# THE IMPACT OF EXERCISE ON POSTURAL CONTROL IN PATIENTS WITH PARKINSON'S DISEASE MEASURED BY COMPUTERIZED DYNAMIC POSTUROGRAPHY

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The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

THE IMPACT OF EXERCISE ON POSTURAL CONTROL IN PATIENTS WITH PARKINSON'S DISEASE USING COMPUTERIZED DYNAMIC POSTUROGRAPHY

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and hereby certify that, in their opinion, it is worthy of acceptance.

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This thesis is dedicated to the clients I've had the honor of working with over the years who have given me the opportunity to develop from a young, fumbling intern into an older, still fumbling exercise physiologist. Over the years that I have been employed to guide them, I have learned more from them than I will ever be able to teach. For that, I express endless gratitude.

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# TABLE OF CONTENTS

# List of Tables and Figures

## ABSTRACT

**INTRODUCTION:** Postural instability (PI) is one of the most debilitating symptoms of Parkinson's Disease (PD) that onsets in early stages of disease. The pathophysiology of PI occurs because of complex sensorimotor dysfunction that is not medically mediated by dopaminergic pharmaceutical agents. Exercise interventions that incorporate progressive resistance training (PRT) and tasks of high motor-complexity have been shown to positively impact motor symptoms of PD, including PI. Several standardized balance assessments and technologies have been validated to assess postural control; however, current literature is inconclusive regarding what standardized tools most accurately quantify PI. We hypothesized that individuals with PD who exercise regularly would show better performance outcomes measured by computerized dynamic posturography (CDP), balance, and physical function, in comparison to sedentary controls. **METHODS:** Thirteen individuals with PD who participate in the Rock Steady Boxing Program (**EX=** 70.1±6.1 yrs, H&Y stage 1.5±0.52, 207.7±56.7 min structured exercise/week) and twelve sedentary controls, also diagnosed with PD (**SED=** 68.5±5.02 yrs, H&Y stage 1.7±0.49, 0 min structured exercise/week) participated. Individuals underwent a single-session CDP testing battery: sensory organization (SOT), motor control (MCT), toes up/toes down adaptations (ADT), and limits of stability (LOS). The Modified Fullerton Advanced Balance scale (MFAB) and the 4-stage CDC (4CDC) were used to assess clinical balance. **RESULTS:** Between-group CDP analysis did not detect differences in performance on SOT, ADT, MCT, or most variables of LOS. Exercisers had faster reactions to horizontal translations (**EX**= 139.7±10.75 msec, **SED=** 150±13.5 msec, $p<0.05$) and more directional control (71.08±5.34%) than sedentary controls (64.6±7.6%, $p=0.022$). No between-group differences were detected in SOT or ADT performance. Exercisers showed better dynamic

balance on the MFAB (**EX=** 33.5±3.3, **SED=** 25.8±4.5, $p<0.01$) and static balance reported by the 4CDC (**EX=** 38.5±2.48, **SED=** 31.3±5.6, $p=0.002$) compared to controls. **CONCLUSION:** CDP was unable to detect differences in balance performance between exercisers and sedentary individuals with PD. Clinical balance assessments, the MFAB and 4CDC, showed the exercising individuals to have better dynamic and static functional balance than sedentary controls. These findings suggest that CDP is not an ideal tool to assess exercise-induced changes in functional balance performance and PI in PD.

# CHAPTER 1: INTRODUCTION

Parkinson's disease is a neurodegenerative movement disorder characterized by the loss of dopaminergic neurons in the substantia nigra region that causes striatal dopamine deficiency, leading to progressive motor decline (1). Loss of balance associated with postural instability (PI) is one of the cardinal symptoms of Parkinson's disease (PD) that presents in early stages and becomes debilitating throughout disease progression (1-4). Individuals with PD who experience loss of balance associated with dysfunctional postural controls strategies are at an elevated risk for experiencing falls and fall-related injuries. Regular exercise training has been shown to improve strength, balance, and overall quality of life in individuals with PD (6-21). The overall goal of this project is to enhance our understanding of how regular exercise impacts postural control in patients with PD using computerized dynamic posturography (CDP) compared to routinely used clinical balance measures. The present investigation was designed to address the following specific aims and testable hypotheses:

**AIM 1: Postural Control.** To evaluate differences in postural control in individuals with PD who exercised versus those who were sedentary. A Sensory Organization Test (SOT), Motor Control Test (MCT), Adaptations Test (ADT), and Limits of Stability Test (LOS) using computerized dynamic posturography were utilized. ***Aim1A.*** **We hypothesized** that people who exercised would exhibit better overall sensory integration of all systems related to balance as measured by the sensory organization test. ***Aim1B.*** **We further hypothesized** that exercising individuals would exhibit faster reaction times and greater directional control as measured by the limits of stability test.

**AIM 2: Clinical Balance.** To examine the difference in postural control using standardized clinical balance assessments among those with PD who exercised versus those who were sedentary. The Modified Fullerton Advanced Balance (MFAB) Scale and the 4-Stage CDC (4CDC) Balance test were utilized. ***Aim2A.*** **We hypothesized** that individuals who exercised would exhibit better dynamic and static balance outcomes, shown by higher scores on both the MFAB and 4CDC.

**AIM 3: Relationship between clinical balance assessment and CDP.** To determine the best clinical assessment measure to assess dynamic postural control when computerized posturography is not available. We explored the relationship between clinical balance assessment performance and CDP. ***Aim3A.*** **We hypothesized** that MFAB scores would correlate with postural control as measured by CDP.

**AIM 4. Physical Function.** To assess differences in physical function using standardized assessments among individuals with PD who exercised versus sedentary controls. The 30 second sit-to-stand (30STS) and 8 foot timed-up-and-go (8TUG) to assess lower body endurance, speed and agility were employed. Physical function outcomes were compared to CDP performance to assess the relationship between physical function and postural control. ***Aim4A.*** **We hypothesized** that physical function, as measured with 30STS and 8TUG, would correlate with postural control as measured by CDP.

## CHAPTER 2: LITERATURE REVIEW

### Clinical relevance of studying postural instability in PD

Parkinson's disease (PD) is currently the most prevalent neurodegenerative movement disorder, with an estimated 9.4 million individuals living with diagnosis globally in 2020, which has increased dramatically from the estimated 6 million cases reported in 2016 (2). Postural instability (PI) is the most debilitating symptom of PD, the primary cause of decline in functional mobility and impairment of balance control that progresses with disease state, ultimately contributing to an elevated risk for falls and associated injuries (3-5). PI was previously believed to be a symptom of late-stage disease; however, newer evidence has indicated that onset can arise in early stages (22,23), with an estimated 52% of patients experiencing their first fall within 3 years of diagnosis (24). Between 45-68% of individuals diagnosed with PD will experience at least one fall annually, while 50-86% will experience recurring falls at a rate 2-3 times greater than that observed of the general elderly population (3-5, 25, 26). As severity of PI increases with progression of disease state, individuals lose the ability to independently ambulate, and eventually experience total loss of independence (1, 3-5).

### Physical Manifestation of Postural Disruptions in PD

Physical upright posture is maintained by prolonged stabilization of postural muscle contractions and maintained in a dynamic environment through reactive stabilization of postural muscle groups in response to perturbation (27,28). PD disrupts both the ability to maintain postural stabilization and to produce adequate postural responses to perturbation, contributing to the development physical disruptions of posture that occur in later disease states. While PI occurs independently of physical postural disorders, development of these conditions profoundly deteriorates postural stability through physical restriction and disruption of the visual vertical,

leading to misconstrued sensory information and disrupted equilibrium. As condition severity becomes unmanageable, progressing into camptocormia, Pisa syndrome, or scoliosis, individuals lose the ability to ambulate safely, requiring assistive devices or wheelchairs. Early implementation of PI interventions is critical to minimizing severity in later stages, especially when physical deformities have evolved to further complicate the condition.

Camptocormia, abnormally stooped forward posture, presents as excessive abnormal thoracolumbar flexion (>30 degrees) (29,30). It presents in standing, is further expressed during walking, and mediated in the supine position. Reported onset is rare, 3-18% of late-stage cases and is commonly associated with the presence of rigidity and akinesia (30). As individuals are fixed into forward flexion, their center of gravity is fixed unnaturally far over the base of support with their heads fixed at an unnatural angle, substantially disrupting the visual vertical, further disrupting postural stability (31). Like PI, it is unresponsive to L-DOPA, however, some literature is indicating a positive response to deep brain stimulation (DBS) surgery (29, 32-35).

Lateral trunk deviation in PD can present as either Pisa syndrome or scoliosis. Pisa syndrome is characterized as lateral flexion (>10 degrees) that can be reduced in the supine position and does not present with vertebral rotation, while scoliosis requires a radiological diagnosis showing excessive lateral trunk deviation combined with vertebral rotation (35-38). Both conditions offset the center of gravity laterally from the base of support, disrupting the visual vertical, compromising the integrity of sensory information and contributing to PI (32). Pisa syndrome and scoliosis cannot be medically managed by L-DOPA but there is some evidence to suggest positive responses to DBS (37-39).

**Implications of PI in PD**

Postural control is a complex, multisystemic function of preserving upright posture through adequately obtaining and interpretating of sensory information to sustain equilibrium. The somatosensory, vestibular, and visual systems must function independently and effectively to facilitate adequate postural reactions required to respond to mechanical and sensory perturbations within the environment to counteract displacement of center of gravity (COG) relative to the base of support (BOS) (40). Redundancy exists within the three systems, as individuals who have one system compromised can maintain adequate postural stability when the information from the two functioning systems is reliable (40,41). In response to sensory information, autonomic and voluntary postural reflexes initiate appropriate muscle activation patterns and multi-joint coordination to re-establish COG over BOS, restoring equilibrium (40). Postural responses can be inadequate based on missing or misinterpreted sensory information, ineffective force production, or initiation of disorganized muscle activation responses that were insufficient for counteracting induced disequilibrium, leading to the loss of postural stability and ultimately a fall.

The implications of dysfunctional motor function manifest in almost all aspects of postural control in PD are primarily responsible for the presentation of PI. Excessive postural sway displacement during quiet stance is common in PD and is a primary indicator of PI (40-43). Automatic postural responses that normally occur have difficulty initiating or are dysfunctional upon initiation due to impaired sensorimotor coordination (40,41,44). Atypical muscle activation patterns usually present as disproportionate co-activation of antagonist muscles as a response to surface perturbations, increasing stiffness in a manner that is counterproductive to equilibrium (41-43). Complications with bradykinesia and inadequate processing of sensory information can delay latency of onset during muscle activation, in turn, compromising the ability to generate

forceful movement through postural reactions (42-45). Postural stability in PD is negatively impacted by motor symptoms of PD and inadequate sensorimotor function that impair postural responses. This results in difficulty maintaining upright posture during both static and dynamic conditions.

**Sensory System Dysfunction in PI with PD**

Underlying mechanisms that facilitate PI onset in PD are complex, given the multisystemic nature of neural circuitry that contribute to postural control. Current pharmaceutical interventions for PD target striatal dopamine deficiency and do not improve PI, with many reports indicating dopaminergic medications increase severity of PI presentation (45-48). Dopa-resistance, combined with the manifestation of PI, suggest dysfunction within the sensorimotor system in PD. Some studies suspect disrupted ability to utilize and organize sensory information related to vestibular dysfunction (49-52) a hypothesis that would be corroborated by reports of overreliance on visual feedback to obtain sensorimotor information **(**53, 54**)** and reports of dysfunctional proprioception observed in voluntary movements (55, 56). Other theories implicate disrupt proprioceptive system as the underlying cause of PI (57). An alternative hypothesis suggests that individuals with PD can process sensory information and integrate it to plan motor responses with a postural disruption occurring when postural reflexes were inflexible and unable to translate into functional postural adjustments, eliciting the onset of PI (58).

**Medical and therapeutic interventions for PI in PD**

***Carbidopa-Levodopa (L-DOPA)***

Levodopa (L-DOPA), commonly prescribed in conjunction with carbidopa or a dopamine agonist, is the gold standard for medical management of motor symptoms of PD. First validated through clinical trial in the late 1960's, it has remained the most effective pharmaceutical agent

available to treat PD (59). Although highly effective for managing symptoms of bradykinesia, rigidity, and tremor, initial studies noted significant side effects of motor fluctuations and L-DOPA induced dyskinesias (59,60). Decades later, these issues remain unsolved. Longer-duration studies have demonstrated prolonged L-DOPA treatment exhibits waning effects over time, onset of motor fluctuations, and L-DOPA induced dyskinesias that are as debilitating as the cardinal symptoms of PD. One study reported motor complications associated following the result of administration within 4-6 years of chronic treatment (61). Longer term follow-up studies reported medical management of symptoms were maximized within the first few years of intervention, with all improvements deteriorating completely after ten and fifteen years (62,63). Discrepancies in duration of effectiveness vary upon when dosages began, progression of L-DOPA intake, and disease progression, which all serve as influencing factors for medication effectiveness.

During initial years of treatment, L-DOPA alleviates symptoms of hypertonicity, bradykinesia, and tremor (60, 64, 65), however, the implications of L-DOPA treatment and PI are somewhat complicated. Postural control requires organization of multiple sensory systems that exist outside of the dopamine pathway, so that some aspects of balance and gait respond to dopaminergic interventions, while others, such as PI, are considered dopa-intolerant (22, 45,46,66). More recent studies suggest different deliveries of L-DOPA, such as intestinal gels and inhalants might lessen the extent of dyskinesia episodes and off-periods, however, PI is still not managed (67,68). Sensory analysis in periods of on- and off- medication usage show dysfunctional performance regardless of medication state, further supporting the hypothesis of dopa-intolerance observed with PI (57). Several reports indicate L-DOPA induced dyskinesia and motor fluctuation further aggravate postural stability through involuntary, high frequency movements that increase

postural sway during resting stance (46-48, 69,70). L-DOPA management of bradykinesia and rigidity allows individuals to produce faster movements, but, without adequate postural adaptations, individuals are less stable and more likely to experience a fall. These implications suggest that to some degree, the presence of rigidity might reduce postural sway, and that removing rigidity might compromise equilibrium (41,46).

***Subthalamic nucleus (STN) Deep Brain Stimulation (DBS)***

Deep brain stimulation (DBS) is a validated neurosurgery involving bilateral implantation of simulating electrodes on the subthalamic nucleus (STN). Simulating electrodes are connected to a pulse generator responsible for electrical regulation of neural activity. As degeneration of PD progresses into advanced stages and motor symptoms become more difficult to medically manage, surgical intervention might be recommended to reduce motor symptoms. Current reports suggest DBS is highly effective for alleviation of tremor, dyskinesias, and hypertonicity at initial 3 months post-operative (70, 71), while measures of gait and postural control were only slightly improved (71) or not at all (72). Studies that only implemented DBS saw postural improvements, such as reduced postural sway and slower movement velocities (71, 73, 74) and improved postural asymmetry between lower extremities. Studies that combined DBS and L-DOPA treatment saw some mediation of L-DOPA with DBS, however, DBS was not sufficient to reduce the consequences of L-DOPA treatment entirely (75-77). Longitudinal studies indicate that progress with initial improvement of symptoms declined significantly within 5-years post-operation (70, 78, 79). Short duration of improvements in symptom management is likely a result of progressive neurodegeneration, indicating that DBS cannot prevent disease progression.

***Therapeutic Interventions***

Due to the multifaceted nature of PD, an interdisciplinary care team is critical for ensuring continuity of care in treatment with disease progression. The team should consist of a neurologist who specializes in movement disorders, a speech and language pathologist, occupational and physical therapists, and a neuropsychiatrist. A care coordinator or social worker could be utilized to facilitate communication between healthcare providers, to advocate for the patient, and to assist with connections to programs as the need arises. Upon PD diagnosis by a neurologist, who might choose to wait to initiate pharmaceutical intervention, preventative care interventions such as physical and occupational therapies should be initiated quickly to promote long term positive outcomes (26).

Physical therapists have a wide scope of practice; however, a specialist might be ideal for individuals with more intensive cases for maximal standard of care. Implementation of residency programs has allowed a unique opportunity for physical therapists to become specialized in specific fields, such as neurorehabilitation. Plan of care would be unique to every individual based on physical condition and personal goals, the overarching aim of physical therapy with PD is to improve functional capacity, quality of life, rehabilitate impairment, and manage pain (80). Individuals with more complex motor complications and sensory impairments would focus mostly on motor coordination and rehabilitation of sensory function (82). The overall goal of exercise interventions would be to correct any painful or dysfunctional movement, manage PD symptoms, and improve physical function. Initial exercise should target movement quality that translates to activities of daily living, build functional capacity, balance, gait, resistance training (80-83). Cognitive components can be added to exercises to challenge motor skills and cognition, introducing tasks of increasing complexity over time (82). Sessions should educate, prepare, and encourage patients to safely partake in a physically active lifestyle outside of

therapy. Participation in physical therapy can be intermittent for prevention or management as symptoms fluctuate or other issues arise.

## Impact of exercise for PD and postural instability

Dopaminergic interventions remain the primary method of medical management for most symptoms of PD. Despite major successes with bradykinesia, tremor, and rigidity, issues with gait and postural stability do not benefit much and directly contribute to high fall rates and associated injuries (3-5, 22). As motor symptoms of PD impair movement, individuals tend to become less physically active, having a detrimental impact on physical function and contributing to further decline (17, 18, 21). Exercise training is recommended to supplement medical interventions, with goals of improving muscle strength, endurance, gait, and balance. For optimal outcomes, exercise should be recommended and initiated during early disease states and minimize deteriorative changes due to the progressive nature of PD. Studies regarding early interventions sustained long-term can delay disease progression, improve symptoms documented by the UPDRS-III, and allow for a reduction in L-DOPA dosage (85-87). Interventions in later stages of PD (Hoehn and Yahr staging > 3) failed to maintain exercise-induced improvements with follow-up, indicating progression of neurodegeneration influences treatment outcomes, therefore further supporting early intervention to maximize physical function (88).

### *Progressive Resistance Training*

Progressive resistance training (PRT) is recommended for older adults to counteract onset of sarcopenia, osteoporosis, to reduce falls, and to generally improve quality of life. Systemic muscle weakness is reported in PD, particularly in the lower extremities, which is highly associated with impaired gait, PI, and bradykinesia. Both strength and power focused PRT

protocols induce adequate muscle adaptations to improve muscular strength and power in PD, although adaptations through PRT alone did not translate to improvements in functional or balance performance (6, 7, 9). On the contrary, protocols that incorporated structurally loaded functional movements and high-complexity motor tasks with PRT reported significant changes to balance performance (12, 16, 17). Increases in functional strength have been correlated with lower UPDRS-III scores and reduced dosage of L-DOPA, suggesting PRT has a positive impact on motor symptoms of PD (12, 16, 17)). Duration of reported interventions typically averaged 12-weeks with generally positive outcomes, while those lasting 6 months and longer report improvements that were sustained long-term, suggesting that longer bouts of training are ideal to optimize performance (7, 16, 17). Due to the progressive nature of PD, continuous participation in PRT is recommended to maintain physical function, modified to meet new needs as they arise with physical decline. PRT must include structurally loading movements and tasks that are cognitively demanding to optimize functional movement and PI.

***Gait and Balance Training***

While PRT alone was reported to positively impact symptoms of PD, muscle strength, power, gait, and balance performance, interventions that took a balance-specific approach to training in conjunction with PRT were highly beneficial for improving balance assessment scores, latency of postural responses, functional reach distance, and gait velocity. Balance-targeted approaches incorporated gait and PRT exercises with motor-cognitive challenges, such as gait training with visual and auditory cueing, to add complexity that challenges the sensory systems (18-22). Interventions that combined resistance training with instability (RTI) to stimulate tasks of complex motor demands improved balance performance and fear of falling (12). Balance programs spanning approximately 8 weeks in duration were adequate to improve measures of

postural stability from pre- to post- assessment (19-22). At one-year of follow up, improvements were maintained and fall reduction was reported as high as 69-85% (20, 21). Like PRT, it is recommended to regularly participate in exercises of motor complexity to maintain positive outcomes for as long as possible throughout disease progression.

**Alternative Modalities of Exercise in PD**

Outside of traditional exercise modalities that include PRT, gait, and balance training, programs that incorporate alternative forms of exercise designed specifically for people with PD have become widely utilized in recent years. Several diverse programs that incorporate large, rhythmic movements have been validated as safe and effective physical activity interventions for PD with high compliance rates (84-87). Studies of therapeutic dance interventions reported improvements in overall mobility and balance performance (84-86, 88). Reports on Tai Chi interventions showed improvements in gait, functional reach, and reduced incidence of falls between 3-6 months post-intervention (87, 89, 90). Based on the rationale that boxing requires agility, motor coordination, and powerful movement production, boxing interventions have become increasingly popular in recent years as a modality to introduce powerful whole-body movements into the PD population. The implementation of Rock Steady Boxing, an international program of community-based exercise for people with PD, has been validated as a safe and effective exercise program for PD, associated with improvements in power production, muscle strength, balance performance, and overall quality of life for participants (91-94). These modalities of exercise cannot replace medications, physical therapies, or PRT, but can be implemented in conjunction with other interventions.

## Assessment of postural control and physical function in PD

### *Posturography Analysis*

Computerized dynamic posturography (CDP) is the current gold standard for postural control assessment through analysis of sensory information and postural reactions to perturbations.

Posturography assessment can be conducted through platform analysis, such as the NeuroCom Smart Balance Master System©, or mobile analysis, using technology such as Vertiguard©. Platform posturography analyzes responses to perturbation in-stance, under conditions of a narrow stance and harness, while mobile posturography captures postural responses during free-field conditions, providing insight into balance related to functional movement (95). With limitations considered, both techniques have been used to evaluate sensory function and postural reactions associated with PD (51, 70, 95-97).

Platform CDP has been validated as an adequate tool to detect differences between individuals with PD and healthy age-matched controls, with individuals diagnosed with PD showing significantly lower scores in measures of sensory organization, adaptations to support system displacement, and limits of stability (96). CDP is used to identify impairment related to sensory function, providing insight into why balance might be disrupted that cannot be detected or quantified by standard clinical assessments (51, 87, 95). Hypotheses regarding the origin of PI in PD within the vestibular and somatosensory systems that contribute to over-reliance on visual input have been validated in several studies that showed lower SOT scores of vestibular function and higher scores of visual preferences in the PD population (51, 87, 96). Sensory analysis and limits of stability measures have been able to identify risk of falls in healthy older adults as well as individuals with PD (86, 96).

***Clinical Balance Assessments***

Several validated clinical balance assessments exist and are heavily relied on in daily practice for healthcare practitioners to evaluate postural control during both static and dynamic tasks. Common assessments discussed to assess balance in PD include static balance: 4-Stage CDC balance assessment (4CDC), and dynamic balance tests: the modified Fullerton advanced

balance scale (MFAB), the Berg Balance Scale (BBS), and the BEST (Balance Evaluation Systems Test) test (5, 99, 100). These tests can be implemented efficiently, are cost effective, and backed by normative data to allow for immediate comparison and identification of impairment (99, 101). 4CDC evaluates ability to maintain 4 static postures unassisted for 10 seconds, while the others are a combination of tasks including static balance, proprioceptive challenges through unstable surfaces and loss of visual input, vestibular challenges, functional reaching tasks, among other functional dynamic tasks. Dynamic balance assessments provide more insight into postural control during functional tasks that are more indicative of fall risk during daily activities in comparison to static-based assessments. The MFAB, BBS, and BESTest assessments have been validated as highly reliable evaluations, without ceiling effects, that correlate with each other and are good predictors of functional balance associated with fall risk for older adults in general and in the presence of PD (99-101).

These tests are heavily utilized because they are easily accessible with minimal equipment, cost effective, functional in nature, and are validated with normative data for easy comparison. Limitations generally lie within clinical application and interpretation. Assessments have well-defined protocols; however, they are ultimately subjective based on the evaluator (97). Clinical assessment performance will detect impairment and may point towards the origin of the issue but cannot adequately quantify or diagnose degree of disability in the manner that more advanced evaluative tools, such as posturography, are able to.

***Physical Function Assessments***

Assessments of physical function, such as the 30-second sit-to-stand (30STS) and 8-foot timed up and go (8TUG) are utilized to assess lower body muscle strength and agility during a turning movement, ultimately provide insight into an older adult's physical function in relation to

activities of daily living (102). Due to the implications of motor symptoms of PD, individuals typically exhibit muscle weakness, difficulty arising from chairs, and maintaining balance during turning movements, leading to below average scores on 30STS and 8TUG when compared to a healthy, age-matched population (103,104). These measures are utilized by healthcare practitioners to evaluate physical function, monitor functional changes, and determine deficiency based on normative data. 8TUG performance has been validated to accurately assess fall risk in 75% of participants, proposing a cut off time of 11.5 seconds for discrimination of fallers and show positive correlation to UPDRS-III scores (105). Although motor symptoms of PD directly impact physical function, 30STS and 8TUG assessments have been validated as adequate measurements of physical function for PD, however, it must be understood that motor symptoms of PD may influence test outcomes.

***Unified Parkinson's Disease Rating Scale (UPDRS) Part III: Motor Examination***

The UPDRS is the most frequently utilized clinical tool for ranking symptom presentation of PD on a standardized scale (0= normal, 1= slight, 2= mild, 3= moderate, 4= severe). The motor examination (Part III) consists of 33 scores based on 18 items evaluating the current state of the following motor functions: speech, facial expression, hypertonicity, fine motor coordination, kinetic/resting tremor, postural tremor, postural stability, postural presentation, global spontaneity of body movement, and gait. Hoehn and Yahr Stage (0-5) is also assigned during this assessment (106). Having a standardized assessment tool gives clinicians a quantitative measure of impairment related to motor symptoms of PD; however, no assessment tool is without limitation. UPDRS motor examination score is indicative of symptom presentation; however, it does not provide insight as to the causes of observed motor functions. Further assessment would be required to analyze the cause of and adequately manage motor dysfunctions. A comparison of

UPDRS motor evaluation and performance on a battery of functional assessments showed a correlation between motor exam scores and performance on the Berg Balance Scale, forward functional reach, and timed-up-and-go performance, but did not have a relationship with measures of gait speed, suggesting that UPDRS motor examination scores do not reflect gait performance (106). Additionally, the only assessment of postural stability is the retropulsion assessment (pull test), an evaluative technique with inconsistent protocols that is difficult to standardize. Retropulsion performance correlates poorly with dynamic posturography, the current gold standard for postural control assessment, which generates reproducible results using standardized protocols (97). Implementing an assessment tool with more objective measures than retropulsion would enhance the efficacy of the UPDRS for evaluation of postural stability.

**Gaps in literature**

The implication that PI is dopa-resistant, and in many cases, aggravated by dopaminergic interventions, is concerning given the need of dopaminergic medications to manage PD and the debilitating implications of PI with disease progression (46,47). To maintain function and safe, independent living for as long as possible, interventions that mediate PI are critical. Exercise interventions are recommended to alleviate impact of motor symptoms, improve muscle strength, and balance performance to reduce overall fall risk and to maintain postural stability (6-17). Balance and gait focused interventions, as well as complementary modalities of exercise, such as dance, Tai Chi, and boxing, have become increasingly popular as supplements to existing treatment models (18-22, 84-94). While most reports are positive, the extent of which regular exercise can combat progressive neurodegeneration and mediate symptoms of PD unclear.

The multifactorial nature of postural control and subjectiveness of balance has made it a difficult trait to assess and quantify. As a result, it is critical that multiple means of assessment are

utilized to assess capabilities. Clinical balance and physical function assessments are widely used in clinical settings to evaluate initial performance and monitor functional changes, which tend to be positively associated with regular exercise in PD, although the assessments are not able to directly diagnose or quantify impairment (97-105). Testing protocols are validated but subjectivity of some aspects must always be considered with interpretation of results (97). CDP, on the other hand, is the current gold standard for measuring postural control, using sensory inputs and postural responses to diagnose and quantify impairments. CDP has been validated as an effective tool for detecting impairments associated with PD (96) and can differentiate between fallers and non-fallers (98), however, the ability to differentiate between exercisers and non-exercisers sensory integration ability is currently unknown.

**Summary**

Medical and therapeutic interventions are targeted at managing motor symptoms of PD to maintain physical function and quality of life, there are no current cures or treatments to prevent neurodegeneration (60-62). L-DOPA remains the gold standard pharmaceutical agent for symptom management, having the highest impact on symptoms of bradykinesia, hypertonicity, and tremor (60-62). Still, dyskinesias and fluctuating motor responses ("on and off" periods) can be as devastating as the initial motor symptoms of PD (65-68). Due to the multifactorial nature of PI, the efficacy of medical mediation is conflicting, with many reports indicating PI cannot be medically managed, and that dopaminergic medications prescribed for PD further disrupt postural stability (64, 65, 67-69). In later stages of disease, DBS might be recommended to control motor symptoms that are no longer responsive to dopaminergic medication, with some evidence to suggest an impact on PI not observed with pharmaceutical interventions (63, 64, 66). Several studies indicate substantial improvement in several aspects of motor function post-

surgery; however, more longitudinal studies are indicating inevitable return to functional decline, although timelines conflict between studies (71-80). Observed declines and eventual re-implementation of dopaminergic medications (76) is likely associated with disease progression, as DBS targets symptom management but cannot stall neurodegeneration (71, 78, 79). To optimize long term outcomes, physical therapy and exercise interventions must serve as adjuncts to medications to improve physical function, balance, and overall quality of life.

Current literature indicates that exercise programs should be multidisciplinary, incorporating PRT that focuses on structurally loaded movements that elicit functional motor coordination patterns to maximize exercise-induced balance improvements (6-17). Programs that incorporate alternative modalities of exercise, such as dancing, Tai Chi, and boxing have been proven safe, effective, and productive methods to complement traditional PRT (84-94). Due to the degenerative nature of PD, improvements are more difficult to observe and quantify. While it is known that individuals who exercise typically perform better on physical function and clinical balance assessments (102), studies that used CDP to assess improvement or compare between exercising and non-exercising individuals have conflicting reports (5, 7, 16, 17, 24, 52, 99-101). These discrepancies could occur for a variety of reasons, including insufficient exercise protocols that lack motor complexity and structural loading, are too short in duration, or there is a discrepancy between different posturography techniques. Understanding the limitations of posturography will assist with determining the impact of exercise on postural control in PD.

# CHAPTER 3: METHODS

## ETHICAL APPROVAL

All experiments were approved by the Institutional Review Board (IRB) at the University of Missouri (IRB #2046064) and conformed to the ethical principles of the Declaration of Helsinki. Written consent was obtained from all subjects prior to study participation (Appendix A).

## SCREENING PROCEDURES

Subjects were recruited from Columbia, MO and surrounding areas using posted advertisements in Mizzou Therapy Services clinics and throughout campus. All subjects were 59 to 84 years of age, diagnosed with PD after age 50, Hoehn and Yahr disease stage 1-2, and independently ambulatory. Exercising individuals (n=13) were studied based on their prior participation in the Rock Steady Boxing program for a minimum of 3 months, 2-3 times per week. Sedentary individuals (n=12) were required to not be actively participating in a structured exercise program or regularly completing more than 150 minutes of physical activity on a weekly basis. In preparation for the visit, participants were asked to refrain from exercise for 24-hours prior to their scheduled visit, take medication as prescribed, and to wear clothing and shoes that they would regularly exercise in. Subjects completed one 1.5-hour visit including screening and data collection. Performance on computerized dynamic posturography, clinical balance, and functional assessments were measured in both groups.

### Participant Screening

Subjects were consented in the Mizzou Therapy Services Faculty Clinic at the University of Missouri. Subjects were provided an informed consent as approved by the Institutional Review Board for the University of Missouri. Participants completed a Physical Activity Readiness Questionnaire (PAR-Q) to ensure they are prepared to be physically active, present with a PD

diagnosis, and document prescribed medications. The Unified Parkinson's Disease Rating Scale (UPDRS) Part III: Motor Examination was completed to evaluate motor symptoms and assign a modified Hoehn and Yahr Scale of disease state. The Global Physical Activity Questionnaire (GPAQ) was administered to evaluate physical activity participation during activities of daily living, work, and recreational exercise.

### Rock Steady Boxing Protocol

The Rock Steady Boxing program was facilitated by the MU Human Performance Program. Classes were offered five days per week for 90-minute sessions, with required attendance of 2-3 days/week to be included in the study. Sessions began with a R.A.M.P protocol warm-up consisting of locomotion patterns to raise core body temperature, ground-based activation of key muscle groups, mobilization of key joints, and potentiation of the central nervous system facilitated through reactive drills, agility, gait mechanics, or dynamic balance work. The strength training portion followed a 12-week periodized program, incorporating major movement patterns scaled to participant ability and progressed accordingly. During energy systems development, participants had the option of cardiovascular exercise equipment, walking, or running on open turf in prescribed intervals. The boxing component of class was programmed as a H.I.I.T protocol using speedbags, mitts, and heavy bags. Post-class, participants were encouraged to cool down and stretch ad libidum **[APPENDIX C].**

## STUDY PROCEDURES

### Study Visit Protocol: COVID-19 Precautions

Study visits took place at PhysZou, the faculty clinic for Mizzou Therapy Services. To abide by MU Healthcare COVID-19 safety precautions, investigators and participants were masked for

the duration of the visit and screened for symptoms prior to entrance. Participant visits were scheduled on an individual basis to avoid close contact with others. All surfaces were sanitized pre- and post- utilization.

**Computerized Dynamic Posturography**

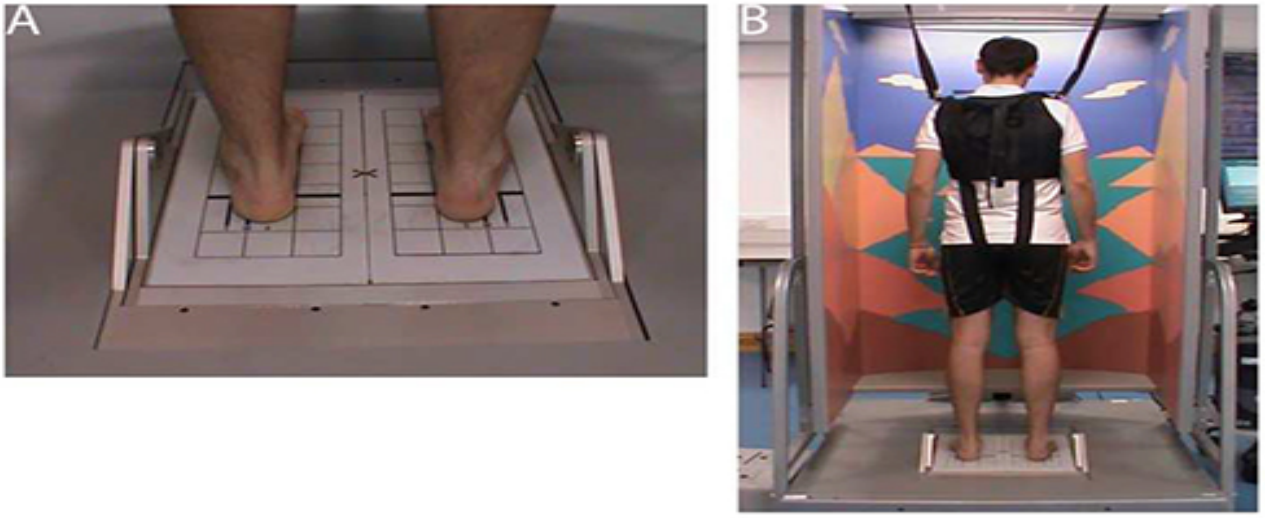


**Figure 1. Subject Positioning in NeuroCom© during Computerized Dynamic Posturography Assessment.** Image courtesy of NeuroCom International, Inc©.

The NeuroCom Smart Balance Master System v 8.3 (NeuroCom International, Inc, Clackamas, OR) was utilized for computerized dynamic posturography assessment. Participant's feet were placed so that the medial malleolus of each foot was centered over the line perpendicular to the subject. The lateral calcaneous was placed according to subject's height ("S" "M" and "T" where S= short, 30-55in, M= medium 56-65in, and T= tall 66-80in) **(Figure 1A)**. Prior to assessment, participants were fitted for a harness attached to the framework of the NeuroCom for safety during test **(Figure 1B)**. Between assessments, ad libidum rest was allowed before moving on to

the next task. All tests were performed according to the manufacturer's protocol (107). A comprehensive report was generated by the software for all assessments **[APPENDIX B].**

*Sensory Organization Test (SOT)*

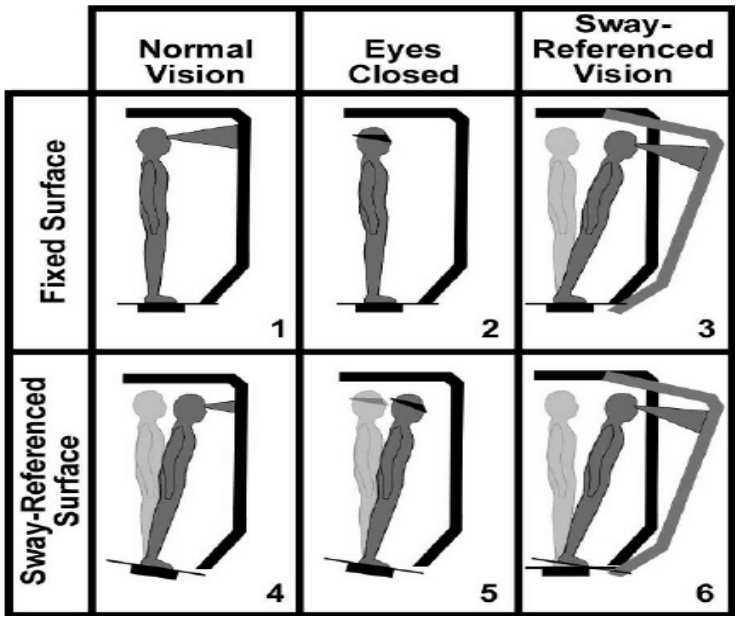


**Figure 2. Sensory Organization Test Conditions -** The 6 conditions sensory conditions of the SOT (Image provided courtesy of NeuroCom International, Inc.©)

**Table 1.** Description of the Sensory Organzation Test Conditions.

| SOT Tasks | Condition Description |
|---|---|
| Condition 1 | Eyes open, surround and platform stable |
| Condition 2 | Eyes closed, surround and platform stable |
| Condition 3 | Eyes open, sway-referenced surround |
| Condition 4 | Eyes open, sway-referenced platform |
| Condition 5 | Eyes closed, sway-reference platform |
| Condition 6 | Eyes open, sway-referenced surround and platform |

The SOT is designed to assess functioning of the sensory systems that contribute to postural stability: the somatosensory, visual, and vestibular systems. The SOT was administered to evaluate how the sensory systems associated with balance communicate with each other and to identify any abnormalities within them. SOT Composite scores have been reported to have a good test-retest reliability (ICC= 0.66) while average of three trials per condition ranged from poor (Condition 3= ICC= 0.68) to fair test-retest reliability (condition 5: ICC= 0.68, condition 6: ICC = 0.64) (108). Age-appropriated normative data is present to assess impairment (107). Current literature indicates a change of 8 points in SOT equilibrium scores are required to meet minimum clinical significance (108).

Participants underwent six conditions that manipulated the somatosensory and visual systems (**Table 1**). The participant underwent three consecutive 20-second trials for each condition, with ad libidum rest between trials (107). An equilibrium score was calculated to quantify postural sway for each of three trials for each condition. Overall performance was designated by a composite equilibrium score, which is the weighted average of all sensory conditions. Sensory analysis ratios were calculated to identify specific impairments of the individual's sensory systems. The four ratios calculated were: Somatosensory (SOM), Visual (VIS), Vestibular (VEST) and Preferential (PREF). (Equations 1-4). Strategy analysis and center of gravity alignment were also configured but data was not utilized for this study.

$$Somatosensory\ Ratio\ (SomatoR) = \frac{Condition\ 2}{Condition\ 1} \qquad \textit{Equation 1.}$$

$$Visual\ Ratio\ (VisR) = \frac{Condition\ 4}{Condition\ 1} \qquad \textit{Equation 2.}$$

$$Vestibular\ Ratio\ (VestibR) = \frac{Condition\ 5}{Condition\ 1} \qquad \textit{Equation 3.}$$

$$Preferential\ Ratio\ (PrefR) = \frac{Condition\ 5}{Condition\ 1} \qquad \textit{Equation 4.}$$

***Motor Control Test (MCT)***

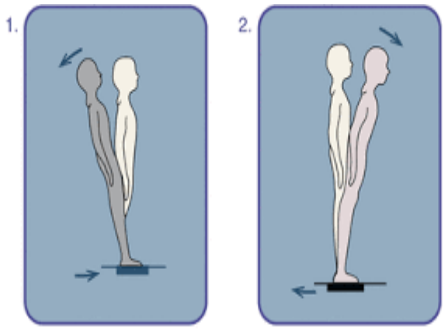


**Figure 3. Motor Control Test Conditions**- Forwards and backwards horizontal translations (Image courtesy of NeuroCom International Inc.©)

The MCT is designed to assess postural reflex latency in response to horizontal translations. Current literature does not identify values of minimal clinically important difference in scores. Comparison to age-appropriated normative data is utilized to identify dysfunction (107). The participant underwent six conditions: three backwards followed by three forwards translations graded in magnitude **(Figure 3)**. Each condition was performed in three trials, with random delays of 1-2 seconds in between trials. Horizontal displacement during translation was scaled according to the participant's height (107). A composite latency score (msec) was calculated to quantify the time lapse between force plate translation and postural response. Weight symmetry and relative response strength scores were also generated but not utilized for the purpose of this analysis.

***Adaptations Test (ADT)***

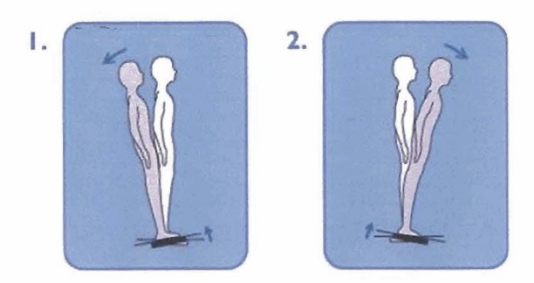


**Figure 4. Adaptations Test Conditions-** 8 degree toes up and toes down rotations (Image courtesy of NeuroCom International Inc.©)

The ADT assessment is designed to evaluate ability to adapt and sustain center of gravity above base of support with minimal sway when exposed to surface irregularities. Current literature does not identify a value of minimal clinically important difference in scores. Age-appropriate. normative data is utilized to identify dysfunction (107). Consecutive platform rotations in the toes-up or toes-down direction elicit automatic motor responses. During initial trials, disruptions are unexpected and must be corrected by secondary response of opposing muscles. In later trials, secondary responses are elicited to reduce sway. Performance on the ADT evaluates adequate ankle range of motion, muscle strength, and motor adaptations. For each trial, a sway energy score quantified the magnitude of force required to overcome disrupted postural stability **(Equation 5)**. An average of sway energy for all 5 trials was calculated for both toes up and toes down conditions to assess performance. Average, raw sway, and center of force data for all five trials was also collected but not utilized for analysis during this study.

$$SwayEnergy = C1 * PY'(RMS) + C2 * PY''(\text{RMS}) \qquad \textit{Equation 5.}$$

$$C1 = \frac{1}{in/sec} \; C2 = \frac{0.025}{sec^2}$$

***Limits of Stability Test (LOS)***

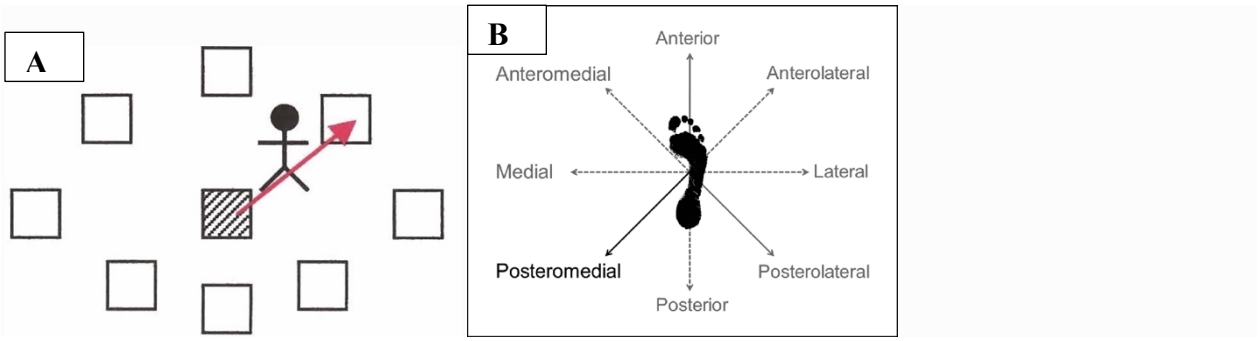


**Figure 5. Limits of Stability Test Conditions-** Subject is required to start from the center and translate their COG in each direction. (Image courtesy of NeuroCom International Inc.©).

The LOS was utilized to assess the voluntary motor system, quantifying impairments in ability to intentionally displace the COG to the patient's stability limits without losing balance. Current literature does not identify values of minimal clinically significant difference in scores. Age-appropriated normative data is utilized to identify dysfunction (107). While viewing a real-time display of their COG relative to the center of the base of support **(Figure 5A)**, participants displaced their COG away from the center in each of eight directions, towards a target (placed at 100% of theoretical limits of stability), on command, holding the position as close to the target as possible for a maximum duration of 8 seconds **(Figure 5B)**.

Based on the eight trials of the LOS test, five measures were calculated: reaction time (RT), movement velocity (MVL), endpoint excursion (EPE), maximum excursion (MXE) and directional control (DCL). RT was measured in seconds as the time between the command to move and initiation of movement. The MVL, measured in degrees per second, is the average speed of the COG movement. EPE, expressed as a percentage, is the distance of the initial movement towards the designated target. MXE, reported as a percentage, is the maximum distance achieved during each trial. DCL, reported as a percentage, depicts the amount of movement in the intended direction to the amount of extraneous movement during a given trial. Data was reported for each component as an average of each of 8 trials for each measure.

**Modified Advanced Fullerton Balance Scale**

The Modified Fullerton Advanced Balance Assessment (MFAB) is a widely used dynamic balance assessment where participants are required to complete ten balance-related tasks. Test-retest reliability has been reported excellent (r= 0.96) for composite scores and adequate to excellent for individual test items (r= 0.52-0.82) (110). Cut off scores of 25/40 produce highest sensitivity (74.6%) and specificity (52.6%) for predicting risk of falls in older adults, with no observed ceiling effects (110). The 10-item scale required the participant to stand with feet together and eyes closed, reach forward to retrieve an object, turn in a full circle in both directions, step up and over a 6' box, tandem walk for 10 steps, hold a single leg stance, stand on foam with eyes closed, a horizontal two-footed jump, walk with head turns to a set cadence, and a reactive postural control test. Performance was scored on each task using an ordinal scale (0-4) with a maximum score of 40 (101, 102, 110).

**4-Stage CDC Balance Assessment**

**Figure 6. CDC Balance Stages:** Participants hold each foot position (narrow stance, semi-tandem stance, tandem stance, and single leg) for 10 seconds each.

The CDC Balance test is a widely used balance assessment that requires participants to maintain balance during four different static postures (111). Test and re-test reliability are reported as moderate (0.66) (112). Individuals are considered an increased risk of fall if they score ≤30 seconds, indicating inability to maintain tandem stance for 10 seconds. Current literature

indicates that no minimal clinically important difference has been established (113-115). Participants held each posture, unassisted for ten seconds before they progressed to the next: feet together mountain stance, semi-tandem stance, tandem stance, and single leg stance as described in the CDC protocol, with a maximum score of 40 seconds **(Figure 6**). Falling out of the posture or reaching towards the table for assistance was considered stage failure and the test was concluded.

**8-Foot Timed-Up-and-Go and 30 Second Sit-to-Stand**

Both dynamic tests were used to assess balance and lower body strength. TUG test-retest reliability is reported as adequate (ICC= 0.85) (116) and excellent (117). Minimal clinically significant difference in TUG times has been determined at 4.85 seconds (118). Individuals are at an increased risk of falling with TUG performance ≥12 seconds (119). The TUG required participants to rise from a seated position, walk around a cone 8 ft away, and return to their seated position. Participants were timed from the "go" cue to when they return to a fully seated position. Each participant underwent two trials, the best of which was recorded as the final score.

The 30 second sit-to-stand measured how many times a participant completed a full sit-to-stand from a 17-inch chair in 30 seconds (120). Current literature shows an excellent test-retest reliability (r= 0.89) with no ceiling effects (120). Minimal clinically significant difference in scores is reported within 2 repetitions (121). The assessment was performed twice; with the best performance kept as a final score.

**Data and Statistical Analysis**

Statistical analysis was completed using SPSS Statistics for Windows, version 27 (IBM Corp. in Armonk, NY). In all cases, two-tailed $p<0.05$ were considered statistically significant and data are reported as Mean (Standard Deviation). Subject demographics were compared using

independent t-test (exercise, sedentary) to ensure no differences between groups for other variables **(Table 1).** Data were assessed for normal distribution (Shapiro-Wilk) and equal variance.

**AIM 1. Postural Control.** Data was taken from performance on the 6 conditions of SOT. The main outcome variables for the SOT were the composite equilibrium score and sensory analysis ratios (SSR, VisR, VestibR, and PrefR). The latency composite score was utilized to assess motor control function. The ADT generated a sway energy score for the toes up and toes down conditions. The main outcome variables for the LOS were RT, MVL, EPE, MXE, and DCL. All CDP main outcome variables were compared between groups to identify significance using an independent t-test **(Figure 7A-F)**.

**AIM 2. Clinical Balance.** The main outcome variables for clinical balance assessment were score on MFAB assessment on a 40- point scale and performance on 4-stage CDC out of 40 seconds. Performance on both clinical balance assessments were compared between groups to identify significance using an independent t-test **(Figure 8)**.

**AIM 3. Relationship between clinical balance assessments and CDP** To evaluate the relationship between CDP and clinical balance assessments, performance for entire sample (n=25) on CDP main outcome variables were compared to MFAB and 4CDC performance using bivariate correlation, specifically Pearson correlations **(Figure 9A-G)**.

**Aim 4. Physical Function.** To assess the relationship between CDP and physical function, performance for the entire sample (n=25) on CDP main outcome variables were compared to 30STS and 8TUG performance using Pearson correlations **(Figure 10A-G, Figure 11A-G)**.

## CHAPTER 4: RESULTS

### Subject Demographics

Twelve sedentary controls and thirteen exercising individuals with PD participated in this study. All demographic data are reported in **Table 2**. Control and exercising subjects were well matched for age (Sed= 68.5±5.02 yrs, Ex= 71.0±6.1 yrs), Hoehn and Yahr Stage (Sed= 1.7±0.49, Ex= 1.5±0.52), and UPDRS MIII scores (Sed= 25.6±8.97, Ex= 23.5±10.37). By design, exercise participants reported more structured exercise time on a weekly basis (Sed= 0 min/week, Ex= 207.7± 56.7 min/week).

### Computerized Dynamic Posturography

SOT Composite equilibrium scores were not different between groups, Sensory analysis did not show a difference in somatosensory, visual, or vestibular system function, or visual preference (**Figure 7A**). Exercisers had lower MCT composite scores, indicating faster response latency than sedentary controls (Sed= 150.0±13.5 msec, Ex= 139.7±10.75 msec, $p<0.05$) (**Figure 7B**), and ADT analysis did not identify a group difference in sway energy scores for either toes up or toes down conditions (**Figure 7C**). LOS analysis revealed that exercisers exhibited higher directional control (Sed= 64.6±7.6%, Ex= 71.08±5.34%, $p<0.05$) **(Figure 7D)**. No group differences were observed in endpoint excursion, maximal endpoint excursion, **(Figure 7D)**, reaction time (**Figure 7E**) or movement velocity (**Figure 7F**).

### Computerized Dynamic Posturography and Clinical Balance

MFAB and 4CDC test performance were different between groups (**MFAB:** Sed= 25.8±4.5, Ex= 33.5±3.3, $p<0.001$, **4CDC:** Sed= 31.3±5.6, 38.5±2.48, $p=0.002$). **(Figure 8).** For all subjects (n=25), SOT composite scores did not correlate with 4CDC or MFAB outcomes **(Figures 9A, 10A)**. As expected, MCT composite scores were negatively correlated with both CDC (r= -

0.629, p<0.001) and MFAB (r= -0.471, p=0.018) outcomes **(Figures 9B, 10B)**. ADT toes up and toes down sway energy scores did not show a relationship with either MFAB or CDC performance **(Figures 9C, 9D, 10C, 10D)**. LOS RT and MVL did not show a relationship with CDC or MFAB **(Figures 9E, 10E, 9F, 10F)** LOS DCL did correlate with MFAB scores (r= 0.433, p <0.05) but not CDC performance **(Figures 9G, 10G)**.

**Computerized Dynamic Posturography and Physical Function**

As expected, sedentary individuals performed fewer repetitions on the 30STS (Sed= 11.6±2.9 repetitions, Ex= 14.3±3.4 repetitions) **(Table 2)**. No group difference was observed for 8TUG performance **(Table 2)**. For all subjects (n=25) 30STS and 8TUG did not show a relationship with SOT performance **(Figures 11A, 12A)**. 30STS and 8TUG did not correlate with MCT composite score **(Figures 11B, 12B)**. 30STS and 8TUG did not relate to ADT toes up and toes down energy sway scores **(Figures 11C, 12C, 11D, 12D)**. As expected, 30STS was significantly correlated to LOS RT, but 8TUG outcomes showed no relationship with LOS RT **(Figures 11E, 12E)**. 30STS and 8TUG showed no relationship with LOS MVL (**Figures 11F, 12F)**. 30 STS and 8TUG did not show a relationship with LOS DCL **(Figures 11G, 12G)**.

**Table 2. Subject Demographics.**

| | Exercise (n=13) | Sedentary (n=12) | P-value |
|---|---|---|---|
| **Age (years)** | 71.0 (6.1) | 68.5 (5.02) | .277 |
| **H&Y Stage** | 1.5 (0.52) | 1.7 (0.49) | .645 |
| **Structured Ex (min/week)** | 207.7 (56.7) | 0 (0) | -- |
| **Vig-Activity Time (min/week)** | 126.5 (124.6) | 12.27 (28.3) | -- |
| **Sed-Time (min/week)** | 2462.7 (1136.9) | 3714.55 (1610.8) | -- |
| **UPDRS-MIII Score** | 23.5 (10.37) | 25.7 (8.97) | .758 |
| **MFAB Score** | **33.5 (3.3)** | **25.8 (4.5)** | **<.001**** |
| **4CDC (seconds)** | **38.5 (2.5)** | **31.3 (5.6)** | **<.001**** |
| **30STS (repetitions)** | **14.3 (3.4)** | **11.6 (2.9)** | **.043*** |
| **8TUG (seconds)** | 7.53 (1.9) | 8.8 (1.6) | .099 |

H&Y Stage= Hoehn and Yahr Stage of PD, Structured Ex= reported structured exercise time, Vig. Activity Time= reported vigorous activity time, Sed-Time= reported sedentary time, UPDRS-MIII Score= Unified Parkinson's Disease Rating Scale: Motor Examination (Part III) Score.

Data are reported as Mean (SD) from Exercise (n=13) and Sedentary (n=12) unless otherwise noted. *p<0.05 vs Control.

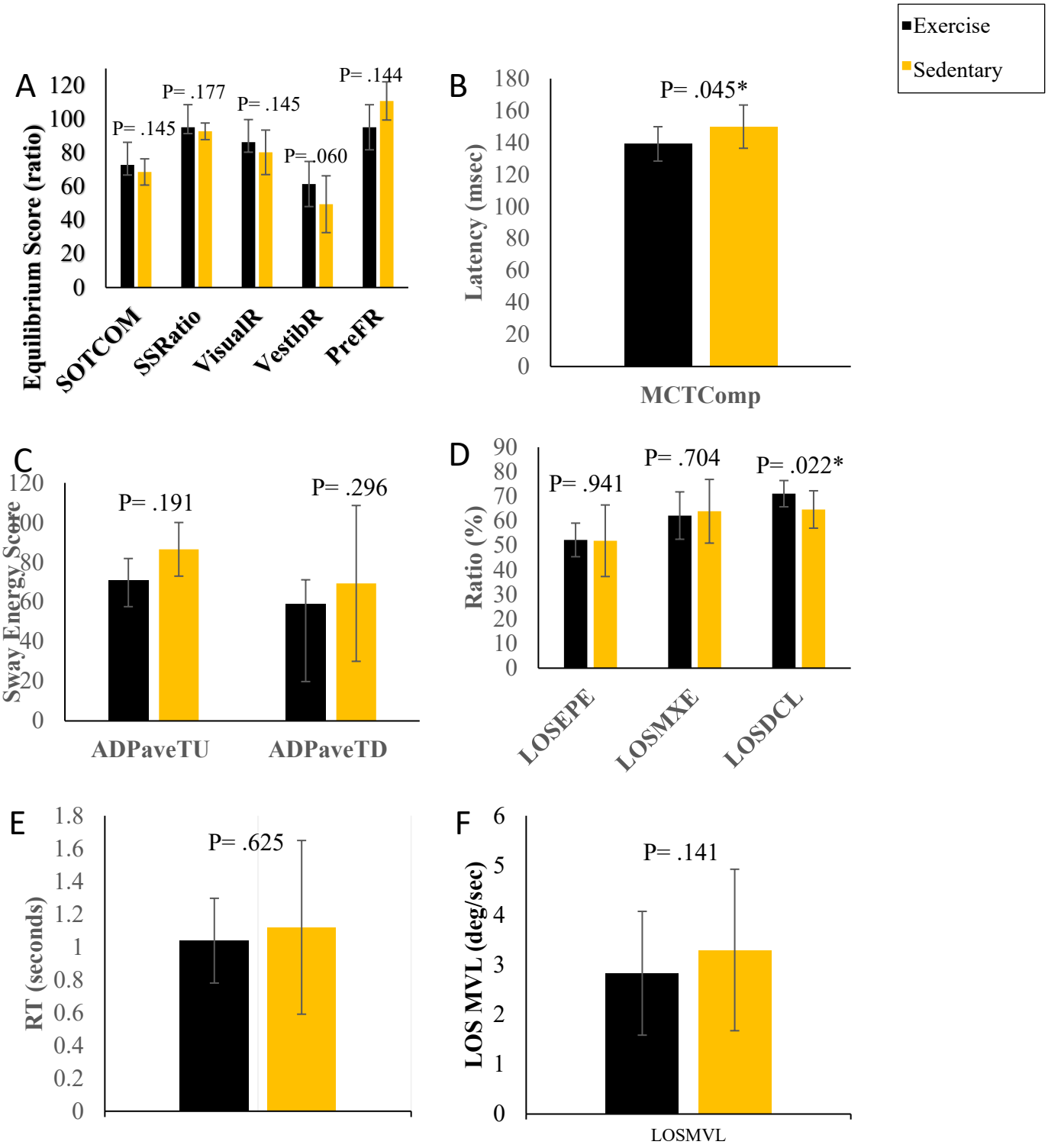


**Figure 7. CDP Performance-** Data are reported as mean (SD) from exercise (n=13) and sedentary (n=12). A) Equilibrium scores from SOT Composite and sensory analysis ratios (SOM, VIS, VESTIB, and PREF). B) MCT Composite (msec) C) ADT toes up and toes down average sway energy scores. D) LOS EPE, MXE, and DCL ratios (%). E) LOS RT (seconds). F) LOS MVL (deg/sec).

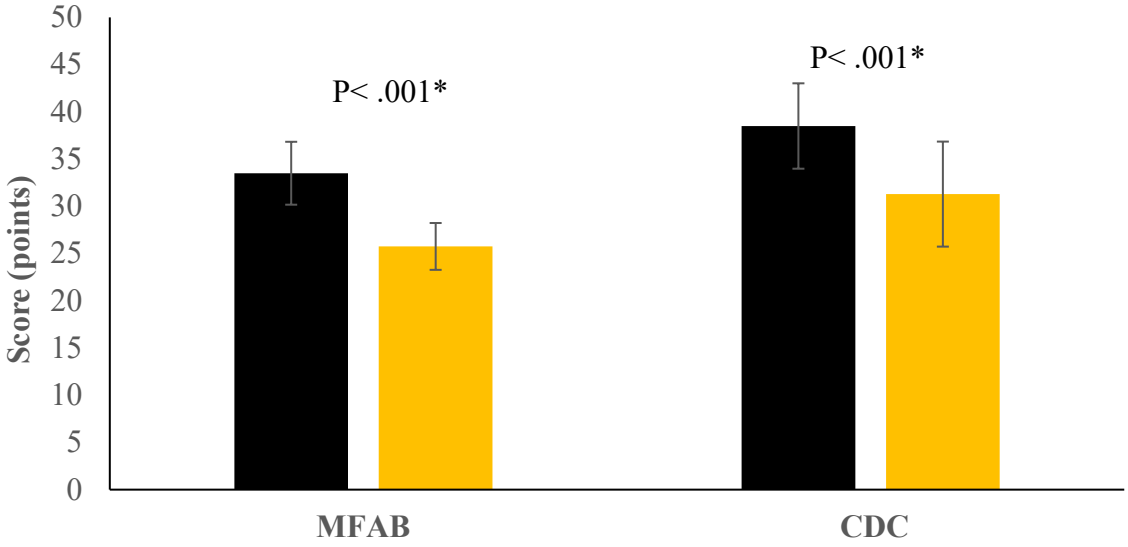


**Figure 8. Clinical Balance Assessments-** Data reported as mean (SD) from exercise (n=13) and sedentary (n=12). Scores on MFAB and 4CDC balance assessments on a scale of 40. Note: equal variance could not be assumed for 4CDC test.

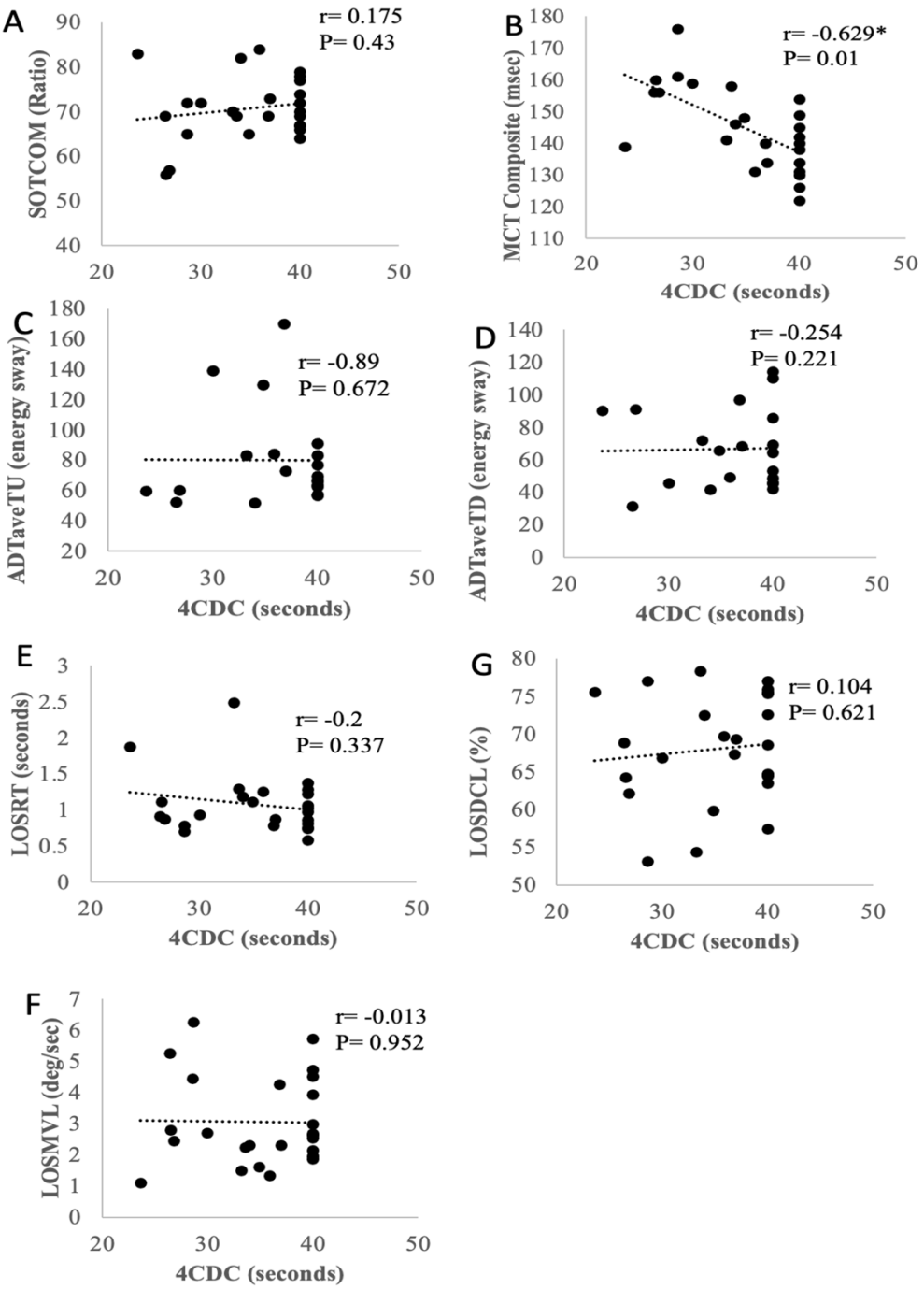


**Figure 9. Relationship between 4-Stage CDC assessment and main outcome variables of CDP.** Data are reported as Mean (SD) from entire dataset (n=25). *p<0.05, **p<0.01. A) SOT composite score compared to 4CDC. B) MCT Composite score compared to CDC. C) ADT toes up (energy sway) compared to 4CDC. D) ADT toes down (energy sway) compared to CDC. E) LOS RT (sec) compared to 4CDC. F) LOS MVL (deg/sec) compared to 4CDC. G) LOS DCL (%) compared to 4CDC.

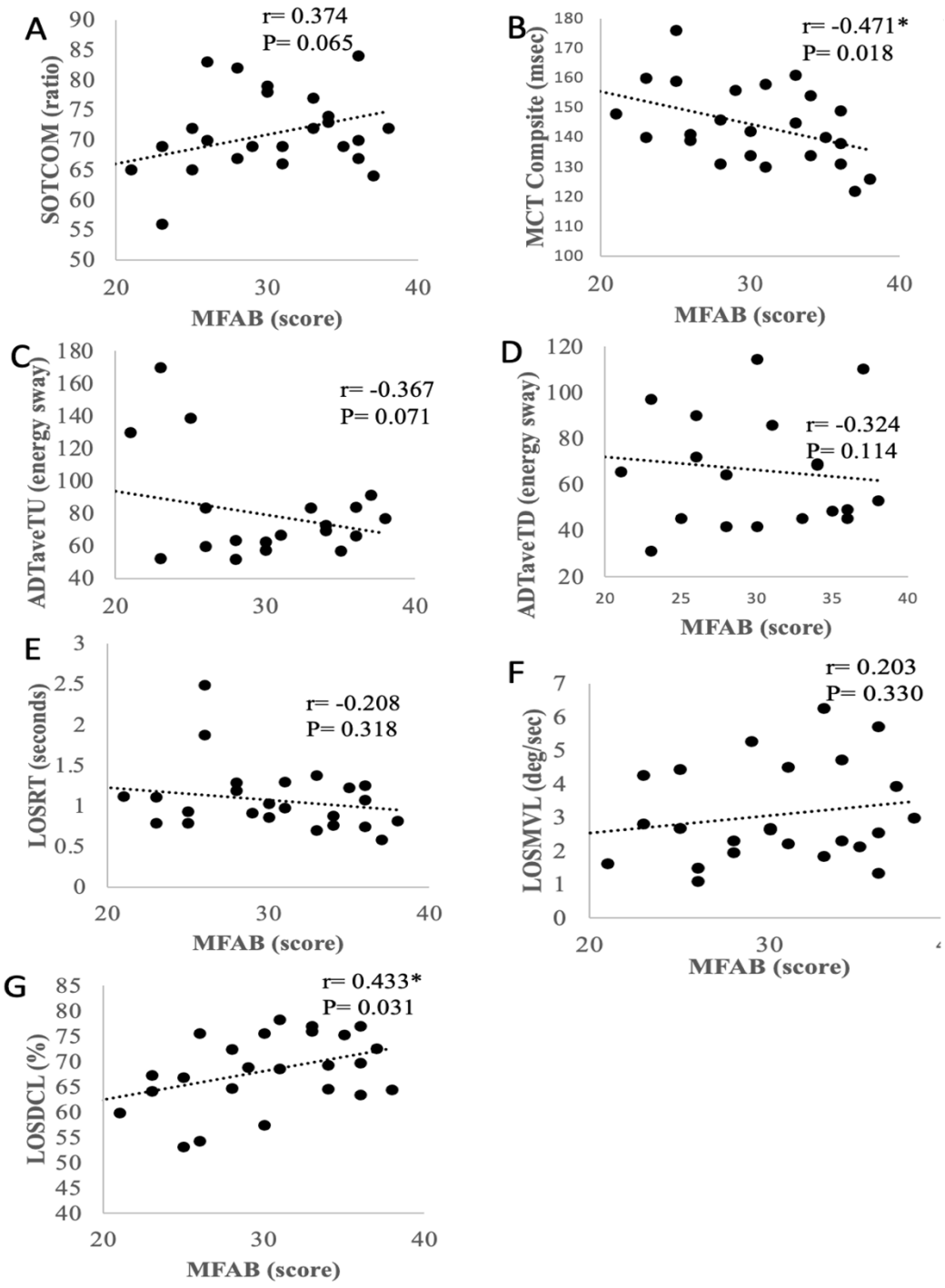


**Figure 10. Relationship between MFAB assessment and main outcome variables of CDP.** Data are reported as Mean(SD) from entire dataset (n=25). *p<0.05, **p<0.01. A) SOT composite score compared to MFAB. B) MCT Composite score compared to MFAB. C) ADT toes up (energy sway) compared to MFAB. D) ADT toes down (energy sway) compared to MFAB. E) LOS RT (sec) compared to MFAB. F) LOS MVL (deg/sec) compared to MFAB. G) LOS DCL (%) compared to MFAB.

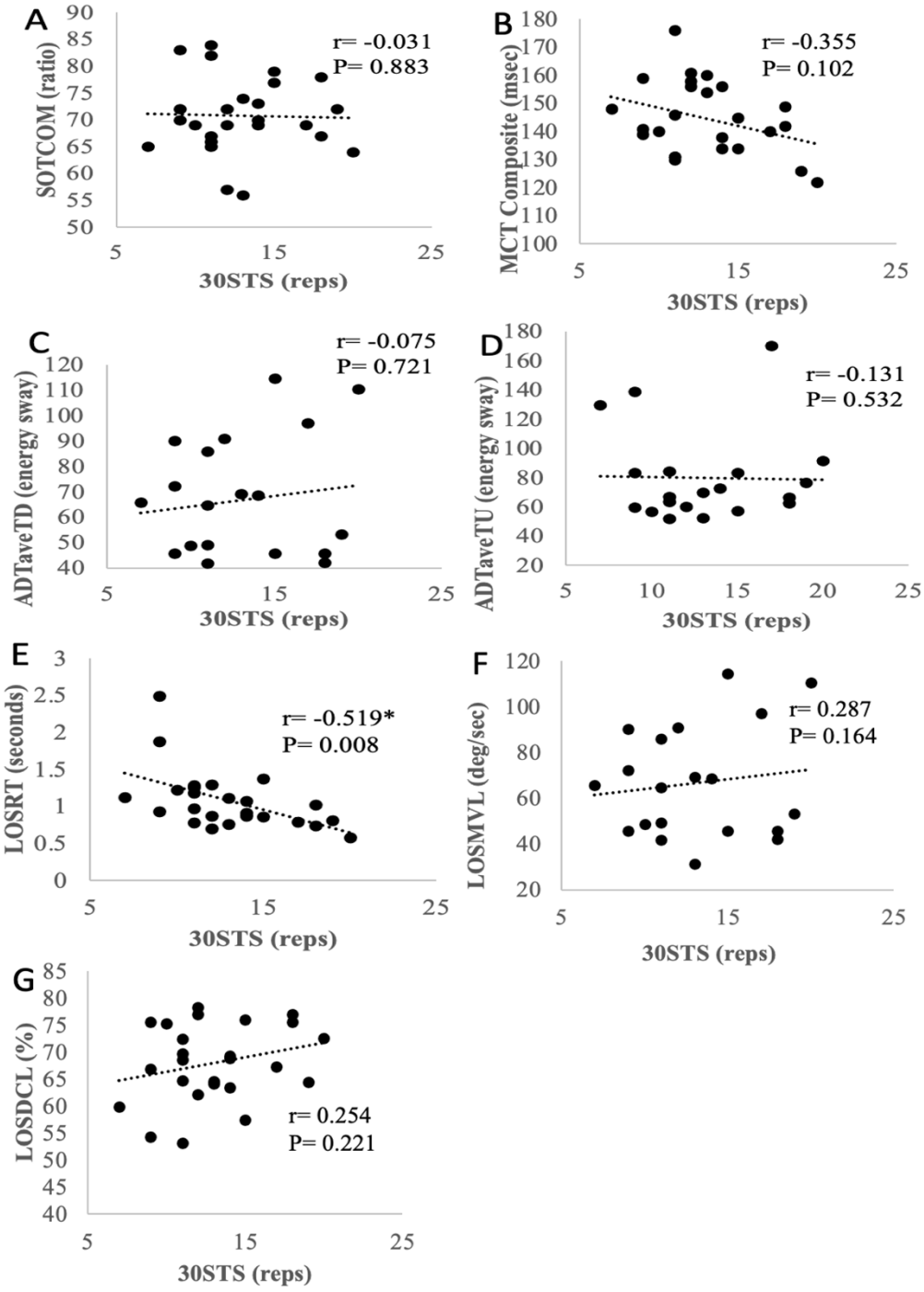


**Figure 11. Relationship between 30STS assessment and main outcome variables of CDP.** Data are reported as Mean(SD) from entire dataset (n=25). *p<0.05, **p<0.01. A) SOT composite score compared to 30STS. B) MCT Composite score compared to 30STS. C) ADT toes up (energy sway) compared to 30STS. D) ADT toes down (energy sway) compared to 30STS. E) LOS RT (sec) compared to 30STS. F) LOS MVL (deg/sec) compared to 30STS. G) LOS DCL (%) compared to 30STS.

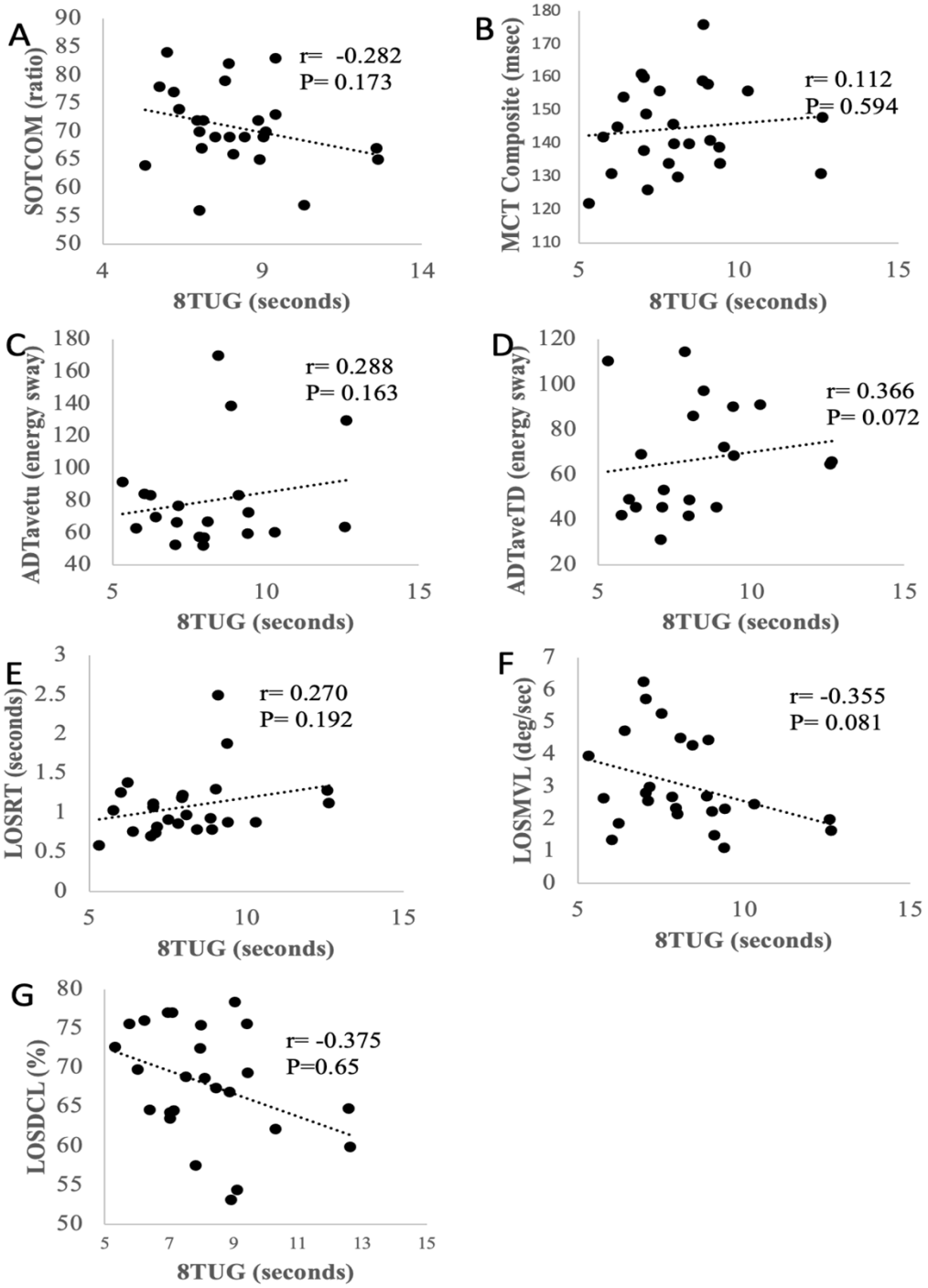


**Figure 12. Relationship between 8TUG assessment and main outcome variables of CDP.** Data are reported as Mean(SD) from entire dataset (n=25). *p<0.05, **p<0.01. A) SOT composite score compared to 8TUG. B) MCT Composite score compared to 8TUG. C) ADT toes up (energy sway) compared to 8TUG. D) ADT toes down (energy sway) compared to 8TUG. E) LOS RT (sec) compared to 8TUG. F) LOS MVL (deg/sec) compared to 8TUG. G) LOS DCL (%) compared to 8TUG.

# CHAPTER 5: DISCUSSION

## Overview

Main findings of the present study were: 1) individuals who exercise did not perform significantly better on CDP assessments in comparison to their sedentary counterparts; 2) exercising individuals did perform better on clinical balance assessments (MFAB and 4CDC) when compared to sedentary controls; and 3) physical function performance (30STS and 8TUG) measures did not significantly relate to CDP assessments. These data agree with current literature that indicates exercise participation positively impacts balance and physical function performance. The CDP outcomes found in this study align with the discrepancies observed in exercise literature and the ability of CDP to detect changes in postural control.

## Computerized Dynamic Posturography

Posturography outcomes in response to exercise- and balance-specific training within the literature are generally inconclusive. Mohieldin et al., reported training induced changes in SOT composite scores for individuals with early-stage PD (H & Y 1-2) (123). Contrary to the previously addressed study, MCT composite scores also were improved post-exercise, which aligns with differences in MCT composite scores observed between exercisers and non-exercisers discussed in the current cohort. UPDRS motor examination scores and Hoehn and Yahr stages for both cohorts are comparable, suggesting that SOT composite score differences could result from implementation of more sensory-specific training than the current cohort and that both interventions are adequate for improving motor control outcomes.

Ehl-Kholy et al. compared a combined medication and physiotherapy intervention to medication only and healthy control postural control performances. Pre- to post- testing showed physiotherapy interventions significantly improved MCT latencies while ADT energy sway

scores did not show between group differences. LOS reaction times, movement velocities, directional control, end point, and maximal excursions were all positively improved post-training (124). Our data showed similar trends for MCT latency outcomes, lack of relationship between training and ADT energy sway changes, and higher directional control outcomes for trained individuals, but did not yield the same outcomes for reaction time, movement velocity, end point, or maximal excursions. CDP performance between the two studies appear to express similar outcomes, findings from this cohort cannot be reasonably compared to the current study, as individuals with early onset PD were not excluded and the study duration spanned from 2-9 years of intervention.

Valverde et al. reported improvements in vestibular function and overall SOT composite score in response to a contemporary dance intervention, with no post-training improvements in visual function, somatosensory function, or visual preference, while MCT composite score was also unchanged post-training (125). The current study partially agrees with these findings, yielding no significant group differences in sensory analysis of visual function, somatosensory function, or visual preference. On the contrary, this study did not detect training-induced improvements to SOT composite score or vestibular function, and group differences were detected shown by the MCT composite score, indicating MCT outcomes in this study were influenced by exercise. Both studies were conducted in early stages of PD, (H & Y < 3) with participants reporting similar UPDRS motor examination scores, indicating a comparable sample size. Because cohort characteristics were generally comparable, these findings could be due to specificity of training: contemporary dance may impact postural control measures differently than boxing.

The relationship between exercise and PI measured by posturography remains unclear. Data from the current study did not detect a difference in SOT composite scores or sensory analysis

between exercising and sedentary individuals. Current literature reports mixed reviews regarding exercise and CDP outcomes (12, 16, 17, 122-125). Variation of exercise duration, training specificity related to dynamic balance, motor symptom expression reported by the UPDRS motor examination, and stage of disease progression are likely contributors to reported discrepancies.

**Clinical Balance and Physical Function in PD**

Several studies implemented clinical balance assessments to evaluate exercise-induced changes in postural control of people with PD (12, 23, 123-126). In comparison to a control group without neurological disease, clinical balance assessments were able to detect balance deficits present in PD (123, 125, 126) Exercise interventions that incorporated balance- and motor-specific training showed improvements in dynamic balance performance reported by clinical assessments, such as the BBS, BESTest, and mini-BESTest (12, 123, 125). In the current study, exercisers averaged 20% higher scores on the MFAB and 24% on the 4CDC tests compared to sedentary individuals. Static balance outcomes, as measured by the 4CDC assessment, during this study observed a ceiling effect **(Figure 9A-G)**, while the MFAB outcomes did not **(Figure 10A-G).** These findings align with current literature that validates the MFAB as a reliable assessment with no ceiling effect (110), suggesting it is a more reliable tool than 4CDC to evaluate functional balance performance.

Based on cut off criteria for the MFAB (≥25/40) and 4CDC (≥30/40) to classify fall risk, the exercise group in this study were classified as a low fall risk, while the sedentary control performances on both assessments met the criteria to be considered a fall risk (**Table 2).** Several reports corroborate these findings, indicating that individuals with PD who exercise have better balance and are at less risk for a fall (6-16, 126-129), especially during early disease stages

(123). These data indicate significant discrepancy between clinical balance assessment outcomes and computerized dynamic posturography,

**Relationship between Clinical Balance, Physical Function, and Computerized Dynamic Posturography Outcomes**

Numerous tools are utilized to assess CDP, physical function, and balance that have been widely validated as adequate measures on their own; however, discrepancies exist within literature regarding how some scales relate to each other. Kalkan et al. reported a direct relationship between performance on the Berg Balance Scale (BBS) with LOS endpoint and maximal excursions, but no correlation between BBS and LOS reaction time (126). This conflicts directly with results from the current study, which identified a negative correlation between the MFAB scale and LOS reaction time (Figure #) but no relationship with endpoint or maximal excursions. Souza et al. reported no relationship between static or dynamic posturography outcomes in comparison to the BBS and mini-BEST balance assessments. Only one component of dynamic posturography, the step-up, showed a negative correlation with TUG times, suggesting that posturography measures during movement are more indicative of functional performance than static stance performance (128). Discrepancies between performance on clinical assessments and posturography be attributed to increased motor demands of posturography in comparison to simpler tasks demanded by the BBS and mini-BEST (130). All assessments of posturography, excluding LOS, evaluate automatic postural reflexes, while clinical assessments and physical function tests incorporate voluntary postural reflexes. Lack of correlation between assessment outcomes suggests that individual motor skills associated with each system do not translate directly to others.

Data collected from the present cohort (n= 25) shows CDP scores do not align with current posturography values in the literature for PD. When compared to normative data for healthy age-matched controls, the present dataset suggests cohort performance (exercise + sedentary) was above average on all CDP assessments. McGuirk et al. originally validated CDP to detect differences in postural control between individuals with PD compared to healthy, age-matched controls. Statistically significant differences were detected during comparison of SOT composite score, visual ratio, vestibular ratio, preferential ratio, LOS reaction time, movement velocity, endpoint excursion, and maximal excursion (96). The exercise group from this current study yielded scores more closely related to data reported for healthy controls in the previous study, while the sedentary cohort mimics, and in a few variables, outperforms the PD population from the earlier study (96). Considering the impact of a PD diagnosis on PI, these reports are highly conflicting.

Current literature suggests that to improve balance and functional mobility, exercise interventions must be multidisciplinary, incorporating PRT with alternative modalities of exercise that emphasize functional and structurally loading movements that demand motor coordination (6-16, 84-94). The exercise program utilized for this intervention encompasses these recommendations, so it was hypothesized that posturography outcomes would be positively influenced by exercise participation, however, posturography outcomes collected in this study did not concur with this hypothesis. Clinical balance assessment outcomes showed that exercising individuals performed at higher levels than sedentary individuals, exhibiting better overall balance. This discrepancy suggests that CDP and clinical assessment tools utilized in this study measure different aspects of balance that do not directly translate to each other, and that CDP is not a sensitive enough tool to detect exercise-induced changes of PI in early stages of PD.

## Conclusion

Computerized posturography appears unable to detect a significant difference in postural control outcomes between exercising and sedentary individuals in initial stages of PD. Clinical balance assessments, the MFAB and CDC, were able to differentiate between exercisers and non-exercisers. The difference may be that clinical balance assessment utilized in this study were more dynamic and exercise specific in nature, and therefore were able to detect higher level balance differences compared to CDP. Regarding physical function outcomes, the 30STS was able to detect higher physical function for the exercisers, while the 8TUG was not. Both physical function outcomes showed no meaningful relationship with CDP, indicating that balance performance is not directly related to physical function outcomes. Alternative posturography measures should be evaluated in relation to clinical balance assessments to establish ideal techniques for evaluating exercise and disease state-induced changes to PI in PD.

# CHAPTER 6: LIMITATIONS AND FUTURE DIRECTIONS

## Limitations

### *Study Design*

This study was not conducted as a blinded, randomized controlled trial. Participants for the exercise group were recruited from an exercise program run by the investigator directly involved with data collection. Duration of regular exercise participation and postural control measures prior to exercise participation could not be accounted for with this study design. This study only included individuals who were considered Hoehn and Yahr Stage I or II (early-stage), therefore none of the data collected can be used to speculate performance as disease state progresses.

### *Computerized Dynamic Posturography Limitations*

During posturography assessment, the subject's feet are positioned in a narrow, slightly abnormal stance on the platform that may impact balance performance. Performance may also be negatively impacted by anxiety driven by fear of falling, especially on the limits of stability test, which measures voluntary postural control (131, 132). Current literature shows that while platform posturography, such as what was utilized in this investigation, provides valid insight into postural sway during stance, mobile posturography provides more data in relation to balance during free-living movement and would be a more effective measurement tool.

### *Implications of the COVID-19 Pandemic*

Prior to the COVID-19 Pandemic, the Human Performance Program had several participants with PD who had been regularly exercising for years. Due to nationwide shutdowns and participant hesitancy until vaccine approval, several participants stopped exercising regularly for almost a year. As a result, the exercise participant pool was severely limited to individuals who had only recently re-started exercise within the last year, which likely impaired performance from where it might've been in years prior. Even sedentary individuals have reported to be significantly more sedentary during the pandemic, which could have compromised their performance as well.

## Future Directions

Future directions include a randomized controlled trial where participants are recruited, randomized into either an exercise intervention or sedentary control group, with pre- and post-testing conducted to evaluate the potential impact of exercise training on improving postural control measures. Outside of computerized dynamic posturography, other top tier postural control assessment systems should be screened for ability to detect exercise-induced changes in balance, such as mobile posturography. This study did not investigate data from strategy analysis

during the SOT or center of pressure differences between groups, which has been reported to be impacted in PD. It would be important to consider including individuals with later stage PD to determine if postural control changes exercise interventions are consistent across the spectrum of disease.

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# APPENDIX A. STUDY DOCUMENTATION

## CONSENT FORM TO PARTICIPATE IN A RESEARCH STUDY

**NAME(S) OF RESEARCHER(S): ELENA DOCTOR, BS**

**PROJECT IRB #: 2046064**

**STUDY TITLE: THE IMPACT OF EXERCISE ON POSTURAL CONTROL IN PATIENTS WITH PARKINSON'S DISEASE MEASURED BY COMPUTERIZED DYNAMIC POSTUROGRAPHY**

This research study is about how exercise training impacts postural control in patients diagnosed with Parkinson's disease.

We invite you to take part in this research study. This consent form tells you why we are doing the study, and what will happen if you join the study.

Please take as much time as you need to read this consent form. You can discuss it with your family, friends, or anyone you choose. If there is anything you do not understand, please ask us to explain. Then you can decide if you want to take part in the study or not.

The Principal Investigator and Co-Investigators are Elena Doctor, Drs. Stephen Ball, Rebecca Bliss, Jill Kanaley. Elena Doctor is a graduate student in the Nutrition and Exercise Physiology Department conducting this study for her master's thesis. Dr. Ball and Dr. Kanaley are professors in the Nutrition and Exercise Physiology Department and Dr. Bliss is a professor in the School of Health Professions.

Research studies help us to answer questions that may improve our understanding of human behavior, attitudes, beliefs, and interactions. Taking part in a research study is voluntary. You are free to say yes or no. We will only include you in this study if you give us your permission first by signing this consent form.

## Why Is This Study Being Done?

The purpose of this research is to understand the impact of exercise participation on postural control in patients diagnosed with Parkinson's disease. We will compare results of postural control assessments to performance on static and dynamic balance assessments as well as results from a 30 second sit-to-stand and 8 foot timed up-and-go assessments. These values will help us evaluate the relationship between

postural control, balance, and fitness in patients with Parkinson's disease who exercise versus those who do not.

#### How Many People Will Be In This Study?

About 32 people will take part in this study with 16 in the exercise group and 16 in the control group.

## What Will Happen If I Take Part In This Study?

We will go through the Physical Activity Readiness Questionnaire (PAR-Q) and the Unified Parkinson's Disease Rating Scale (UPDRS) to ensure that you are eligible to participate and classify you into the exercise or sedentary group. If you choose to continue, we will use the NeuroCom Smart Balance Master System to perform a series of assessments that will tell us how your visual, somatosensory, and vestibular systems all work together to help you maintain your posture, how well you adapt to unexpected changes in

## How Long Will I Be In The Study?

You will be in the study for a total of 1.5 hours for one day.

## Can I Stop Being In The Study?

Yes, you can stop being in the study at any time without giving a reason. Just tell the researcher or study staff right away if you wish to stop taking part.

Also, the researcher may decide to take you off this study at any time, even if you want to stay in the study. The researcher will tell you the reason why you need to stop being in the study. These reasons may be:

- You are unable to complete the study protocol
- You do not wish to continue participation at any given time
- You are found to have contraindications to exercise

## Are There Any Benefits To Taking Part In This Study?

There will be no financial compensation offered for partaking in this study, however, you will be given feedback regarding your performance on the computerized dynamic posturography, balance, and fitness assessments. The information we learn from you during this study will help us to better understand the

relationship between fitness levels, balance, and postural control and how they are affected by exercise training in people with Parkinson's disease.

## Are There Any Risks From Being In This Study?

With any exercise, there is a potential for risk of injury. Prior to all assessments, we will use your responses on the Physical Activity Readiness Questionnaire (PAR-Q) to be sure that you do not show any contraindications to participating in physical activity. During the computerized dynamic posturography assessments in the NeuroCom, you will be secured into a harness so that you are not at risk of falling. During balance and fitness assessments, you will be given clear instructions and always monitored by a qualified exercise professional. You will be provided with rest breaks as often and long as needed.

## Will Information About Me Be Kept Private?

The information we collect about you will be stored in the researcher's electronic/computer or paper files. Computer files are protected with a password and the computer is in a locked office that only study team members can open. Paper files are kept in a locked drawer in a locked office that only study team members can open.

We will give your records a code number and they will not contain your name or other information that could identify you. The code number that connects your name to your information will be kept in a separate, secure location. Information that may identify you may not be given to anyone who is not working on this study without your written consent, or if required by law.

We will do our best to make sure that your personal information from this study is kept private, but we cannot guarantee total privacy. We may give out your personal information if the law requires it. If we publish the results of this study or present them at scientific meetings, we will not use your name or other personal information.

We will keep the information we collect from you for this study to use in future research/to share with other investigators to use in future studies without asking for your consent again. Information that could identify you will be removed from your research information so no one will know that it belongs to you.

## Will I Be Paid For Taking Part In This Study?

You will not be paid for taking part in this study.

## What Are My Rights as a Study Participant?

Taking part in this study is voluntary. If you do decide to take part, you have the right to change your mind and drop out of the study at any time. Whatever your decision, there will be no penalty to you in any way.

We will tell you about any new information discovered during this study that might affect your health, welfare, or change your mind about taking part.

### WHO CAN I CALL IF I HAVE QUESTIONS, CONCERNS, OR COMPLAINTS?

If you have more questions about this study at any time, you can call Elena Doctor at 716-803-0705.

You may contact the University of Missouri Institutional Review Board (IRB if you:

- Have any questions about your rights as a study participant;
- Want to report any problems or complaints; or
- Feel under any pressure to take part or stay in this study.
- The IRB is a group of people who review research studies to make sure the rights of participants are protected. Their phone number is 573- 882-3181.

If you want to talk privately about your rights or any issues related to your participation in this study, you can contact University of Missouri Research Participant Advocacy by calling 888-280-5002 (a free call), or emailing MUResearchRPA@missouri.edu.

We will give you a copy of this consent form. Please keep it where you can find it easily. It will help you to remember what we discussed today.

## Signature of Partipicpant

**Consent to Participate in Research**

By signing my name below, I confirm the following:

- I have read/had read to me this entire consent form.
- All of my questions were answered to my satisfaction.
- The study's purpose, procedures/activities, potential risks and possible benefits were explained to me.

- I voluntarily agree to take part in this research study. I have been told that I can stop at any time.

| | |
|---|---|
| | |
| **Subject's Signature** | **Date** |

## I. Participant Information

Date of Assessment: _____

DOB: _____

ID: _____ Age: _____

UPDRS Part III Score: _____ Hoehn and Yahr: _____

Medication(s) and time last taken/dosage: _____

## II. Balance Assessments

Modified FAB Score: _____ Notes: _____

4 Stage CDC Score: _____

## III. Functional Assessments

8-Foot Timed-Up-and-Go

Trial 1: _____ Notes: _____

Trial 2: _____

**Best: _____**

30 Second Sit-to-Stand Notes: _____

Trial 1: _____

Trial 2: _____ **Best: _____**

# 2020 PAR-Q+

## The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

## GENERAL HEALTH QUESTIONS

| **Please read the 7 questions below carefully and answer each one honestly: check YES or NO.** | **YES** | **NO** |
|---|---|---|
| 1) Has your doctor ever said that you have a heart condition ☐ **OR** high blood pressure ☐? | ☐ | ☐ |
| 2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity? | ☐ | ☐ |
| 3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise). | ☐ | ☐ |
| 4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** _____ | ☐ | ☐ |
| 5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** _____ | ☐ | ☐ |
| 6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:** _____ | ☐ | ☐ |
| 7) Has your doctor ever said that you should only do medically supervised physical activity? | ☐ | ☐ |

**If you answered NO to all of the questions above, you are cleared for physical activity.**
**Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.**

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age (https://apps.who.int/iris/handle/10665/44399).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

**PARTICIPANT DECLARATION**

If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

**If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.**

**Delay becoming more active if:**

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

 

01-11-2019

# 2020 PAR-Q+

## FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

**1. Do you have Arthritis, Osteoporosis, or Back Problems?**

If the above condition(s) is/are present, answer questions 1a-1c  If **NO** ☐ go to question 2

| | | |
|---|---|---|
| 1a. | Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) | YES ☐ NO ☐ |
| 1b. | Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)? | YES ☐ NO ☐ |
| 1c. | Have you had steroid injections or taken steroid tablets regularly for more than 3 months? | YES ☐ NO ☐ |

**2. Do you currently have Cancer of any kind?**

If the above condition(s) is/are present, answer questions 2a-2b  If **NO** ☐ go to question 3

| | | |
|---|---|---|
| 2a. | Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck? | YES ☐ NO ☐ |
| 2b. | Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)? | YES ☐ NO ☐ |

**3. Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm**

If the above condition(s) is/are present, answer questions 3a-3d  If **NO** ☐ go to question 4

| | | |
|---|---|---|
| 3a. | Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) | YES ☐ NO ☐ |
| 3b. | Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction) | YES ☐ NO ☐ |
| 3c. | Do you have chronic heart failure? | YES ☐ NO ☐ |
| 3d. | Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months? | YES ☐ NO ☐ |

**4. Do you currently have High Blood Pressure?**

If the above condition(s) is/are present, answer questions 4a-4b  If **NO** ☐ go to question 5

| | | |
|---|---|---|
| 4a. | Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) | YES ☐ NO ☐ |
| 4b. | Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure) | YES ☐ NO ☐ |

**5. Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes**

If the above condition(s) is/are present, answer questions 5a-5e  If **NO** ☐ go to question 6

| | | |
|---|---|---|
| 5a. | Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies? | YES ☐ NO ☐ |
| 5b. | Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness. | YES ☐ NO ☐ |
| 5c. | Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet? | YES ☐ NO ☐ |
| 5d. | Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)? | YES ☐ NO ☐ |
| 5e. | Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future? | YES ☐ NO ☐ |

# 2020 PAR-Q+

**6. Do you have any Mental Health Problems or Learning Difficulties?** This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome

If the above condition(s) is/are present, answer questions 6a-6b  If **NO** ☐ go to question 7

| | | |
|---|---|---|
| 6a. | Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) | YES ☐ NO ☐ |
| 6b. | Do you have Down Syndrome **AND** back problems affecting nerves or muscles? | YES ☐ NO ☐ |

**7. Do you have a Respiratory Disease?** This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure

If the above condition(s) is/are present, answer questions 7a-7d  If **NO** ☐ go to question 8

| | | |
|---|---|---|
| 7a. | Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) | YES ☐ NO ☐ |
| 7b. | Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy? | YES ☐ NO ☐ |
| 7c. | If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week? | YES ☐ NO ☐ |
| 7d. | Has your doctor ever said you have high blood pressure in the blood vessels of your lungs? | YES ☐ NO ☐ |

**8. Do you have a Spinal Cord Injury?** This includes Tetraplegia and Paraplegia

If the above condition(s) is/are present, answer questions 8a-8c  If **NO** ☐ go to question 9

| | | |
|---|---|---|
| 8a. | Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) | YES ☐ NO ☐ |
| 8b. | Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting? | YES ☐ NO ☐ |
| 8c. | Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)? | YES ☐ NO ☐ |

**9. Have you had a Stroke?** This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event

If the above condition(s) is/are present, answer questions 9a-9c  If **NO** ☐ go to question 10

| | | |
|---|---|---|
| 9a. | Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments) | YES ☐ NO ☐ |
| 9b. | Do you have any impairment in walking or mobility? | YES ☐ NO ☐ |
| 9c. | Have you experienced a stroke or impairment in nerves or muscles in the past 6 months? | YES ☐ NO ☐ |

**10. Do you have any other medical condition not listed above or do you have two or more medical conditions?**

If you have other medical conditions, answer questions 10a-10c  If **NO** ☐ read the Page 4 recommendations

| | | |
|---|---|---|
| 10a. | Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months? | YES ☐ NO ☐ |
| 10b. | Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)? | YES ☐ NO ☐ |
| 10c. | Do you currently live with two or more medical conditions? | YES ☐ NO ☐ |

**PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE:** _____

_____

**GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.**



11-01-2019

# 2020 PAR-Q+

**If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:**

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

**Delay becoming more active if:**

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

## PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

*I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.*

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

For more information, please contact

**www.eparmedx.com**

**Email: eparmedx@gmail.com**

**Citation for PAR-Q+**
Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

**Key References**

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11-01-2019

## GPAQ

| Physical Activity | | | |
|---|---|---|---|
| Next I am going to ask you about the time you spend doing different types of physical activity in a typical week. Please answer these questions even if you do not consider yourself to be a physically active person.<br>Think first about the time you spend doing work. Think of work as the things that you have to do such as paid or unpaid work, study/training, household chores, harvesting food/crops, fishing or hunting for food, seeking employment. *[Insert other examples if needed].* In answering the following questions 'vigorous-intensity activities' are activities that require hard physical effort and cause large increases in breathing or heart rate, 'moderate-intensity activities' are activities that require moderate physical effort and cause small increases in breathing or heart rate. | | | |
| **Questions** | | **Response** | **Code** |
| **Activity at work** | | | |
| 1 | Does your work involve vigorous-intensity activity that causes large increases in breathing or heart rate like *[carrying or lifting heavy loads, digging or construction work*] for at least 10 minutes continuously?<br>*[INSERT EXAMPLES] (USE SHOWCARD)* | Yes 1<br>No 2 *If No, go to P 4* | P1 |
| 2 | In a typical week, on how many days do you do vigorous-intensity activities as part of your work? | Number of days ⌊__⌋ | P2 |
| 3 | How much time do you spend doing vigorous-intensity activities at work on a typical day? | Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋<br>hrs mins | P3 (a-b) |
| 4 | Does your work involve moderate-intensity activity that causes small increases in breathing or heart rate such as brisk walking *[or carrying light loads*] for at least 10 minutes continuously?<br>*[INSERT EXAMPLES] (USE SHOWCARD)* | Yes 1<br>No 2 *If No, go to P 7* | P4 |
| 5 | In a typical week, on how many days do you do moderate-intensity activities as part of your work? | Number of days ⌊__⌋ | P5 |
| 6 | How much time do you spend doing moderate-intensity activities at work on a typical day? | Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋<br>hrs mins | P6 (a-b) |
| **Travel to and from places** | | | |
| The next questions exclude the physical activities at work that you have already mentioned.<br>Now I would like to ask you about the usual way you travel to and from places. For example to work, for shopping, to market, to place of worship. [insert other examples if needed] | | | |
| 7 | Do you walk or use a bicycle (*pedal cycle*) for at least 10 minutes continuously to get to and from places? | Yes 1<br>No 2 *If No, go to P 10* | P7 |
| 8 | In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places? | Number of days ⌊__⌋ | P8 |
| 9 | How much time do you spend walking or bicycling for travel on a typical day? | Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋<br>hrs mins | P9 (a-b) |
| **Recreational activities** | | | |
| The next questions exclude the work and transport activities that you have already mentioned.<br>Now I would like to ask you about sports, fitness and recreational activities (leisure), [insert relevant terms]. | | | |
| 10 | Do you do any vigorous-intensity sports, fitness or recreational (*leisure*) activities that cause large increases in breathing or heart rate like [*running or football,]* for at least 10 minutes continuously?<br>*[INSERT EXAMPLES] (USE SHOWCARD)* | Yes 1<br>No 2 *If No, go to P 13* | P10 |
| 11 | In a typical week, on how many days do you do vigorous-intensity sports, fitness or recreational (*leisure*) activities? | Number of days ⌊__⌋ | P11 |
| 12 | How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day? | Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋<br>hrs mins | P12 (a-b) |

| **Physical Activity (recreational activities)** contd. | | | |
|---|---|---|---|
| **Questions** | | **Response** | **Code** |
| 13 | Do you do any moderate-intensity sports, fitness or recreational *(leisure*) activities that causes a small increase in breathing or heart rate such as brisk walking,(*cycling, swimming, volleyball*)for at least 10 minutes continuously?<br>*[INSERT EXAMPLES] (USE SHOWCARD)* | Yes 1<br>No 2 *If No, go to P16* | P13 |
| 14 | In a typical week, on how many days do you do moderate-intensity sports, fitness or recreational (*leisure*) activities? | Number of days ⌊__⌋ | P14 |
| 15 | How much time do you spend doing moderate-intensity sports, fitness or recreational (*leisure*) activities on a typical day? | Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋<br>hrs mins | P15 (a-b) |
| **Sedentary behaviour** | | | |
| The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television], but do not include time spent sleeping. *[INSERT EXAMPLES] (USE SHOWCARD)* | | | |
| 16 | How much time do you usually spend sitting or reclining on a typical day? | Hours : minutes ⌊__⌋⌊__⌋ : ⌊__⌋⌊__⌋<br>hrs min s | P16 (a-b) |

## Part III: Motor Examination

Overview: This portion of the scale assesses the motor signs of PD. In administering Part III of the MDS-UPDRS the examiner should comply with the following guidelines:

At the top of the form, mark whether the patient is on medication for treating the symptoms of Parkinson's disease and, if on levodopa, the time since the last dose.

Also, if the patient is receiving medication for treating the symptoms of Parkinson's disease, mark the patient's clinical state using the following definitions:

**ON** is the typical functional state when patients are receiving medication and have a good response.
**OFF** is the typical functional state when patients have a poor response in spite of taking medications.

The investigator should "rate what you see." Admittedly, concurrent medical problems such as stroke, paralysis, arthritis, contracture, and orthopedic problems such as hip or knee replacement and scoliosis may interfere with individual items in the motor examination. In situations where it is absolutely impossible to test (e.g., amputations, plegia, limb in a cast), use the notation "**UR**" for Unable to Rate. Otherwise, rate the performance of each task as the patient performs in the context of co-morbidities.

All items must have an integer rating (no half points, no missing ratings).

Specific instructions are provided for the testing of each item. These should be followed in all instances. The investigator demonstrates while describing tasks the patient is to perform and rates function immediately thereafter. For Global Spontaneous Movement and Rest Tremor items (3.14 and 3.17), these items have been placed purposefully at the end of the scale because clinical information pertinent to the score will be obtained throughout the entire examination.

At the end of the rating, indicate if dyskinesia (chorea or dystonia) was present at the time of the examination, and if so, whether these movements interfered with the motor examination.

**3a** Is the patient on medication for treating the symptoms of Parkinson's disease? ☐ No ☐ Yes

**3b** If the patient is receiving medication for treating the symptoms of Parkinson's disease, mark the patient's clinical state using the following definitions:

☐ ON: On is the typical functional state when patients are receiving medication and have a good response.

☐ OFF: Off is the typical functional state when patients have a poor response in spite of taking medications.

**3c** Is the patient on levodopa ? ☐ No ☐ Yes

**3.C1** If yes, minutes since last levodopa dose: _____

| | SCORE |
|---|---|
| **3.1 SPEECH**<br><br>Instructions to examiner: Listen to the patient's free-flowing speech and engage in conversation if necessary. Suggested topics: ask about the patient's work, hobbies, exercise, or how he got to the doctor's office. Evaluate volume, modulation (prosody), and clarity, including slurring, palilalia (repetition of syllables), and tachyphemia (rapid speech, running syllables together).<br><br>0: Normal: No speech problems.<br><br>1: Slight: Loss of modulation, diction, or volume, but still all words easy to understand.<br><br>2: Mild: Loss of modulation, diction, or volume, with a few words unclear, but the overall sentences easy to follow.<br><br>3: Moderate: Speech is difficult to understand to the point that some, but not most, sentences are poorly understood.<br><br>4: Severe: Most speech is difficult to understand or unintelligible. | ☐ |
| **3.2 FACIAL EXPRESSION**<br><br>Instructions to examiner: Observe the patient sitting at rest for 10 seconds, without talking and also while talking. Observe eye-blink frequency, masked facies or loss of facial expression, spontaneous smiling, and parting of lips.<br><br>0: Normal: Normal facial expression.<br><br>1: Slight: Minimal masked facies manifested only by decreased frequency of blinking.<br><br>2: Mild: In addition to decreased eye-blink frequency, masked facies present in the lower face as well, namely fewer movements around the mouth, such as less spontaneous smiling, but lips not parted.<br><br>3: Moderate: Masked facies with lips parted some of the time when the mouth is at rest.<br><br>4: Severe: Masked facies with lips parted most of the time when the mouth is at rest. | ☐ |

**3.3 RIGIDITY**

Instructions to examiner: Rigidity is judged on slow passive movement of major joints with the patient in a relaxed position and the examiner manipulating the limbs and neck. First, test without an activation maneuver. Test and rate neck and each limb separately. For arms, test the wrist and elbow joints simultaneously. For legs, test the hip and knee joints simultaneously. If no rigidity is detected, use an activation maneuver such as tapping fingers, fist opening/closing, or heel tapping in a limb not being tested. Explain to the patient to go as limp as possible as you test for rigidity.

0: Normal: No rigidity.

1: Slight: Rigidity only detected with activation maneuver.

2: Mild: Rigidity detected without the activation maneuver, but full range of motion is easily achieved.

3: Moderate: Rigidity detected without the activation maneuver; full range of motion is achieved with effort.

4: Severe: Rigidity detected without the activation maneuver and full range of motion not achieved.

**SCORE**

☐ Neck

☐ RUE

☐ LUE

☐ RLE

☐ LLE

**3.4 FINGER TAPPING**

Instructions to examiner: Each hand is tested separately. Demonstrate the task, but do not continue to perform the task while the patient is being tested. Instruct the patient to tap the index finger on the thumb 10 times as quickly AND as big as possible. Rate each side separately, evaluating speed, amplitude, hesitations, halts, and decrementing amplitude.

0: Normal: No problems.

1: Slight: Any of the following: a) the regular rhythm is broken with one or two interruptions or hesitations of the tapping movement; b) slight slowing; c) the amplitude decrements near the end of the 10 taps.

2: Mild: Any of the following: a) 3 to 5 interruptions during tapping; b) mild slowing; c) the amplitude decrements midway in the 10-tap sequence.

3: Moderate: Any of the following: a) more than 5 interruptions during tapping or at least one longer arrest (freeze) in ongoing movement; b) moderate slowing; c) the amplitude decrements starting after the 1st tap.

4: Severe: Cannot or can only barely perform the task because of slowing, interruptions, or decrements.

☐ R

☐ L

| | SCORE |
|---|---|
| **3.5 HAND MOVEMENTS**<br><br>Instructions to examiner: Test each hand separately. Demonstrate the task, but do not continue to perform the task while the patient is being tested. Instruct the patient to make a tight fist with the arm bent at the elbow so that the palm faces the examiner. Have the patient open the hand 10 times as fully AND as quickly as possible. If the patient fails to make a tight fist or to open the hand fully, remind him/her to do so. Rate each side separately, evaluating speed, amplitude, hesitations, halts, and decrementing amplitude.<br><br>0: Normal: No problems.<br><br>1: Slight: Any of the following: a) the regular rhythm is broken with one or two interruptions or hesitations of the movement; b) slight slowing; c) the amplitude decrements near the end of the task.<br><br>2: Mild: Any of the following: a) 3 to 5 interruptions during the movements; b) mild slowing; c) the amplitude decrements midway in the task.<br><br>3: Moderate: Any of the following: a) more than 5 interruptions during the movement or at least one longer arrest (freeze) in ongoing movement; b) moderate slowing; c) the amplitude decrements starting after the 1st open-and-close sequence.<br><br>4: Severe: Cannot or can only barely perform the task because of slowing, interruptions, or decrements. | ☐ R<br><br>☐ L |
| **3.6 PRONATION-SUPINATION MOVEMENTS OF HANDS**<br><br>Instructions to examiner: Test each hand separately. Demonstrate the task, but do not continue to perform the task while the patient is being tested. Instruct the patient to extend the arm out in front of his/her body with the palms down, and then to turn the palm up and down alternately 10 times as fast and as fully as possible. Rate each side separately, evaluating speed, amplitude, hesitations, halts, and decrementing amplitude.<br><br>0: Normal: No problems.<br><br>1: Slight: Any of the following: a) the regular rhythm is broken with one or two interruptions or hesitations of the movement; b) slight slowing; c) the amplitude decrements near the end of the sequence.<br><br>2: Mild: Any of the following: a) 3 to 5 interruptions during the movements; b) mild slowing; c) the amplitude decrements midway in the sequence.<br><br>3: Moderate: Any of the following: a) more than 5 interruptions during the movement or at least one longer arrest (freeze) in ongoing movement; b) moderate slowing; c) the amplitude decrements starting after the 1st supination-pronation sequence.<br><br>4: Severe: Cannot or can only barely perform the task because of slowing, interruptions, or decrements. | ☐ R<br><br>☐ L |

| | SCORE |
|---|---|
| **3.7 TOE TAPPING**<br><br>Instructions to examiner: Have the patient sit in a straight-backed chair with arms, both feet on the floor. Test each foot separately. Demonstrate the task, but do not continue to perform the task while the patient is being tested. Instruct the patient to place the heel on the ground in a comfortable position and then tap the toes 10 times as big and as fast as possible. Rate each side separately, evaluating speed, amplitude, hesitations, halts, and decrementing amplitude.<br><br>0: Normal: No problems.<br><br>1: Slight: Any of the following: a) the regular rhythm is broken with one or two interruptions or hesitations of the tapping movement; b) slight slowing; c) amplitude decrements near the end of the ten taps.<br><br>2: Mild: Any of the following: a) 3 to 5 interruptions during the tapping movements; b) mild slowing; c) amplitude decrements midway in the task.<br><br>3: Moderate: Any of the following: a) more than 5 interruptions during the tapping movements or at least one longer arrest (freeze) in ongoing movement; b) moderate slowing; c) amplitude decrements after the 1st tap.<br><br>4: Severe: Cannot or can only barely perform the task because of slowing, interruptions or decrements. | ☐ R<br><br>☐ L |
| **3.8 LEG AGILITY**<br><br>Instructions to examiner: Have the patient sit in a straight-backed chair with arms. The patient should have both feet comfortably on the floor. Test each leg separately. Demonstrate the task, but do not continue to perform the task while the patient is being tested. Instruct the patient to place the foot on the ground in a comfortable position and then raise and stomp the foot on the ground 10 times as high and as fast as possible. Rate each side separately, evaluating speed, amplitude, hesitations, halts and decrementing amplitude.<br><br>0: Normal: No problems.<br><br>1: Slight: Any of the following: a) the regular rhythm is broken with one or two interruptions or hesitations of the movement; b) slight slowing; c) amplitude decrements near the end of the task.<br><br>2: Mild: Any of the following: a) 3 to 5 interruptions during the movements; b) mild slowness; c) amplitude decrements midway in the task.<br><br>3: Moderate: Any of the following: a) more than 5 interruptions during the movement or at least one longer arrest (freeze) in ongoing movement; b) moderate slowing in speed; c) amplitude decrements after the 1st tap.<br><br>4: Severe: Cannot or can only barely perform the task because of slowing, interruptions, or decrements. | ☐ R<br><br>☐ L |

| | SCORE |
|---|---|
| **3.11 FREEZING OF GAIT**<br><br>Instructions to examiner: While assessing gait, also assess for the presence of any gait freezing episodes. Observe for start hesitation and stuttering movements especially when turning and reaching the end of the task. To the extent that safety permits, patients may NOT use sensory tricks during the assessment.<br><br>0: Normal: No freezing.<br><br>1: Slight: Freezes on starting, turning, or walking through doorway with a single halt during any of these events, but then continues smoothly without freezing during straight walking.<br><br>2: Mild: Freezes on starting, turning, or walking through doorway with more than one halt during any of these activities, but continues smoothly without freezing during straight walking.<br><br>3: Moderate: Freezes once during straight walking.<br><br>4: Severe: Freezes multiple times during straight walking. | ☐ |
| **3.12 POSTURAL STABILITY**<br><br>Instructions to examiner: The test examines the response to sudden body displacement produced by a quick, forceful pull on the shoulders while the patient is standing erect with eyes open and feet comfortably apart and parallel to each other. Test retropulsion. Stand behind the patient and instruct the patient on what is about to happen. Explain that s/he is allowed to take a step backwards to avoid falling. There should be a solid wall behind the examiner, at least 1-2 meters away to allow for the observation of the number of retropulsive steps. The first pull is an instructional demonstration and is purposely milder and not rated. The second time the shoulders are pulled briskly and forcefully towards the examiner with enough force to displace the center of gravity so that patient MUST take a step backwards. The examiner needs to be ready to catch the patient, but must stand sufficiently back so as to allow enough room for the patient to take several steps to recover independently. Do not allow the patient to flex the body abnormally forward in anticipation of the pull. Observe for the number of steps backwards or falling. Up to and including two steps for recovery is considered normal, so abnormal ratings begin with three steps. If the patient fails to understand the test, the examiner can repeat the test so that the rating is based on an assessment that the examiner feels reflects the patient's limitations rather than misunderstanding or lack of preparedness. Observe standing posture for item 3.13.<br><br>0: Normal: No problems. Recovers with one or two steps.<br><br>1: Slight: 3-5 steps, but subject recovers unaided.<br><br>2: Mild: More than 5 steps, but subject recovers unaided.<br><br>3: Moderate: Stands safely, but with absence of postural response; falls if not caught by examiner.<br><br>4: Severe: Very unstable, tends to lose balance spontaneously or with just a gentle pull on the shoulders. | ☐ |

| | SCORE |
|---|---|
| **3.13 POSTURE**<br><br>Instructions to examiner: Posture is assessed with the patient standing erect after arising from a chair, during walking, and while being tested for postural reflexes. If you notice poor posture, tell the patient to stand up straight and see if the posture improves (see option 2 below). Rate the worst posture seen in these three observation points. Observe for flexion and side-to-side leaning.<br><br>0: Normal: No problems.<br><br>1: Slight: Not quite erect, but posture could be normal for older person.<br><br>2: Mild: Definite flexion, scoliosis or leaning to one side, but patient can correct posture to normal posture when asked to do so.<br><br>3: Moderate: Stooped posture, scoliosis or leaning to one side that cannot be corrected volitionally to a normal posture by the patient.<br><br>4: Severe: Flexion, scoliosis or leaning with extreme abnormality of posture. | ☐ |
| **3.14 GLOBAL SPONTANEITY OF MOVEMENT (BODY BRADYKINESIA)**<br><br>Instructions to examiner: This global rating combines all observations on slowness, hesitancy, and small amplitude and poverty of movement in general, including a reduction of gesturing and of crossing the legs. This assessment is based on the examiner's global impression after observing for spontaneous gestures while sitting, and the nature of arising and walking.<br><br>0: Normal: No problems.<br><br>1: Slight: Slight global slowness and poverty of spontaneous movements.<br><br>2: Mild: Mild global slowness and poverty of spontaneous movements.<br><br>3: Moderate: Moderate global slowness and poverty of spontaneous movements.<br><br>4: Severe: Severe global slowness and poverty of spontaneous movements. | ☐ |
| **3.15 POSTURAL TREMOR OF THE HANDS**<br><br>Instructions to examiner: All tremor, including re-emergent rest tremor, that is present in this posture is to be included in this rating. Rate each hand separately. Rate the highest amplitude seen. Instruct the patient to stretch the arms out in front of the body with palms down. The wrist should be straight and the fingers comfortably separated so that they do not touch each other. Observe this posture for 10 seconds.<br><br>0: Normal: No tremor.<br><br>1: Slight: Tremor is present but less than 1 cm in amplitude.<br><br>2: Mild: Tremor is at least 1 but less than 3 cm in amplitude.<br><br>3: Moderate: Tremor is at least 3 but less than 10 cm in amplitude.<br><br>4: Severe: Tremor is at least 10 cm in amplitude. | ☐<br>R<br><br>☐<br>L |

| | SCORE |
|---|---|
| **3.16 KINETIC TREMOR OF THE HANDS**<br><br>Instructions to examiner: This is tested by the finger-to-nose maneuver. With the arm starting from the outstretched position, have the patient perform at least three finger-to-nose maneuvers with each hand reaching as far as possible to touch the examiner's finger. The finger-to-nose maneuver should be performed slowly enough not to hide any tremor that could occur with very fast arm movements. Repeat with the other hand, rating each hand separately. The tremor can be present throughout the movement or as the tremor reaches either target (nose or finger). Rate the highest amplitude seen.<br><br>0: Normal: No tremor.<br>1: Slight: Tremor is present but less than 1 cm in amplitude.<br>2: Mild: Tremor is at least 1 but less than 3 cm in amplitude.<br>3: Moderate: Tremor is at least 3 but less than 10 cm in amplitude.<br>4: Severe: Tremor is at least 10 cm in amplitude. | ☐ R<br>☐ L |
| **3.17 REST TREMOR AMPLITUDE**<br><br>Instructions to examiner: This and the next item have been placed purposefully at the end of the examination to allow the rater to gather observations on rest tremor that may appear at any time during the exam, including when quietly sitting, during walking, and during activities when some body parts are moving but others are at rest. Score the maximum amplitude that is seen at any time as the final score. Rate only the amplitude and not the persistence or the intermittency of the tremor.<br>As part of this rating, the patient should sit quietly in a chair with the hands placed on the arms of the chair (not in the lap) and the feet comfortably supported on the floor for 10 seconds with no other directives. Rest tremor is assessed separately for all four limbs and also for the lip/jaw. Rate only the maximum amplitude that is seen at any time as the final rating.<br><br>Extremity ratings<br>0: Normal: No tremor.<br>1: Slight: < 1 cm in maximal amplitude.<br>2: Mild: ≥ 1 cm but < 3 cm in maximal amplitude.<br>3: Moderate: ≥ 3 cm but < 10 cm in maximal amplitude.<br>4: Severe: ≥ 10 cm in maximal amplitude.<br><br>Lip/Jaw ratings<br>0: Normal: No tremor.<br>1: Slight: < 1 cm in maximal amplitude.<br>2: Mild: ≥ 1 cm but < 2 cm in maximal amplitude.<br>3: Moderate: ≥ 2 cm but < 3 cm in maximal amplitude.<br>4: Severe: ≥ 3 cm in maximal amplitude. | ☐ RUE<br>☐ LUE<br>☐ RLE<br>☐ LLE<br>☐ Lip/Jaw |

**3.18 CONSTANCY OF REST TREMOR**

**SCORE**

Instructions to examiner: This item receives one rating for all rest tremor and focuses on the constancy of rest tremor during the examination period when different body parts are variously at rest. It is rated purposefully at the end of the examination so that several minutes of information can be coalesced into the rating.

0: Normal: No tremor.

1: Slight: Tremor at rest is present ≤ 25% of the entire examination period.

2: Mild: Tremor at rest is present 26-50% of the entire examination period.

3: Moderate: Tremor at rest is present 51-75% of the entire examination period.

4: Severe: Tremor at rest is present > 75% of the entire examination period.

☐

**DYSKINESIA IMPACT ON PART III RATINGS**

A. Were dyskinesias (chorea or dystonia) present during examination? ☐ No ☐ Yes

B. If yes, did these movements interfere with your ratings? ☐ No ☐ Yes

**HOEHN AND YAHR STAGE**

0: Asymptomatic.

1: Unilateral involvement only.

2: Bilateral involvement without impairment of balance.

3: Mild to moderate involvement; some postural instability but physically independent; needs assistance to recover from pull test.

4: Severe disability; still able to walk or stand unassisted.

5: Wheelchair bound or bedridden unless aided.

☐

# Scoring Form for Fullerton Advanced Balance (FAB) Scale

| Trial 1 Date/ Initials: _____ Score: ___ / 40 | Trial 2 Date/ Initials:: _____ Score: ___ / 40 | Trial 3 Date/ Initials: _____ Score: ___ / 40 | Trial 4 Date/ Initials: _____ Score: ___ / 40 |
|---|---|---|---|
| ☐ ≤ 25/40 risk of fall ( long form) | ☐ ≤ 25/40 risk of fall ( long form | ☐ ≤ 25/40 risk of fall ( long form | ☐ ≤ 25/40 risk of fall ( long form |

**1. STANDING FEET TOGETHER, EYES CLOSED**

*"Bring feet together, fold arms, close eyes."*

- **4** Maintain safely 30 sec, eyes closed
- **3** Maintain 30 sec with close supervision, eyes closed
- **2** Maintain more than 10 sec less than 30 sec, eyes closed
- **1** Maintain more than 10 sec, eyes closed
- **0** Unable to obtain correct position independently

Trial: 1_____ 2_____ 3_____ 4_____

**2. FORWARD REACH**

*"Lean forward to reach 10inch without moving your feet."*

- **4** Able to reach, without moving feet, independently
- **3** Able to reach, without moving feet, supervision
- **2** Able to reach, takes one step
- **1** Able to reach, takes two steps
- **0** Unable to reach without taking more than two steps

Trial: 1_____ 2_____ 3_____ 4_____

**3. TURN 360 degrees Right/Left**

*"Turn full circle, pause then turn in the opposite direction."*

- **4** Turn 360 safely in 4 steps or fewer in both directions
- **3** Turns 360 ,unable to complete in 4 steps or fewer in one direction
- **2** Turns 360,takes more than 4 steps in both direction
- **1** Needs close supervision or cueing
- **0** Needs manual assist

Trial: 1_____ 2_____ 3_____ 4_____

**4. STEP UP & OVER 6 inch bench**

*"Step on bench swing opposite leg directly up and over bench."*

- **4** Complete step up and over in both directions independently
- **3** Completes in both directions requires supervision in one or both directions
- **2** Able to step onto bench with leading leg, trail leg contact bench or swings around in one direction
- **1** Able to step onto bench with leading leg, trail leg contact bench or swings around in both directions
- **0** Unable, LOB or manual assistance provided

Trial: 1_____ 2_____ 3_____ 4_____

**5. TANDEM WALK**

*"Walk forward in a straight line, place one foot directly in front of the other."*

- **4** Able to complete 10 steps independently
- **3** Able to complete 10 steps with 1-2 interruptions
- **2** Able to complete 10 steps with 3-5 interruptions
- **1** Able to complete 10 steps with more than 5 interruptions
- **0** Unable to complete 10 steps independently

Trial: 1_____ 2_____ 3_____ 4_____

**6. STAND ON ONE LEG**

*"Fold arms across chest, lift one leg off floor."*

- **4** Able to lift leg and maintain for full 20 sec
- **3** Able to lift leg and maintain for 12 sec or more but less than 20 sec
- **2** Able to lift leg and maintain for more than 5 sec but less than 12 sec
- **1** Able to lift leg and maintain for more than 5 sec
- **0** Unable to or needs assistance

Trial: 1_____ 2_____ 3_____ 4_____

# Scoring Form for Fullerton Advanced Balance (FAB) Scale

### 7. STAND on FOAM & EYES CLOSED

*"Step onto foam, feet shoulder width apart, cross arms over chest and eyes closed."*

**4** Able to step onto foam and maintain standing with eyes closed for 20 sec

**3** Able to step onto foam and maintain standing with eyes closed for more than 10 sec but less than 20 sec

**2** Able to step onto foam and maintain standing with eyes closed for 10 sec or less

**1** Able to step onto foam and maintain standing but unable/ unwilling to close eyes

**0** Unable to step onto foam and maintain with eyes open

Trial: 1_____ 2_____ 3_____ 4_____

### 8. TWO – FOOTED JUMP

*"Jump as far but safely as you can. Make sure that both feet leave the floor and land at same time."*

**4** Able to perform two-footed jump and achieve a distance greater than twice the length of their own feet

**3** Able to jump two-footed jump and achieve a distance greater than length of their own feet

**2** Able to perform two-footed jump, but unable to jump farther than the length of their own feet

**1** Able to initiate two- footed jump, but one foot either leaves or lands before the other

**0** Unwilling , unable to attempt,or attempts but one or both feet do not leave the floor

Trial: 1_____ 2_____ 3_____ 4_____

### 9. WALK with HEAD TURNS

*"Turn your head to the beat of metronome then start walking forward while turning head side to side with each beat of the metronome."*

**4** Able to walk 10 steps in a straight line while performing required number of 30 degree head turns at established pace

**3** Able to walk 10 steps in straight path while performing 30 degree head turns at the established pace but head turns less than 30 degrees in one or both directions

**2** Able to walk 10 steps but veers from straight line while performing 30 degree head turns at established pace

**1** Able to walk 10 steps but unable to complete required number of 30 degree head turns at established pace

**0** Unable to walk 10 steps while maintaining 30 degree head turn at established pace

Trial: 1_____ 2_____ 3_____ 4_____

### 10. REACTIVE POSTURAL CONTROL

*" Slowly lean back into my hand until I ask you to stop."*

**4** Unable to maintain upright balance but able to restore balance independently with only one step

**3** Unable to maintain upright balance, takes two steps but able to restore balance independently

**2** Unable to maintain upright balance, takes more than two steps but able to restore balance independently

**1** Unable to maintain upright balance, takes two or more steps and requires manual assist

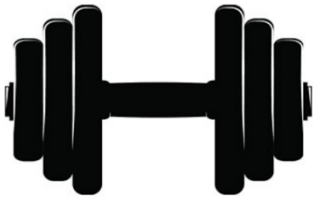
**0** Unable to maintain upright balance, no observable attempt to step, requires manual assist

Trial: 1_____ 2_____ 3_____ 4_____

_____

**Therapist Signature/ Initials**

# EXERCISE AND PARKINSON'S DISEASE RESEARCH STUDY



THE DEPARTMENT OF NUTRITION AND EXERCISE PHYSIOLOGY IS LOOKING FOR INDIVIDUALS WHO HAVE BEEN DIAGNOSED WITH PARKINSON'S DISEASE TO HELP US UNDERSTAND THE IMPACT OF EXERCISE PARTICIPATION ON POSTURAL CONTROL

## THE STUDY INCLUDES:

Nutrition & Exercise Physiology
University of Missouri

- 1.5 HOUR VISIT
- ASSESSMENT OF POSTURAL CONTROL FUNCTIONAL STRENGTH AND BALANCE ASSESSMENTS FREE OF CHARGE TO PARTICIPANTS

## HOW DO I QUALIFY?

- Parkinson's disease diagnosis after age 50
- Not wheelchair bound
- Participating in Rock Steady Boxing 2 times per week for the last 3 months

For more information, contact:
Elena Doctor emd7m9@umsystem.edu
(716) 803-0705

# Appendix B. Computerized Dynamic Posturography Comprehensive Report

University of Missouri
Department of Physical Therapy
801 Clark Hall
Columbia, MO 65011

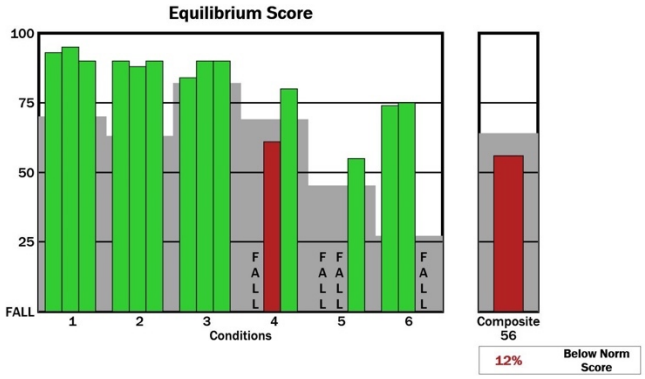
[redacted]
Referral Source: Not Specified
Diagnosis: Not Specified
Comments:

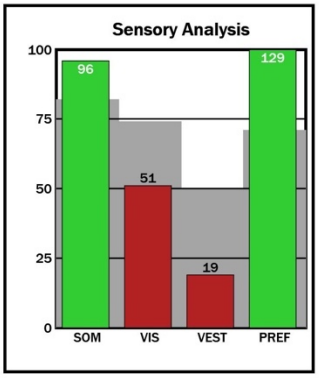
Height: 5'7"

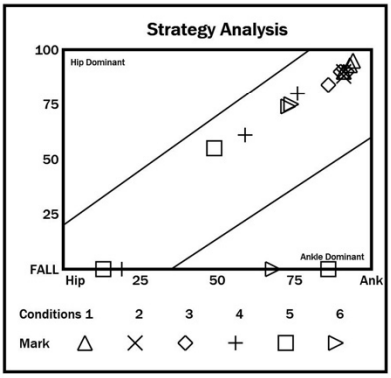
ID: 7b2d7e77-6b52-4340-b59e-f141efddf6b4
File: FD7b2d7e77-6b52-4340-b59e-f141efddf6b4.XDRX2
Operator: Not Specified
Date: 8/5/2021
Time: 19:15:23

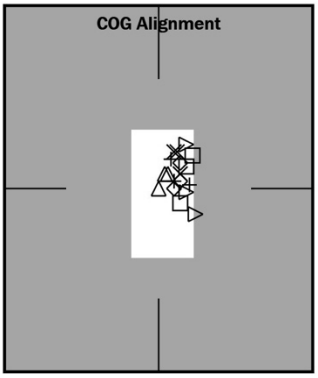
## Sensory Organization Test

(Sway Referenced Gain: 1.0)




**Data Range Note:** NeuroCom Data Range: 70 - 79

Post Test Comment:

University of Missouri
Department of Physical Therapy
801 Clark Hall
Columbia, MO 65011

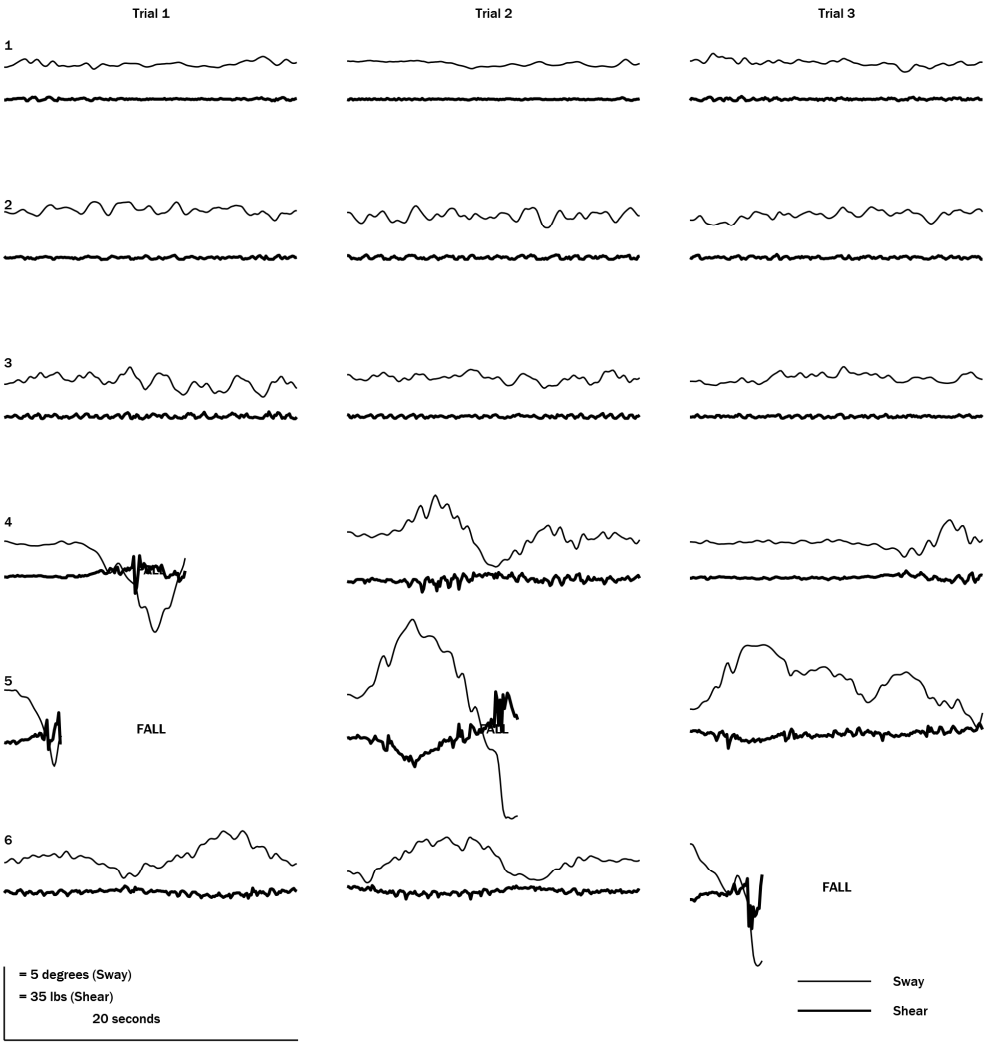
[redacted]

**Height:** 5'7"

**ID:** 7b2d7e77-6b52-4340-b59e-f141efddf6b4
**File:** FD7b2d7e77-6b52-4340-b59e-f141efddf6b4.XDRX2
**Operator:** Not Specified
**Date:** 8/5/2021
**Time:** 19:15:23

**Referral Source:** Not Specified
**Diagnosis:** Not Specified
**Comments:**

## Sensory Organization Test Raw Data



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Department of Physical Therapy
801 Clark Hall
Columbia, MO 65011

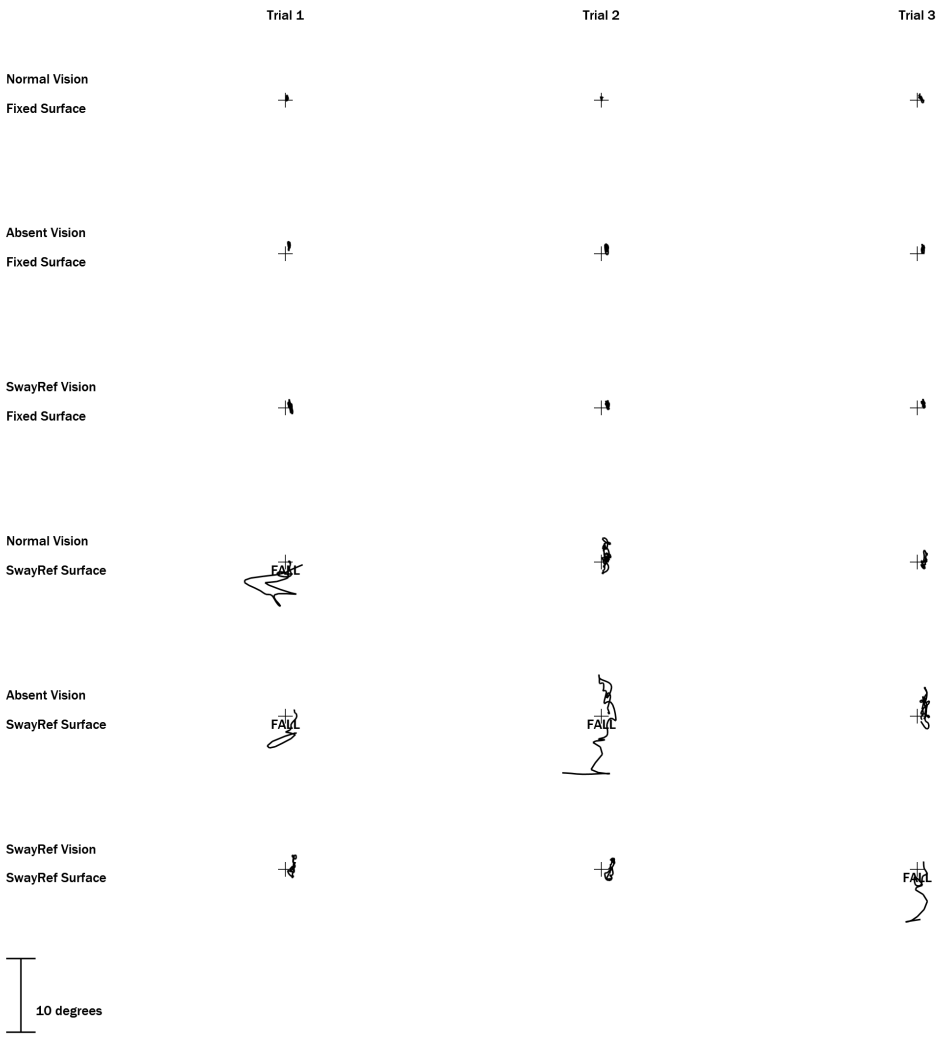
[redacted]

**Height:** 5'7"

**ID:** 7b2d7e77-6b52-4340-b59e-f141efddf6b4
**File:** FD7b2d7e77-6b52-4340-b59e-f141efddf6b4.XDRX2
**Operator:** Not Specified
**Date:** 8/5/2021
**Time:** 19:15:23

**Referral Source:** Not Specified
**Diagnosis:** Not Specified
**Comments:**

## Sensory Organization Test COG Trace



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Department of Physical Therapy
801 Clark Hall
Columbia, MO 65011

[redacted]
Date of Birth: [redacted]
Referral Source: Not Specified
Diagnosis: Not Specified
Comments:

Height: 5'7"

ID: 7b2d7e77-6b52-4340-b59e-f141efddf6b4
File: FD7b2d7e77-6b52-4340-b59e-f141efddf6b4.XDRX2
Operator: Not Specified

## Sensory Organization Test

Test Date: 8/5/2021
Test Time: 19:15:23

| | EQUILIBRIUM | | | STRATEGY | | | COG Alignment | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Conditions | Trial 1 | Trial 2 | Trial 3 | Trial 1 | Trial 2 | Trial 3 | Trial 1 | | Trial 2 | | Trial 3 | |
| 1 | 93 | 95 | 90 | 93 | 94 | 91 | 0.0 | 0.0 | 0.2 | 0.4 | 0.3 | 0.4 |
| 2 | 90 | 88 | 90 | 91 | 91 | 91 | 0.5 | 1.0 | 0.6 | 1.0 | 0.7 | 0.4 |
| 3 | 84 | 90 | 90 | 86 | 90 | 92 | 0.5 | 0.0 | 0.7 | 0.7 | 0.7 | 0.2 |
| 4 | FALL | 61 | 80 | 19 | 59 | 76 | 0.5 | 0.2 | 0.4 | 0.8 | 1.0 | 0.1 |
| 5 | FALL | FALL | 55 | 86 | 13 | 49 | 1.1 | 0.9 | 0.9 | 0.6 | 0.7 | -0.4 |
| 6 | 74 | 75 | FALL | 73 | 74 | 68 | 0.9 | -0.1 | 1.2 | -0.7 | 0.9 | 1.2 |

Composite = 56

Composite Normative Value = 64

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[redacted]

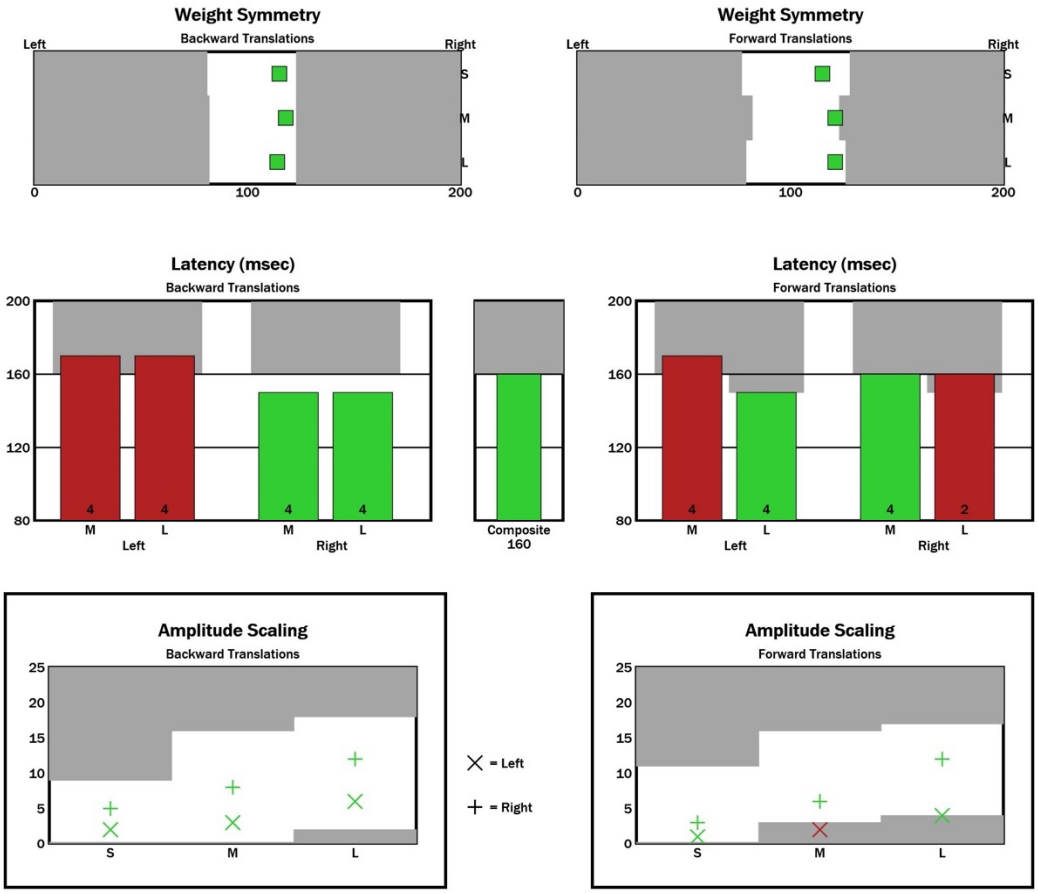
Height: 5'7"

ID: 7b2d7e77-6b52-4340-b59e-f141efddf6b4
File: FD7b2d7e77-6b52-4340-b59e-f141efddf6b4.XDRX2

Referral Source: Not Specified
Diagnosis: Not Specified
Comments:

Operator: Not Specified
Date: 8/5/2021
Time: 19:31:39

## Motor Control Test




**Data Range Note:** NeuroCom Data Range: 70 - 79

Post Test Comment:

University of Missouri
Department of Physical Therapy
801 Clark Hall
Columbia, MO 65011

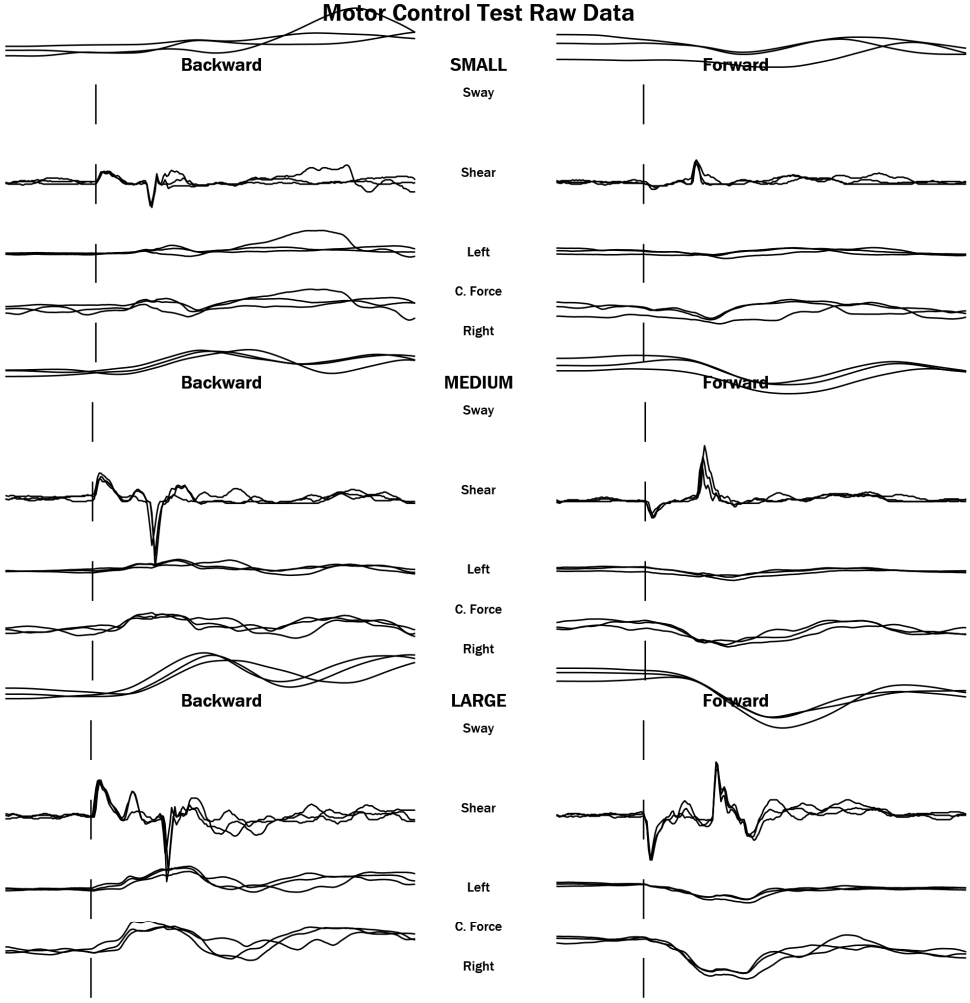
[redacted]

**Height:** 5'7"

**ID:** 7b2d7e77-6b52-4340-b59e-f141efddf6b4
**File:** FD7b2d7e77-6b52-4340-b59e-f141efddf6b4.XDRX2
**Operator:** Not Specified
**Date:** 8/5/2021
**Time:** 19:31:39

**Referral Source:** Not Specified
**Diagnosis:** Not Specified
**Comments:**

## Motor Control Test Raw Data



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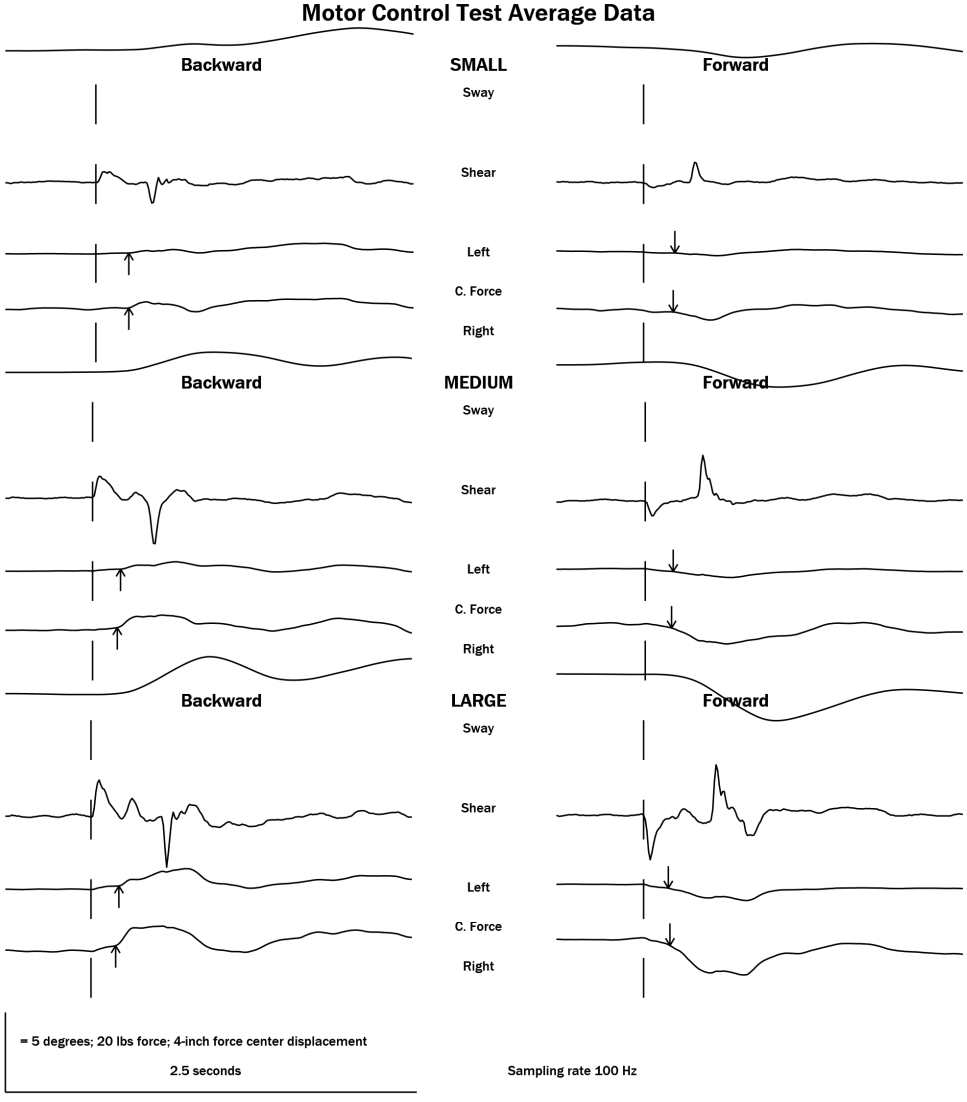
[redacted]

**Height:** 5'7"

**ID:** 7b2d7e77-6b52-4340-b59e-f141efddf6b4
**File:** FD7b2d7e77-6b52-4340-b59e-f141efddf6b4.XDRX2
**Operator:** Not Specified
**Date:** 8/5/2021
**Time:** 19:31:39

**Referral Source:** Not Specified
**Diagnosis:** Not Specified
**Comments:**

## Motor Control Test Average Data



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Columbia, MO 65011

[redacted]

Height: 5'7"

ID: 7b2d7e77-6b52-4340-b59e-f141efddf6b4
File: FD7b2d7e77-6b52-4340-b59e-f141efddf6b4.XDRX2
Operator: Not Specified

Referral Source: Not Specified
Diagnosis: Not Specified
Comments:

## Motor Control Test

Test Date: 8/5/2021
Test Time: 19:31:39

| Translation | WEIGHT SYMMETRY | Latency (msec) Left | | Latency (msec) Right | | Amplitude Scaling Left | Amplitude Scaling Right | STRENGTH SYMMETRY |
|---|---|---|---|---|---|---|---|---|
| Small B | 115 | 200 | 3 | 200 | 3 | 2 | 5 | 142 |
| Medium B | 118 | 170 | 4 | 150 | 4 | 3 | 8 | 145 |
| Large B | 114 | 170 | 4 | 150 | 4 | 6 | 12 | 133 |
| Small F | 115 | 190 | 3 | 180 | 3 | 1 | 3 | 150 |
| Medium F | 121 | 170 | 4 | 160 | 4 | 2 | 6 | 150 |
| Large F | 121 | 150 | 4 | 160 | 2 | 4 | 12 | 150 |

Composite = 160

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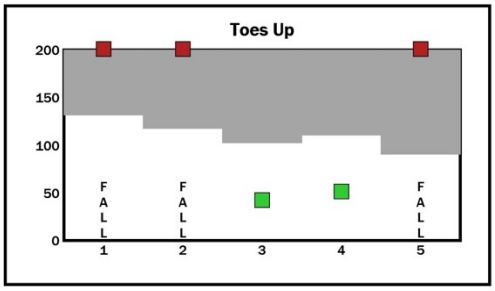
[redacted]

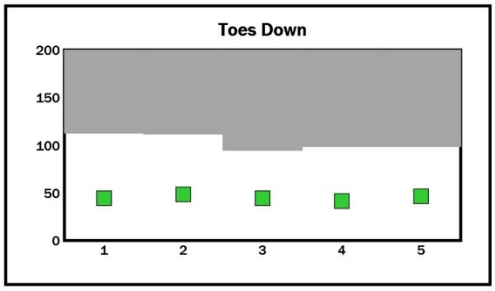
Height: 5'7"

ID: 7b2d7e77-6b52-4340-b59e-f141efddf6b4
File: FD7b2d7e77-6b52-4340-b59e-f141efddf6b4.XDRX2
Operator: Not Specified
Date: 8/5/2021
Time: 19:37:07

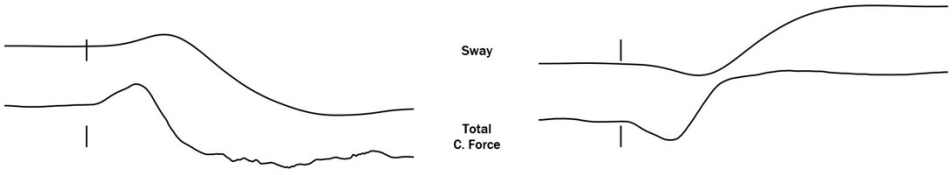
Referral Source: Not Specified
Diagnosis: Not Specified
Comments:

## Adaptation Test

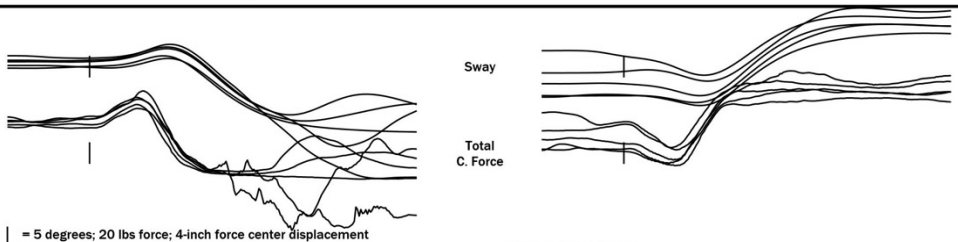



Toes Up | Average Data | Toes Down




Toes Up | Raw Data | Toes Down




= 5 degrees; 20 lbs force; 4-inch force center displacement
2.5 seconds

Sampling rate 100 Hz

**Data Range Note:** NeuroCom Data Range: 70 - 79

Post Test Comment:

University of Missouri
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[redacted]

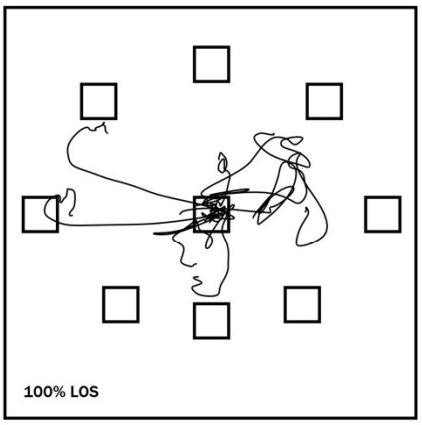
Height: 5'7"

ID: 7b2d7e77-6b52-4340-b59e-f141efddf6b4
File: FD7b2d7e77-6b52-4340-b59e-f141efddf6b4.XDRX2

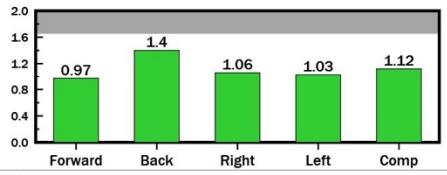
Referral Source: Not Specified
Diagnosis: Not Specified
Comments:

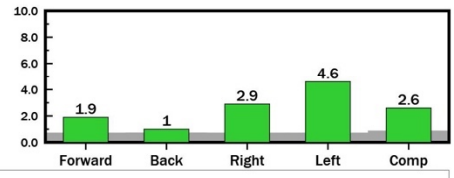
Operator: Not Specified
Date: 8/5/2021
Time: 19:46:30

## Limits Of Stability

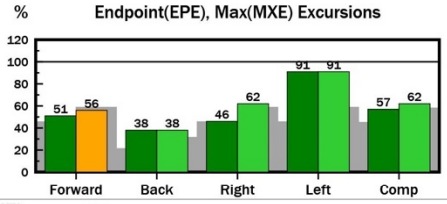


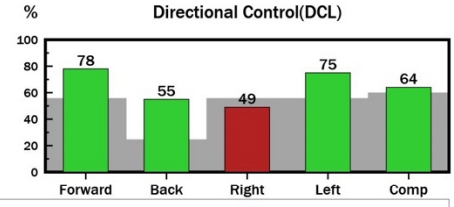

| Transition | RT (sec) | MVL (deg/sec) | EPE (%) | MXE (%) | DCL (%) |
|---|---|---|---|---|---|
| 1 (F) | 1.18 | 0.8 | 29 | 41 | 81 |
| 2 (RF) | 0.70 | 2.2 | 74 | 74 | 81 |
| 3 (R) | 1.07 | 2.2 | 23 | 68 | 58 |
| 4 (RB) | 1.40 | 3.5 | 33 | 34 | 0 |
| 5 (B) | 1.37 | 1.8 | 78 | 78 | 83 |
| 6 (LB) | 1.46 | 2.0 | 43 | 43 | 54 |
| 7 (L) | 0.91 | 5.3 | 97 | 97 | 87 |
| 8 (LF) | 0.82 | 4.7 | 95 | 95 | 70 |




Below Norm Score




Below Norm Score 5% 12%

**Data Range Note:** NeuroCom Data Range: 70 - 79

Post Test Comment:

University of Missouri
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Columbia, MO 65011

[redacted]

**Height:** 5'7"

**ID:** 7b2d7e77-6b52-4340-b59e-f141efddf6b4
**File:** FD7b2d7e77-6b52-4340-b59e-f141efddf6b4.XDRX2
**Operator:** Not Specified

**Referral Source:** Not Specified
**Diagnosis:** Not Specified
**Comments:**

## Limits Of Stability

Test Date: 8/5/2021
Test Time: 19:46:30

| Transition | RT (sec) | MVL (deg/sec) | EPE (%) | MXE (%) | DCL (%) |
|---|---|---|---|---|---|
| 1 | 1.18 | 0.8 | 29 | 41 | 81 |
| 2 | 0.70 | 2.2 | 74 | 74 | 81 |
| 3 | 1.07 | 2.2 | 23 | 68 | 58 |
| 4 | 1.40 | 3.5 | 33 | 34 | 0 |
| 5 | 1.37 | 1.8 | 78 | 78 | 83 |
| 6 | 1.46 | 2.0 | 43 | 43 | 54 |
| 7 | 0.91 | 5.3 | 97 | 97 | 87 |
| 8 | 0.82 | 4.7 | 95 | 95 | 70 |

**Appendix C. Rock Steady Boxing Strength Training Program**

| | | |
|---|---|---|
| **R. A. M. P. Protocol Warm Up**<br><br>**Raise: Dynamic** Locomotion Patterns<br>**Activation/Mobilization:** Focus on major muscle groups and joints, core activation<br>**Potentiation:** Isometric holds, Running Mechanics, Balance and Agility Tasks | | |
| **Phase 1: Week 1-4, Repetition Scheme: 3x15** | | |
| **A Day** | **B Day** | **C Day** |
| Kettlebell Deadlift | Sit-to-Stand (Assisted, Bodyweight) | TRX Split Squat (Isometric Hold or Dynamic) |
| TRX Row | Single-Arm Military Press | TRX Push Ups |
| TRX Lateral Lunge | Assisted Single Leg Hinge | Dumbbell RDL |
| Band Pull-Aparts | Band Lat Pulldown | TRX Row |
| TRX Fallouts | Athletic Stance Band Paloff Press | Dumbbell Single-Arm Suitcase Carry |
| **Phase II: Week 5-8, Repetition Scheme: 3X12** | | |
| Kettlebell Deadlift | Goblet Squat to Box | Bodyweight Split Squat (Isometric Hold or Dynamic) |
| TRX Row | Single-Arm Military Press | TRX Push Ups |
| Bodyweight Lateral Lunge | Bodyweight Single-Leg Hinge | Dumbbell RDL |
| Band Pull-Aparts | Band Lat Pulldown | TRX Row |
| TRX Fallouts | Athletic Stance Band Palloff Press | DB Suitcase Carry |
| **Phase III: Week 9-12, Repetition Scheme: 4X8** | | |
| Kettlebell Deadlift | Goblet Squat | Dumbbell Split Squat |
| TRX Row | Single-Arm Military Press | TRX Push Ups |
| DB Lateral Lunge | Dumbbell Single Leg Hinge | Dumbbell RDL |
| Band Pull-Aparts | Band Lat Pulldown | TRX Row |
| TRX Fallouts | Athletic Stance Band Palloff Press | DB Suitcase Carry |
| **Boxing Segment (15-20 minutes)**<br>**HIIT Intervals- :20 on/:10 off, :30 on/:30 off, :45 on/:15 off**<br>Shadow Boxing<br>Heavy Bags<br>Speedbag Work | | |
| **Energy Systems Development (10-15 minutes):**<br>**Walking, Running, Rowing, Biking** | | |
| **2 x 6:00 minutes**<br>Steady State (60-80% RPE) | **2 X 6:00 minutes:**<br>:30 on/:30 rest | **2 X 6:00 minutes:**<br>:15 on/:15 off |

**Appendix 3 Table 3a-d: Pearson Correlations.**

**Table 3A.** Correlations between MFAB and CDP performance described as a correlation coefficient.

| | **MFAB** | **P-value** |
|---|---|---|
| **SOTCOM** | .374 | .065 |
| **MCTCOM** | -.471* | 0.018 |
| **ADTaveTu** | -.367 | .071 |
| **ADTaveTD** | -.324 | .114 |
| **LOSRT** | -.208 | .318 |
| **LOSMVL** | .203 | .330 |
| **LOSDCL** | .433* | .031 |

**Table 3B.** Correlations between CDC and CDP performance described as correlation coefficient.

| | **CDC** | **P-value** |
|---|---|---|
| **SOTCOM** | .175 | .403 |
| **MCTCOM** | -.629** | .001 |
| **ADTaveTu** | -.089 | .672 |
| **ADTaveTD** | -.254 | .221 |
| **LOSRT** | -.200 | -.337 |
| **LOSMVL** | -.013 | .952 |
| **LOSDCL** | .104 | .621 |

**Table 3C.** Correlations between 30STS and CDP performance described as a correlation coefficient.

| | **30STS** | **P-value** |
|---|---|---|

| | | |
|---|---|---|
| **SOTCOM** | -.031 | .883 |
| **MCTCOM** | -.335 | .102 |
| **ADTaveTu** | -.131 | .532 |
| **ADTaveTD** | -.075 | .721 |
| **LOSRT** | -.519** | .008 |
| **LOSMVL** | .287 | .164 |
| **LOSDCL** | .254 | .221 |

**Table 3D.** Correlations between 30 STS and CDP performance described as a correlation coefficient.

| | **8TUG** | **P-value** |
|---|---|---|
| **SOTCOM** | -.282 | .173 |
| **MCTCOM** | .112 | .594 |
| **ADTaveTu** | .288 | .163 |
| **ADTaveTD** | .366 | .072 |
| **LOSRT** | .270 | .192 |
| **LOSMVL** | -.355 | .081 |
| **LOSDCL** | -.375 | .065 |