other participant was resting in sitting. Limb agility training lasted for a total of 15 minutes.

Computerized Balance Training

Computerized Balance Training was used with the Bertec Balance Advantage. Individuals were harnessed for safety. The protocol was fifteen minutes long, including the quick training and vision training modules. Quick training was used to emphasize weight shifting and limits of stability by requiring the individual to shift their weight to various targets with their feet remaining on the platform. The level of difficulty was tailored by increasing the pace or increasing the target distance. Manipulating sway or camera gain allowed the therapist to target somatosensory or vestibular systems. The vision training module involved weight shifting through a virtual reality grocery store to avoid obstacles. The level of difficulty could increase by increasing speed and movement gain, shelf width, shelf density, or floor type.

Overground Gait Training and
Obstacle Training

The investigator had one participant at a time go through various activities focusing on stepping, up, down and turning. The other participant was resting in sitting. The participant wore a gait belt during the activity and gait training was paced to individual tolerance. Overground gait training emphasized speed, trunk rotation, and gait mechanics with or without the use of a metronome. As individuals progressed, gait training began to include step ups-step downs, stepping over and around obstacles, agility ladder negotiation, and backwards walking. Gait training lasted for a total of 15 minutes.

Dual Task Walking Program

Dual task walking program included turning head side to side, up and down, visual activities while walking, changing speeds and step length, and cognitive tasks while walking such as counting backwards or verbally navigating through the environment. Dual-task walking was performed for 15 minutes and was paced to the individual.

Yoga

Individuals participated in group-yoga for 45 minutes consisting of flexibility and slow task based exercise. This class consisted of chair activities, upright activities, and floor activities. For individuals who needed assistance, there were 2 to 3 individuals trained in PD and/or physical therapists. All activities were gradually increased in difficulty throughout the program.

Data Analysis

Data was analyzed using Microsoft Excel 16.16.3 and SPSS 25. Pre, mid and post-test data were analyzed by compiling the mean and SD for each outcome measure. Demographic comparisons were examined to establish the within group distinctions in age, H&Y classifications, PD diagnosis duration, and on/off status for PD medication. Data collections were performed 6 weeks prior to initiating the study, prior to onset of the study and at the end of the 5-week program. Statistics involved a repeated group comparison for gait kinematics, including gait velocity, stride velocity, double support time, and TUGc using a repeated measures ANOVA and post hoc testing using the Bonferroni correction. Variance of data was assessed using Mauchly's test statistic. If the data violated sphericity, the Greenhouse-Geisser estimate of sphericity was used. If this number was greater than 0.75, the Huynh-Feldt correction was used, and if it was less than 0.75 the Greenhouse-Geisser correction was used. Statistical significance was set at $P \leq 05$.

RESULTS

The sample of subjects were recruited through the Greater Fresno Parkinson’s Disease Support Group. Sixteen individuals consented for the study. Four individuals did not complete the intervention, as 2 participants were assessed but did not initiate the study and two participants did not complete the study due to personal reasons. Twelve individuals completed the 6-week no intervention period and 5-week intervention period, as well as participated in post-testing. Participants were 7 males and 5 females aged 58 to 76 years old (M: 66.67 years, SD: 8.09 years). Participants were H&Y 1-4, 6.09 ± 3.75 years since diagnosis and had an average of 1.58 ± 1.44 falls in the last year. See Table 2 for subject characteristics.

Cognitive TUG

A repeated measures ANOVA indicated that the mean TUGc times differed significantly at different assessment points F(2, 22) = 5.107, P=.015. Post hoc analysis using the Bonferroni correction revealed a significant change between T_1 (M=16.0 seconds, SD=1.46), and T_3 (M=12.2 seconds, SD= 1.11), P=.008. The mean change in time from T_1 to T_3 was 3.77 seconds. There was not a significant change between T_1 and T_2 (M=14.57 seconds, SD=1.83, P= 1.0) or between T_2 and T_3 (P=.20). However, TUGc scores decreased during the control period and further decreased during the intervention period. These improvements at T_2 and T_3 fall under the cutoff for fall risk of 14.7 seconds. There is no MCID for the TUGc for PD or community dwelling older adults.[57] See Table 3 and Figures 1 and 2 for Cognitive TUG times.

Gait Velocity

A repeated measures ANOVA indicated that gait velocity differed significantly at different assessment points during the TUGc, $F(2, 14) = 7.312$, $P=.007$ and during the straight line gait walk across the zenomat $F(2, 22) = 4.874$, $P=.018$. Post hoc analysis using the Bonferroni revealed a significant change between T_1 (M=60.5 cm/second, SD=7.02), and T_3 (post M=77.8 cm/second, SD=7.67), P=.024 for TUGc and during straight line gait (T_1 M=100.3 cm/second, SD=4.36; T_3 M= 109.6 cm/second, SD=6.09), P=.05. Post hoc analysis revealed there were significant changes in gait velocity between T_1 and T_2 during the TUGc (P=.026) but not between T_2 and T_3 (P=1.00). Post hoc analysis using the Bonferroni revealed no significant difference between T_1 and T_2 gait velocity (P=.918) and T_2 and T_3 (P=.13) during straight line gait. The mean change in time from T_1 to T_3 during the TUGc was 17.28 cm/s and during straight line gait was 9.27 cm/s. See Tables 4 and 5 and Figures 5-7 for whole group gait velocity results.

Double Support Time

A repeated measures ANOVA indicated that the mean double support time did not differ significantly at different assessment points when performing the TUGc $F(2, 14) = 3.325$, $P=.66$. A repeated measures ANOVA with a Greenhouse-Geisser correction indicated that mean double support time did not differ at different assessment points during straight line gait $F(1.085, 10.9) =2.32$, $P=.156$. See Tables 4 and 5 and Figures 9 and 10 for whole group double support time data.

Stride Velocity

Stride velocity was analyzed with a repeated measures ANOVA with a Greenhouse-Geisser correction indicating that the mean difference of stride velocity times did not differ significantly at different assessment points during the TUGc, $F(1.085, 10.9) = 2.32$, $P=.156$ or during straight line gait $F(1.318, 14.5) = 2.025$, $P=.175$. The mean change in limb velocity from T_1 to T_3 was 5.56 cm/second. The mean change in limb velocity from T_1 to T_3 was 5.72 cm/second during straight line gait. See Tables 4 and 5 and Figure 11 for whole group stride velocity data.

Cognitive TUG: H&Y 2 and H&Y 3

When we analyzed those subjects who were H&Y 2 a repeated measures ANOVA indicated that the mean time to perform TUGc differed significantly at different time points $F(2,12)= 20.994$, $P<.001$. Post hoc analysis using the Bonferroni revealed there was a significant lower time to complete the TUGc in T_3 (M=11.2 seconds, SD=1.11) compared to T_1 (M=14.1 seconds, SD=1.10), $P=.002$. The mean change in time was 2.86 seconds. However, there was also a significant change between T_1 and T_2 (M=12.38 seconds, SD= 1.07), $P=.04$. Whereas, there was no significant change between T_2 and T_3 ($P=.084$) for H&Y 2. In contrast, when we analyzed those subjects who were H&Y 3, there was no significant difference in time to perform TUGc at different time points $F(2,4)=1.607$, $P=.307$. The mean change in time from T_1 to T_3 was 1.31 seconds. See Table 3 for group TUGc times. See Table 6 and Figures 1-4 for TUGc analysis of H&Y 2 and 3.

Gait Velocity: H&Y 2 and H&Y 3

When we analyzed those subjects that were H&Y 2 a repeated measures ANOVA indicated that gait velocity differed significantly at different assessment points during the TUGc F(2, 6) = 9.025, P=.016 and during straight line gait F(2, 12) = 5.479, P=.02. The change from T_1 to T_3 testing in gait speed during the TUGc for the study was .17 m/s falling within the meaningful clinical important difference (MCID) for gait velocity in adults with a pathology 0.1-0.2 m/s.[59,60] Post hoc analysis using the Bonferroni showed TUGc gait velocity met the MCID, though did not meet statistical significance for H&Y 2 from T_1 (M=62.1 cm/second, SD=10.86) to T_3 (M=86.9 cm/second, SD=11.47), P=.09).[59] Post hoc analysis using the Bonferroni revealed no significant difference between T_1 and T_2 gait velocity (P=.14) and T_2 and T_3 (P=1.00) during TUGc. Similarly, post hoc analysis using the Bonferroni showed straight line gait velocity did not improve significantly for H&Y 2 from T_2 (M=103.84, SD=4.98) to T_3 (M= 113.6 cm/second, SD=6.05), P=.82, T_1 (M=104.1 cm/second, SD=4.98) to T_3, P=.159 or T_1 and T_2 gait velocity (P=1.00).

When we analyzed those subjects that were H&Y 3, gait velocity did not differ significantly at different assessment points during the TUGc F (2, 4) = 1.544, P=.318 and straight line gait velocity F(2, 4)= 3.225, P=.147. See Table 7 and Figures 5-7 for gait velocity analysis of H&Y 2 and H&Y 3.

DISCUSSION

The purpose of the current study was to address all motor aspects of PD with the incorporation of dual task training within a multimodal program that follows the framework of the four parallel channels including limb agility, postural training, overground and obstacle training, dual task gait training, and yoga. This study further analyzed H&Y 2 and H&Y 3 ability to improve in an intervention program, comparing within group straight line gait and serial dual task. The interventions were selected for variability, speed, and dual tasking.

There were statistically significant differences in T_1 versus T_3 TUGc time, and gait velocity during the TUGc. These results were replicated in studies with various treatments including long term multimodal training and overground gait training, by Vitorio et al.,[18] Wang et al.,[45] and Wong et al.[47,48] The current study, however, was a shorter term multimodal activity program. Significant improvements in these spatiotemporal gait parameters therefore allowed us to partially accept our hypothesis that there will be a significant difference between pre testing and post testing gait measures and TUGc scores in a 5-week program of cognitive and motor intervention using limb agility, postural control, overground and obstacle training, dual task gait training, and yoga. We accepted that there were significant differences in overall TUGc time and gait velocity during the TUGc from T_1 to T_3. However, we rejected that there will be significant differences in stride velocity and double support time. Additionally, the study revealed significance in TUGc time for H&Y 2.

Looking further at the data, particularly spatiotemporal parameters during the TUGc, there were significant improvements between T_1 and T_2 after the 5-week no treatment period. A potential explanation is the second testing period did not include the entire assessment protocol (did not include the computerized posturography, questionnaires, and the Six Minute Walk Test). Additionally, the participants underwent TUG testing, where they did not demonstrate any change at T_2 from T_1, seen in unpublished article Shirk et al. 2019.[61] The results from the TUG indicate the physical tasks were not affected by the order of assessments, but the TUGc was affected due to the cognitive fatigue at the T_1 and T_3 testing days. Since there were more items to perform on T_1 and T_3, and the computerized posturography is primarily a static activity requiring significant concentration, it could have created more cognitive fatigue than on T_2. Therefore, due to this order effect, to assess the change in spatiotemporal parameters of the participants within the TUGc, the T_1 to T_3 data is a better option. Kluger et al.[62] found that fatigue correlates with processing speed, visuospatial and executive function in individuals with PD. Martino et al.[63] discusses how fatigue in PD is unique in that it encompasses both physical and cognitive elements, where individuals have difficulty initiating and continuing activities that require attention and a physical aspect when they are fatigued.

Cognitive TUG

In the present study, there were significant improvements in TUGc time from pre to post testing. This finding replicated Yamagami et al.[64], using a multimodal study, however the studies revealed differences. Yamagami's study included flexibility, upright agility training and computerized balance training with minimal gait training.[64] The focus was postural changes and fall reduction.[64] The current study specifically emphasized dual task training which significantly increased TUGc results. Our results are also similar to those found in multiple studies addressing balance, gait, and agility with dual tasking which found significant decreases in TUGc time.[44,47,50] Brauer & Morris[65], a test retest design study assessing twenty participants, determined that dual tasking can be improved in individuals with PD based off improvements in gait speed during 6 different dual task assessments. Their results showed gait velocity improvements in straight line gait of 14 cm/s and TUGc of 8 cm/s. This was different than the results in the current study of 9.27 cm/s improvement during straight line gait 17.82 cm/s during TUGc, where there were greater improvements in dual tasking than a single task.

Additionally, individuals who were classified as H&Y 2 had significant improvements in TUGc times from T_1 to T_3 testing, though H&Y 3 did not have significant improvement in TUGc times. This suggests the ability to improve dual tasking in people with less severe PD. Though there was some improvement with persons with PD classified as H&Y 3, perhaps this population requires a longer intervention program to create significant improvements. Improvements on the TUGc have not been stratified in any past studies.

In unpublished study Shirk et al.,[61] the mean change from T_1 to T_3 was greater in TUGc time (3.77 s) than the TUG (2.55 s). The larger increase in TUGc time suggests a relationship between task specific practice of dual task training interventions and improvements in dual tasking, as the only difference in the TUGc and TUG is the addition of a cognitive task.[57] The current study is one of the few studies to review TUGc pre and post physical therapy interventions with dual tasking while performing multiple types of interventions. However, there were two 8 week studies performed by Wong et al.[47,48] that used overground gait training in crowds, walking while talking, and walking over obstacles which significantly increased TUGc scores. The studies were similar in that the TUGc time (-2.1 s) showed greater improvements than TUG time (-0.4 s). These studies provide evidence that improvements in serial tasks and cognitive tasks are possible.

Gait Velocity

Gait velocity displayed statistically significant changes from pre to post during the TUGc. The mean change in gait velocity was greater during the TUGc (17.82 cm/s) than straight line gait (9.27 cm/s). Lee[34] determined that double support time influences gait velocity, although double support time did not improve significantly during the TUGc or straight line gait in the current study. An explanation could be found in a meta-analysis by Wang et al.,[45] who determined that dual task interventions significantly increase gait speed. It is evident that dual task interventions improve gait parameters during serial task dual tasking and straight line gait. The gait velocity changes in the current study during the TUGc also met the MCID of 0.1-0.2 m/s increased gait speed in older adults with a patholgy.[59,60] This again suggests a potential relationship between the emphasis on dual task training during the intervention program and improvement in dual tasking evidenced by the TUGc. However, it could also suggest a learning effect during the TUGc. A past study by Yamagami et al.[64] did not find significant improvements in gait velocity using a multimodal program, however this program did not emphasize dual task gait training in their program. The current study did emphasize dual task gait training, so it appears that task specificity in gait incorporating dual task activities promotes greater improvements in gait parameters.

The study analyzed several gait parameters by stratification of H&Y classifications. These sub-analyses assessed gait velocity in straight line measurements in H&Y 2 and H&Y 3 which did not reveal significant improvements pre to post in gait velocity, although it revealed greater mean change improvements for H&Y 2 (24.76 cm/s) than for H&Y 3 (19.16 cm/s) in the TUGc. This is consistent with the stratification results for improvement on TUGc time. This finding emphasizes the potential for greater improvements in dual task ability for H&Y 2.

Stride Velocity

In the present study there were improvements in stride velocity post intervention, or an increase in lower extremity limb velocity, thus a decrease in bradykinesia. However the findings were not statistically significant. Kim et al.,[66] an observational study, found that clinical bradykinesia showed a higher correlation to limb velocity than amplitude (r=.72-.81), indicating interventions should emphasize speed over excursion. This is consistent with intervention studies with the goal to improve lower extremity bradykinesia.[67,68] The current study emphasized velocity and amplitude, rather than velocity alone which could potentially be why there were not significant changes in stride velocity. Ni et al.[51] emphasized resistance training, balance, and agility in a 3-month intervention program which resulted in significant improvements on upper and lower limb bradykinesia seen in the Unified Parkinson's Disease Rating Scale. Vitorio et al.[18] found significant increase in stride velocity with a 6-month multimodal pilot study addressing coordination of limb movements, resistance exercise, and balance training. Since the current study was only 5 weeks, it may explain why there was not statistically significant increases in stride velocity. The improvements in the present study and the current literature are clinically relevant as bradykinesia is one of the best predictors for quality of life in PD.[66]

Limitations

This study was a continuation of the pilot study performed by Yamagami et al.[64] Further refinement of the current study can be done if the following limitations are addressed. The current study had a small sample size of 12 individuals, and started with sixteen individuals recruited from a support group in Fresno, California. Two individuals dropped out due to inability to attend the frequent program sessions and two did not complete more than one fourth of the study. Due to this small sample size, one participant's results can significantly affect the data. Additionally, this small and local sample size is not representative to the United States' PD population. The study also assessed short-term improvements, but did not assess with a long term follow up.

The assessment days were comprehensive for T_1 and T_3, however the assessment day was not comprehensive for T_2. This clearly impacted the results, as the patients did not have as much cognitive fatigue on the second day. This in combination with a learning effect could potentially explain the improvements at T_2 in this study.

Due to the heterogeneity of the disease, it is difficult to standardize exercise programs, especially across four H&Y levels. Therefore, there were discrepancies in standardization between subjects both with volume, rest breaks, and difficulty. Due to the multimodal nature of the study, there were many interventions that could have contributed to the significant improvements seen.

There were many gait parameters that were not investigated in this study. Further analysis of stride length, single support time, and gait kinematics should be explored to further determine the changes being documented from the multimodal program.

Clinical Relevance/Implications for Practice

The current study demonstrated benefits in some gait parameters following a 5-week, 3 times per week multimodal program for people with PD. A program should address gait, balance, dual tasking, and postural control deficits. The current study also suggests that a 5-week program is successful in addressing several gait deficits. Additionally, previous studies emphasized the use of medical devices which contrasts with the present study with the relative ease of clinical application in that over ground gait training, agility, and dual tasking do not require significant amounts of equipment.

When comparing this program to the previous study done by Yamagami et al., there was no program that was embedded specifically for gait training velocity, this program relegated 15-20 minutes per session on gait training and velocity.[64] The improvements in gait parameters were evident in the current study. Thus, in the clinic it is imperative to practice task-specific gait training both indoors and outdoors, with incorporation of dual task training.

This intervention program gave the opportunity to practice serial tasks and dual tasking, where the participants made resounding gains in just 5 weeks. This could imply the use it or lose it principle of neuroplasticity, as many participants may not have been routinely implementing these activities at home.[7] This study shows the capability of improvement and practice is there, however they need to practice these skills in physical therapy.

This program created improvements in bradykinesia in the stated outcome measures, though did not reach statistical significance. As bradykinesia is one of the strongest predictors of quality of life, it is imperative to address this deficit in physical therapy by including a high intensity, multimodal program.[66]

Looking at both the significant results from TUGc times and gait velocity, it is important to discuss early intervention for individuals with PD stage H&Y 2. Though these individuals may not feel significantly disabled and may not actively seek physical therapy at this stage, their improvements go to show their impairments they had not only with dual tasking and gait velocity, but also their gains made. With a program that is able to be individualized, this allows higher level individuals to still be challenged.

Further Direction

Future research can address if the improvements are in fact sustainable by doing a long term re-assessment to determine if the dual task and gait parameter improvements last long term.

Future research could use the Alternating Intake Test (AIT) as an outcome measure that has been established as a valid and reliable measure of assessing executive function in PD.[69] The AIT was shown to predict ability to improve dual task gait velocity in Strouwen et al.[46]

Additionally, vestibular training could be incorporated in the overground and obstacle training portion of the multimodal program as Rossi Izquierdo[6] found vestibular processing was deficient in all stages of PD.

As there were significant improvements on both dual tasks and non-dual motor tasks resulting from the dual task interventions, it is clear that dual task training should be a focus in the clinic. Since there were improvements, but not significant changes for H&Y 3 with TUGc outcomes, it may suggest these individuals require a longer intervention program in the clinic.

Future research could also determine an MCID for the TUGc and the PD population.

Conclusions

The results of this study indicate that a 5-week multimodal intervention program improves TUGc time and gait velocity. Individuals with H&Y I-IV all made improvements, however those with H&Y II made larger improvements. This study can influence clinicians to incorporate dual tasking and gait training in their intervention programs for individuals with PD as well as give a guideline on volume of intervention needed to see improvements.

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TABLES

Table 1. Sixty Minute Intervention Schedule

Participant 1-2		Participant 3-4		Participant 5-6		Participant 7-8	
Limb agility with cognitive tasks	15 min	Overground gait training	15 min	Dual Task walking	15 min	Computerized Balance Training	15 min
Computerized Balance Training	15 min	Dual Task walking	15 min	Limb agility with cognitive tasks	15 min	Overground gait training	15 min
Overground gait training	15 min	Computerized Balance Training	15 min	Dual Task walking	15 min	Limb agility with cognitive tasks	15 min
Dual Task walking	15 min	Limb agility with cognitive tasks	15 min	Computerized Balance Training	15 min	Overground gait training	15 min

Table 2. Subject Characteristics

Subject Demographics							
PD #	Sex	H&Y	Age	Years Since Diagnosis	Number of Falls in the Last Year	Number of Falls in the Past 6 Months	Number of Falls in the Past Month
01	M	2	59	5	0	0	0
02	M	4	82	8	2	1	0
03	F	2	59	3	1	1	0
05	F	2	65	6	1	0	0
06	M	3	70	7	3	1	1
07	M	2	76	3	0	0	0
09	M	3	61	8	3	0	0
12	M	3	73	12	4	2	0
13	M	1	59	2	2	2	2
15	F	2	74	1	3	1	0
16	F	2	58	N/A	0	0	0
17	F	2	64	12	0	0	0
Mean		2.33	66.67	6.09	1.58	0.67	0.25
SD		0.78	8.09	3.75	1.44	0.78	0.62
Legend: PD: Parkinson’s Disease; H&Y: Hoehn & Yahr Scale; SD: Standard Deviation							

Table 3. Cognitive TUG Times

	Cognitive TUG (seconds)			
PD#	T_1	T_2	T_3	
01	17.34	12.96	13.12	
02	22.50	29.31	21.75	
03	13.00	12.60	11.45	
05	10.87	09.15	07.66	
06	26.00	12.81	13.84	
07	14.03	13.06	12.84	
09	20.64	24.97	11.81	
12	13.37	10.85	11.16	
13	10.19	10.19	09.00	
15	18.60	17.72	15.31	
16	13.65	11.47	11.06	
17	11.23	9.72	07.25	
MEAN	15.95	14.57	12.18	T_1-T_2: P=1.00
				T_2-T_3: P=0.200
SD	1.46	1.83	1.11	T_1-T_3: P=0.008
Legend: TUG: Timed Up and Go; PD: Parkinson's Disease; SD: Standard Deviation				

Table 4. Gait Parameters Cognitive TUG

	Gait Velocity (cm/second)				Double Support Time (seconds)				Stride Velocity (cm/second)			
PD #	T_1	T_2	T_3		T_1	T_2	T_3		T_1	T_2	T_3	
01	50.08	N/A	67.33		1.04	N/A	0.46		53.48	N/A	69.17	
02	N/A	42.09	40.76		N/A	0.57	0.56		N/A	41.67	41.42	
03	36.39	80.74	80.77		0.68	0.33	0.33		37.03	81.62	81.23	
05	76.77	93.31	86.89		0.37	0.30	0.31		76.96	96.92	87.06	
06	38.61	62.94	57.09		0.76	0.47	0.52		42.01	62.43	57.51	
07	68.20	N/A	77.74		0.43	N/A	0.39		68.22	N/A	77.82	
09	42.28	34.41	72.85		0.53	0.66	0.41		40.97	34.95	73.79	
12	72.31	87.86	80.71		0.41	0.37	0.39		77.66	84.48	80.85	
13	77.84	99.24	74.14		0.44	0.39	0.35		77.59	98.95	75.57	
15	54.02	N/A	72.10		0.50	N/A	0.39		56.95	N/A	72.14	
16	63.16	75.01	91.95		0.31	0.39	0.33		64.02	79.92	92.08	
17	86.35	105.08	131.49		0.35	0.29	0.28		86.63	105.27	136.87	
MEAN	60.54	75.96	77.82	T_1-T_2: P=0.026 T_2-T_3: P= 1.00	0.53	0.42	0.39	T_1-T_2: P= 0.64 T_2-T_3: P=0.96	61.96	76.25	78.79	T_1-T_2:P= 0.34 T_2-T_3: P=0.51
SD	7.02	8.15	7.67	T_1-T_3: P=0.024	0.06	0.04	0.03	T_1-T_3: P=0.09	17.10	22.80	20.31	T_1-T_3: P=1.00

Legend: TUG: Timed Up and Go; PD: Parkinson's Disease; SD: Standard Deviation

Table 5. Gait Parameters Straight Line Gait

	Gait Velocity (cm/second)				Double Support Time (seconds)				Stride Velocity (cm/second)			
PD #	T_1	T_2	T_3		T_1	T_2	T_3		T_1	T_2	T_3	
01	122.8	107.3	120.5		0.29	N/A	0.31		123.0	107.6	120.8	
02	77.89	79.01	62.00		0.38	0.46	0.46		80.29	79.31	62.51	
03	97.89	108.3	111.9		0.28	0.27	0.28		97.91	108.5	112.3	
05	101.7	113.3	127.0		0.28	0.34	0.27		110.7	113.5	127.1	
06	82.13	79.35	96.83		0.48	0.51	0.36		82.40	81.49	97.26	
07	95.80	93.47	94.57		0.33	0.36	0.38		95.73	136.1	94.93	
09	87.67	37.12	105.1		0.50	1.08	0.32		86.40	48.75	105.3	
12	110.3	104.4	119.8		0.33	0.35	0.36		110.6	106.7	121.2	
13	117.0	116.9	136.0		0.34	0.36	0.31		117.5	118.6	136.2	
15	88.49	82.65	90.23		0.39	0.42	0.40		88.75	83.13	90.59	
16	100.0	104.8	117.7		0.27	0.35	0.31		102.3	104.8	117.8	
17	122.0	117.1	133.1		0.28	0.31	0.27		122.7	117.4	133.4	
MEAN	100.30	95.35	109.57	T_1-T_2: P= 1.00 T_2-T_3: P=0.13	0.35	0.44	0.34	T_1-T_2: P= 0.34 T_2-T_3: P=0.51	101.5	100.5	110.0	T_1-T_2: P= 1.00 T_2-T_3: P=0.45
SD	4.36	6.60	6.09	T_1-T3: P=0.05	0.02	0.07	0.02	T_1-T3: P=1.00	4.43	6.75	6.08	T_1-T3: P=0.07

Legend: PD: Parkinson's Disease; SD: Standard Deviation

Table 6. Cognitive TUG H&Y Stratification

	H&Y 2: Cognitive TUG (seconds)			
PD #	T_1	T_2	T_3	
01	17.34	12.96	13.12	
03	13.00	12.60	11.45	
05	10.87	09.15	07.66	
07	14.03	13.06	12.84	
15	18.60	17.72	15.31	
16	13.65	11.47	11.06	
17	11.23	09.72	07.25	
MEAN SD	14.10 1.10	12.38 1.07	11.24 1.11	T_1-T_2: P= 0.04 T_2-T_3= P= 0.40 T_1-T_3: P=0.002
	H&Y 3: Cognitive TUG (seconds)			
PD#	T_1	T_2	T3	
06	26.00	12.81	13.84	
09	20.64	24.97	11.81	
12	13.37	10.85	11.16	
MEAN SD	20.00 3.67	16.21 4.42	12.27 .81	T_1-T_2: P=1.00 T_2-T_3: P=1.00 T_1-T_3: P=0.36

Legend: TUG: Timed Up and Go; PD: Parkinson’s Disease; H&Y: Hoehn & Yahr Scale; SD: Standard Deviation

Table 7. Gait Velocity H&Y Stratification

H&Y 2: Gait Velocity (cm/second)								
	Cognitive TUG				Straight Line Gait			
PD #	T_1	T_2	T_3		T_1	T_2	T_3	
01	50.08	N/A	67.33		122.8	107.27	120.5	
03	36.39	80.74	80.77		97.89	97.89	111.9	
05	76.77	93.31	86.89		101.7	101.71	127.0	
07	68.20	N/A	77.74		95.80	117.87	94.57	
15	54.02	N/A	72.10		88.49	88.49	90.23	
16	63.16	75.01	91.95		100.0	100.02	117.7	
17	83.35	105.1	131.5		122.0	121.95	133.1	
MEAN	62.14	89.28	86.90	T_1-T_2: P= 0.14 T_2-T_3: P=1.00	104.10	103.84	113.58	T_1-T_2:P= 1.00 T_2-T_3=0.82
SD	10.86	6.93	11.47	T_1-T3: P=0.09	4.98	4.52	6.05	T_1-T3: P=0.16
H&Y 3: Gait Velocity (cm/second)								
	Cognitive TUG				Straight Line Gait			
PD#	T_1	T_2	T_3		T_1	T_2	T_3	
06	38.61	62.94	57.09		82.13	79.35	96.83	
09	42.28	34.40	72.85		87.67	37.72	105.1	
12	72.31	87.86	80.71		110.3	104.36	119.8	
MEAN	51.06	61.73	70.22	T_1-T_2: P= 1.00 T_2-T_3: P=1.00	93.38	73.81	107.2	T_1-T_2:P= 0.98 T_2-T_3:P=0. 56
SD	10.68	15.44	6.94	T_1-T3: P=0.29	8.62 19.44		6.73	T_1-T3: P=0.081
Legend: TUG: Timed Up and Go; PD: Parkinson's Disease; H&Y: Hoehn & Yahr Scale; SD: Standard Deviation								

FIGURES

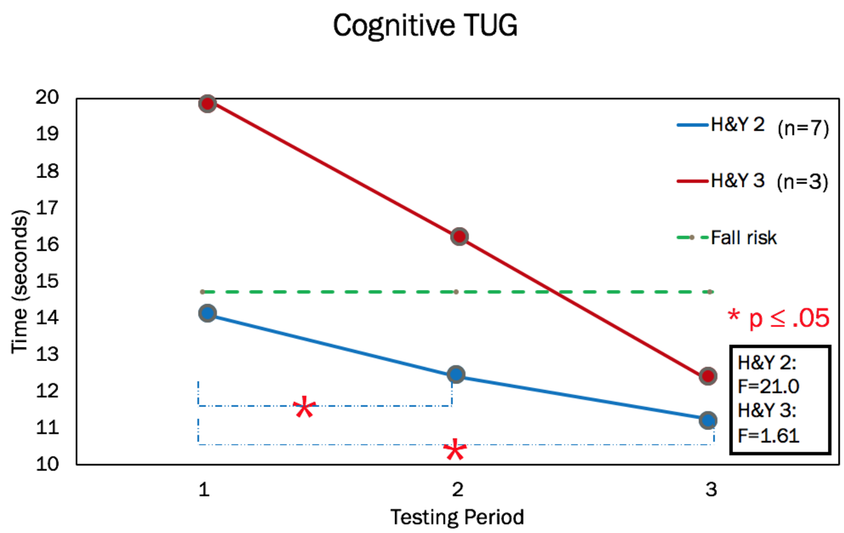

Figure 1. Cognitive TUG: Asterisk represents significance.
There was significance between T_1 and T_2 and T_1 and T_3 during the TUGc for H&Y 2. There was no significance for H&Y 3.

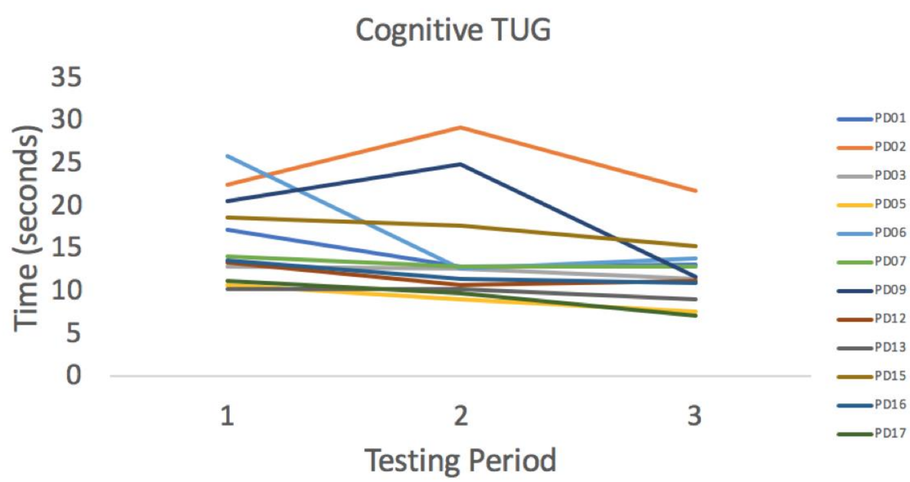

Figure 2. Cognitive TUG data.

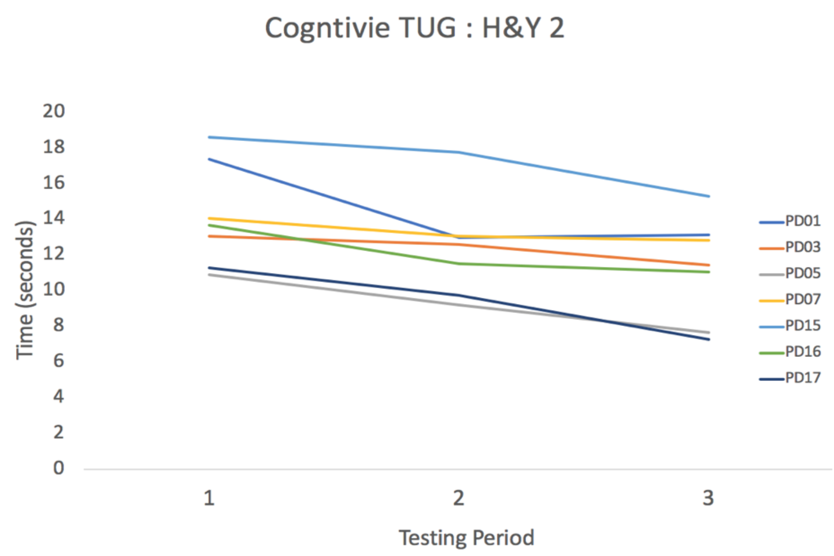

Figure 3. Cognitive TUG data for H&Y 2.

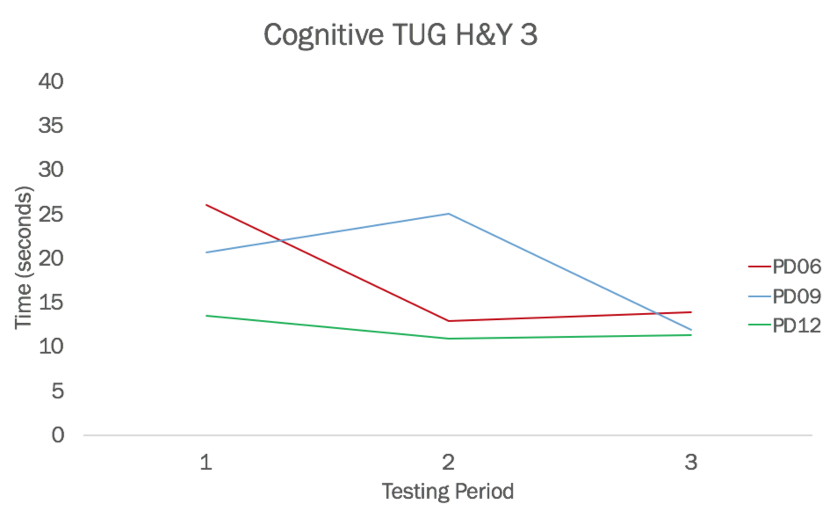

Figure 4. Cognitive TUG data for H&Y 3.

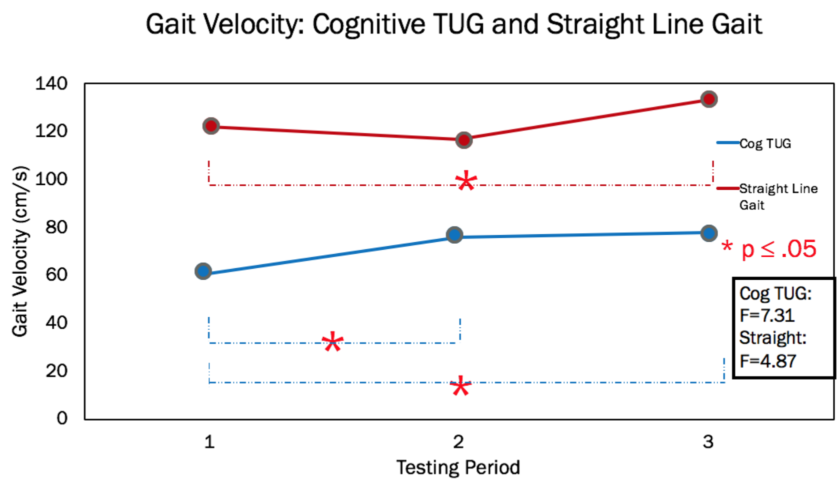

Figure 5. Gait velocity: Asterisk represents significance.
There was significance between T_1 and T_3 during straight line gait. There was significance between T_1 and T_2 and T_1 and T_3 during the TUGc.

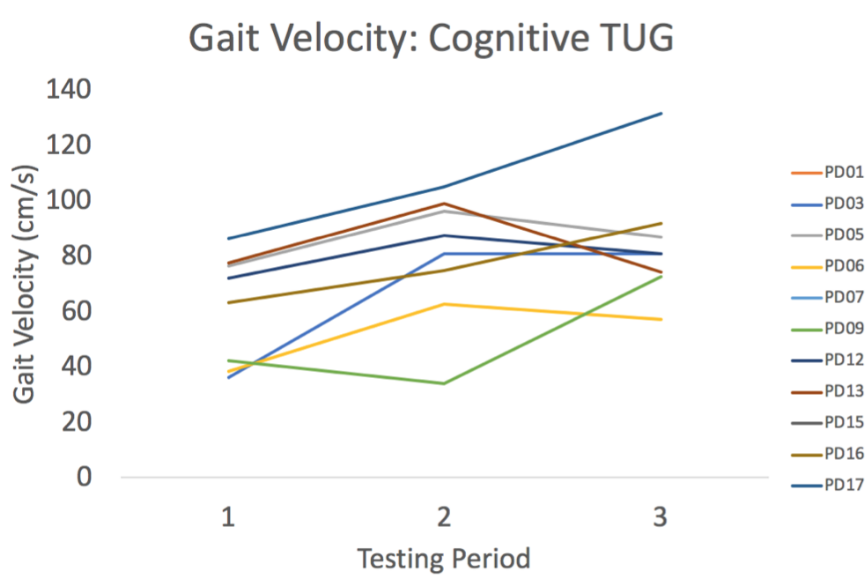

Figure 6. Gait velocity data during the cognitive TUG.

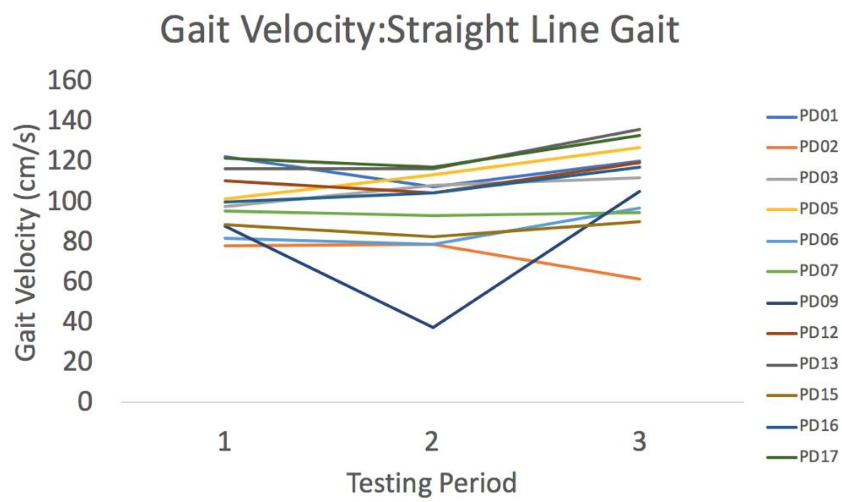

Figure 7. Gait velocity data during straight line gait.

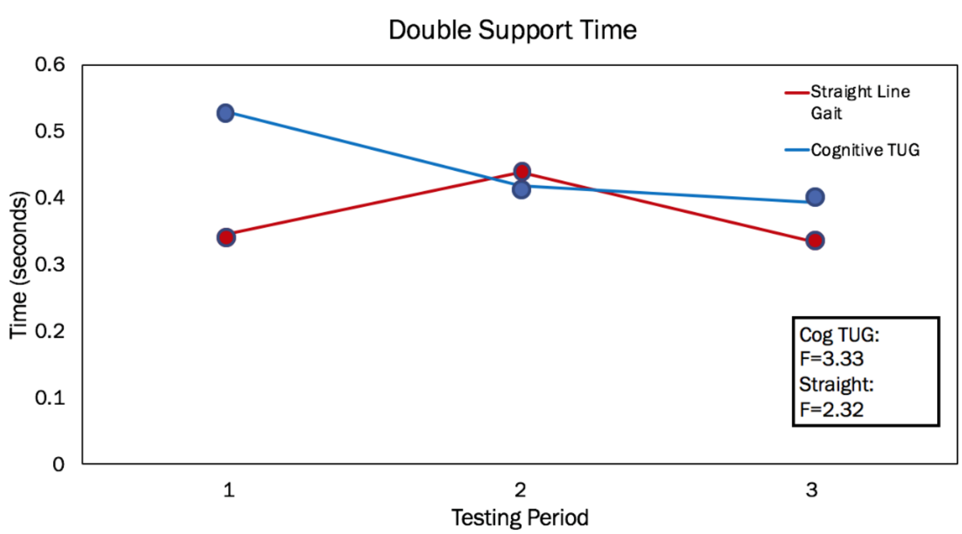

Figure 8. Double support time
There was no significance in any condition.

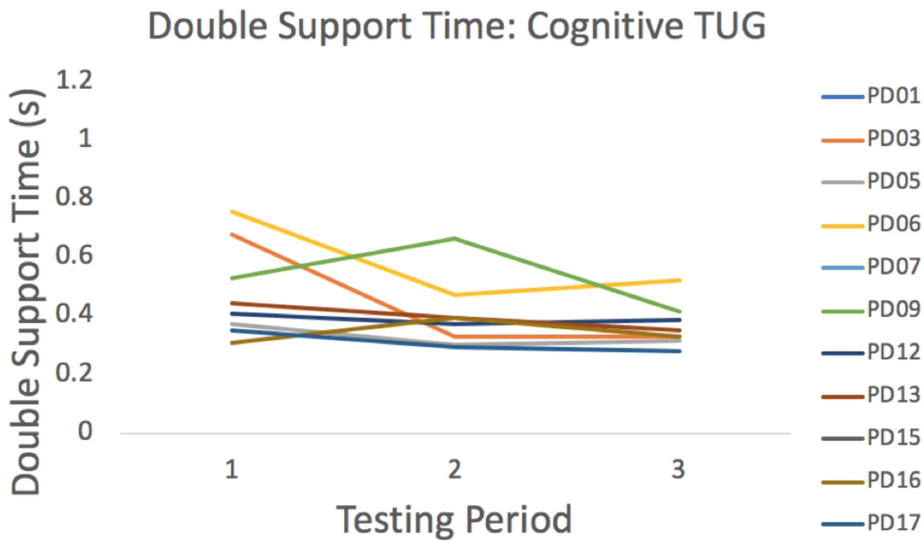

Figure 9. Double support time data during the cognitive TUG.

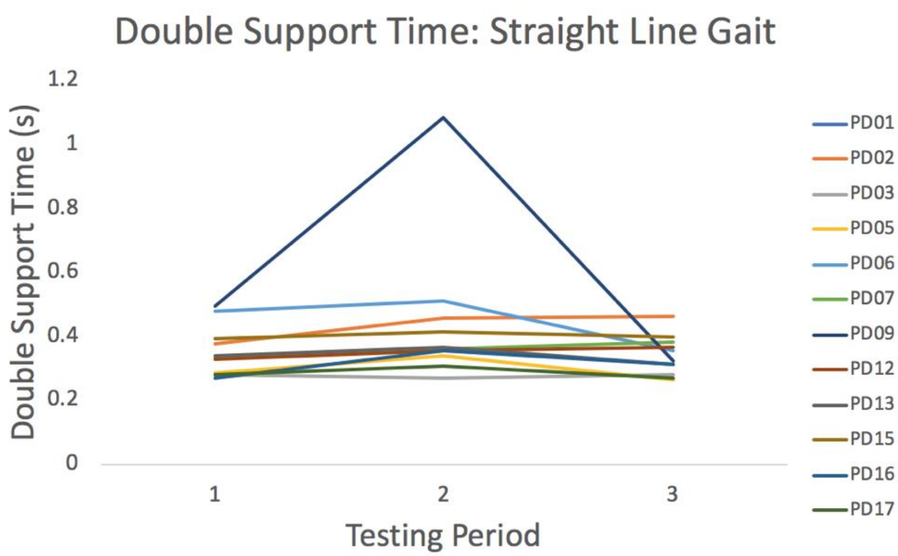

Figure 10. Double support time data during straight line gait.

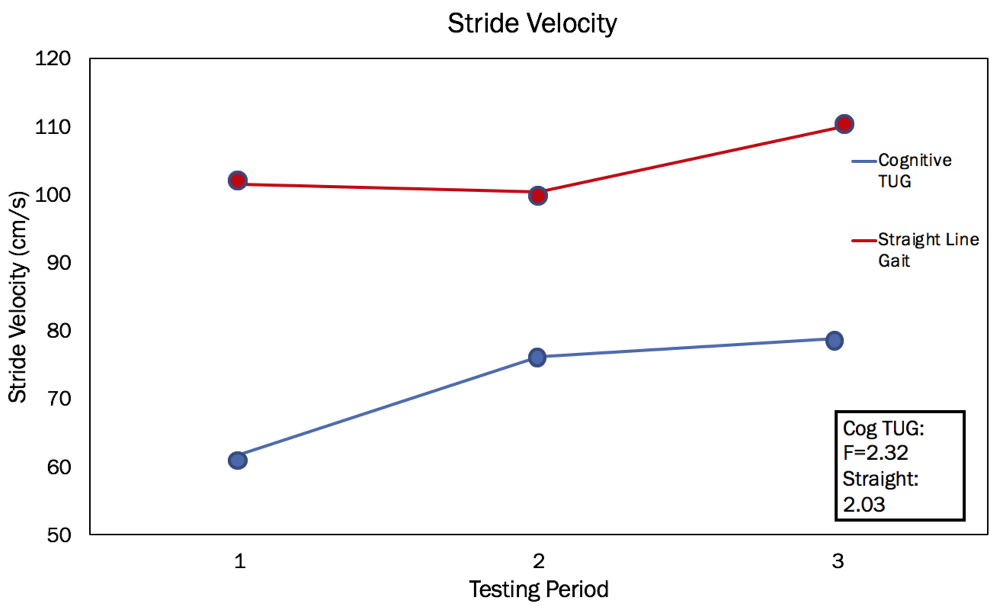

Figure 11. Stride velocity
There was no significance in any conditions.