Efficacy of LSVT BIG on Parkinson's Disease: A Pilot Study

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ABSTRACT

Objectives: Parkinson's Disease (PD) is a debilitating, neurodegenerative disorder with many different intervention techniques. The investigators sought to test the LSVT BIG treatment on local participants who have PD using multiple clinical and instrumented outcome measures to determine efficacy of the intervention. The investigators also sought to provide evidence showing the accuracy of using clinical measures compared to "gold standard" instrumented measures. Finally, the investigators were interested in determining if there was a change at the muscular level after completing the LSVT BIG intervention. Methods: Balance measures included Five Times Sit to Stand (FTSTS), Brief BESTest, Multi-Directional Reach Test (MDRT), and Postural Stability on the Biodex Balance SD (BBSD). Gait measures included Six Minute Walk Test (6MWT), Functional Gait Assessment (FGA), gait velocity, relative and absolute anticipatory response time, EMG force generated, double limb stance, single limb stance, and integrated EMG. This pilot study of two participants showed little conclusive evidence that LSVT BIG is an effective treatment for PD; however, significant benefits were shown in the Functional Gait Assessment and Brief-BESTest, demonstrating improvements in gait, balance, and fall risk. Unfortunately, multiple limitations diminished the ability to make firm conclusions in this study. Future research opportunities include gathering a larger sample size for better participant selection as well as studying the effects of LSVT BIG on other neurodegenerative disorders, studying whether BIG treatment is most effective during "on" or "off" stages of medication, and utilizing upper extremity outcome measures.

Key words: Parkinson's Disease; LSVT BIG; physical therapy treatment; clinical measures; instrumental measures; dyskinesias

INTRODUCTION

Parkinson's Disease (PD) is a common, sporadic neurodegenerative disorder. The etiology is poorly understood, but is thought to be a combination of environmental factors and genetic predisposition. The "classic triad" symptoms include bradykinesia, resting tremor, and rigidity often in conjunction with postural instability that leads to unsteady gait. It is characterized by the loss of dopamine producing cells in the substantia nigra pars compacta (SNc) in the basal ganglia resulting in decreased dopamine input in the corpus striatum. Therefore, the decreased inhibition from the dopamine causes a relative increase in the cholinergic pathways of the basal ganglia.[1,2,3]

The primary focus of pharmacologic therapy is re-establishing the balance between dopamine and acetylcholine. Levodopa is the gold standard treatment because it directly creates increases in the dopamine levels by metabolizing into dopamine after crossing the blood-brain barrier.[1] While it is effective in decreasing PD symptoms, unfortunately, there are many adverse effects to using levodopa. Dyskinesias, involuntary movements, are challenging side effects that occur in approximately 80% of individuals who take levodopa for an extended amount of time. End-of-dose akinesia is simply when the dose "wears off" prior to the appropriate time to take the next dose. On/off phenomenon is a less understood fluctuation where the PD symptoms suddenly increase, then spontaneously or in response to the next dose, the symptoms decrease again.[1,4]

Because of the limitations to the medical management of PD, it is imperative to find effective non-pharmacological treatment options for these individuals through physical therapy. Literature review reveals a broad variety of treatment options available; however, the gold standard physical therapy treatment has yet to be established. The purpose of the literature

review was to determine appropriate and effective intervention techniques and to determine what makes them effective and how they relate to LSVT BIG.

A systematic review by Petzinger et al demonstrates the effect exercise has on the facilitation of the basal ganglia in people with Parkinson's Disease. They report a finding of 6 different categories of exercise studies on PD, including the following: balance activities, gait, passive range of motion, active range of motion, resistance training, and functional activities with functional movements. They discovered that central, neuroplastic changes are created once a "critical threshold" is reached. The threshold is achieved by high complexity and intensity of tasks that keep the individual engaged. This requires that multiple neuronal circuits are recruited and strengthened. They also determined that reaching critical threshold for skill acquisition through the parameters of intensity, repetition, duration, and complexity is more important than the actual mode of exercise.[5]

Dance is considered a great way to address motor deficits because it is generally enjoyable and engaging, encouraging frequent participation. Specifically, the Argentine tango has been shown to be an effective activity to address gait and balance deficits in the elderly population. Hackney, Kantorovich and Earhart conducted a study showing that the Argentine tango is a more effective intervention technique to improve balance and gait velocity in participants with PD compared to traditional exercise that includes breathing exercises, stretching, resistance, and dexterity exercises. The Argentine tango includes rhythmical experimentation, balance activities, postural stretching, and tango-style walking, individually and with a partner. This requires complexity in rotation, movement initiation and termination, and moving in sync with another person simulating movement in close quarters.[6]

Tai chi is a balance-based exercise used to prevent falls in older adults by improving strength, balance, and physical function. Rhythmic weight shifting, symmetric foot steppage, and controlled movements near the limits of stability are all components of the exercise. A study by Li et al shows tai chi to be more effective in improving maximal excursion, directional control, postural stability, gait quality, and decreased incidence of falls after 24 weeks. In addition to decreased probability of falls, the changes in gait suggest an alleviation of bradykinetic movements.[7]

LSVT BIG is a protocol developed by Dr. Becky Farley to provide intensive amplitude-specific therapy for those with PD based on the fundamental principles of LSVT LOUD. The goal of the protocol is to re-teach everyday movements in a new way such that they become continuous exercise. This ensures carryover and maintenance in daily life once the participant has addressed sensorimotor deficits that result in the small, bradykinetic movements associated with PD.[8] A study by Ebersbach et al compares LSVT BIG, Nordic walking, and an unassisted home exercise program. They found that LSVT BIG produces the greatest results in UPDRS motor score, gait speed, and reaching movements.[9]

Throughout the literature review, common themes were found across successful exercise techniques for PD. Exercises needed to be at a high intensity and encourage the participants to move to their limits of stability. This is best accomplished with whole-body movements and when effort is high enough to effect central motor processing. BIG is designed to address these primary concepts by one-on-one sessions where the therapist ensures effort is high throughout the treatment and large amplitude motions are created with the whole body. Also, these studies do not compare accuracy of clinical versus instrumented measures nor do they utilize EMG or

force plates to determine if changes are made to the muscle themselves when using these interventions.

The questions to be addressed in the research report include the following: Is the LSVT BIG protocol an effective treatment for individuals with Parkinson's Disease? Are common clinical measures consistent with instrumented measures for determining change in physical function in individuals with PD? Is there a change in the muscle activation during sit-to-stand and gait initiation as demonstrated through EMG after completing LSVT BIG?

METHODS

Design Overview

This pilot study followed a clinical trial with a small intervention group to assess effectiveness of the LSVT BIG exercise protocol on clinical and instrumental measures of balance and gait in participants with PD.

Participants

IRB approval was received through the IRB committee of Angelo State University. Participants were recruited through the local Parkinson's Disease support group. The researchers presented information about the research project and provided contact information for anyone interested. Inclusion and exclusion criteria are listed in Appendix A. Three individuals volunteered for the research project, with two fitting our inclusion/exclusion criteria. One did not fit our criteria because he had Lewy body dementia resulting in parkinsonism, and he was unable to walk the distance suggested; however, the researchers chose to include him in the study to determine if there was any improvement when the diagnosis is not strictly Parkinson's Disease.

Detailed participant information is listed in Table 1. PDB02 was the only participant to complete the research schedule to the 4 month follow-up. PDB01 completed the BIG

intervention and the immediate follow-up data collection; however, she was unable to return for the 4 month follow-up after the death of her spouse. PDB03 failed to complete protocol requirements for continuing participation in the study after he missing 4 of the 16 BIG intervention days, or 25%, making him no longer a study candidate.

Outcome Measures

Participants were assessed at 3 time points: baseline within one week prior to initiation of the intervention, within one week post-BIG intervention, and 4 months post-BIG intervention. All participants provided informed consent.

Outcome measure instructions and reliability are located in Appendix B.

Five Times Sit-To-Stand (FTSTS). As stated previously, balance is greatly affected in people with PD. Several studies demonstrated that sit-to-stand performance is influenced by balance.[10,11] A study by Duncan et al demonstrated that in the PD population a time of greater than 16 seconds to complete this task indicated the fall risk. Therefore, a cut off score of 16 seconds discriminates fallers from non-fallers.[12]

Brief BESTest. Through psychometric analysis, this condensed version of the Balance Evaluation Systems Test (BESTest) was developed to enhance clinical usefulness. MCID scores have not yet been established for this outcome measures, but in a study performed by Duncan et al, cut-off scores to determine fall risk in the PD population was $\leq 11/24$.[13]

Multi-directional Reach Test (MDRT). Although MCID scores have not yet been established, a study performed by Newton et al, determined that cut off scores for the community dwelling elderly were 8.38 inches (21.29cm) forward, 4.06 inches (10.31cm) backward, 6.12 inches (15.55cm) to the right, and 5.67 inches (14.40cm) to the left. This clinical measure was added because daily activities such as bending or reaching up or to the side require a shift in the center

of gravity (COG) within the base of support (BOS) and once this occurs, the LOS for the currently executed strategy are exceeded. If an appropriate movement strategy (realigning the COG or evoking a stepping strategy) is not executed effectively to establish a new BOS, an individual may stumble or fall in an attempt to regain balance.[14] Also, this is the clinical equivalent to limits of stability on the Biodex Balance SD.

Biodex Balance SD (BBSD). The BBSD is designed to provide quantitative data about a person's ability to maintain their body's center of mass within its base of support.

Postural stability. Greater amounts of body movement associated with an unstable posture produce a high stability index (SI); a low SI indicates little body movement and is associated with a more stable posture.[15] Postural instability tends to occur in the later stages of PD.

Limits of Stability. BIG emphasizes weight shift so it would be expected to see improvements on this measure.

6 Minute Walk Test (6MWT). A study performed by Perera et al established the MCID for a geriatric and stroke population was 50 meters, or 164 feet.[16] The purpose for implementing this test into our clinical outcome measures was derived from a study performed by Falvo and Earhart stating that mobility impairments were related to 6 MWT distance in individuals with PD.[17]

Functional Gait Assessment (FGA). The FGA was originally developed for persons with vestibular disorders but in a study performed by Leddy et al, it was used with persons with PD. The study established a cut-off score of 15/30 to indicate predictive ability to clinically identify fallers within the PD population.[18] This specific measure was chosen due to the inclusion of backwards walking since persons with PD frequently have difficulty with this task.

Instrumented Sit-to-stand, Gait initiation, and Gait Analysis. Common equipment for all three activities included an electrogoniometer on the ankle joints to measure ankle movements, surface electromyography (EMG) electrodes on the soleus and anterior tibialis muscles bilaterally. This collection of data was sent via telemetry from a transmitter attached to the participant's waist to the data collection computer.

Sit-to-stand. The ankle goniometry recorded the ankle flexion and extension. The EMG electrodes recorded muscle activation patterns showing force generated and muscle work.

Gait Initiation. To initiate gait, a weight shift off the leg the participant intends to move needs to be accomplished. EMG activity and the movement of the center of pressure on the HR Gait Mat by Tekscan are the standard means of assessing gait initiation.[19]

Gait. People with PD are known to take short steps and increase double limb stance time. This information was measured using the GAITRite Gait Analysis System. LSVT BIG focuses on challenging movements and bigger steps, resulting in more normal gait measurements following LSVT BIG. According to Perry and Burnfield in their book titled *Gait Analysis: Normal and Pathological Function*, 2nd edition, single limb stance (SLS) should consist of 40% of the gait cycle (GC) while double stance (DLS) made up 20% of the gait cycle in normal, generic gait.[20]

Procedures

The total duration of our study occurred over the span of 5 months (2 days of baseline measurements, 4 weeks of intervention, 2 days of post-BIG measurements, and 1 day of post-BIG measurements at the 4-month follow-up). The time of day that testing and intervention were performed remained consistent across the study in an effort to collect results at the same point of the participants' medication cycle.

Initial evaluations included a full explanation of the study where a consent form was signed, with one copy provided to the participant. A brief medical history, physical examination, and neurological examination were completed with each participant. Baseline and pre-training assessments were performed by a minimum of 3 investigators, including the following: examiner, technical assistance, and participant safety assistance. Clinical (FTSTS, 6MWT, MDRT, Brief BESTest) and instrumented (BBSD Postural Stability and Limits of Stability, and Instrumented Sit to Stand, Gait Initiation and Gait) measures were completed at least 48 hours apart to avoid fatigue.

Intervention phase BIG A certified LSVT BIG therapist was present to supervise the examiners during the BIG intervention. Participants were scheduled for 4 consecutive days per week for 4 weeks, totaling 16 individualized sessions in one month. 75 minutes per session was allotted for performance of the intervention as well as for rest breaks, subjective reports, and review of daily homework. Each intervention session included all components of the LSVT BIG protocol as described in Appendix C. Throughout this intervention, focus on effort and amplitude was emphasized, and participants were encouraged to verbalize each movement and count as loud as possible with "finger flicking" occurring with each count.

Post-intervention. Within one week of completion of the BIG intervention, data collection of both clinical and instrumented measures took place by the same examiners for increased inter-rater consistency. Approximately 4 months later, data collection of both clinical and instrumented measures was once again completed to determine retention.

Statistical Analysis Due to the complications of losing participants throughout the study and the changes in our study design, the most accurate depiction of statistically significant change

required a change in the mean of 2 standard deviations. Participant attendance is listed in Table 2.

RESULTS

Balance Measures. FTSTS results are shown in Figure 1A. PDB01 showed a decreased performance post-BIG. PDB02 showed no significant change, but there was a small improvement in performance immediately post-BIG and at the 4 month follow-up. Performance on the Brief-BESTest was similar. PDB01 showed a slight decrease in score post-intervention, but PDB02 showed a significant increase in score post-BIG and 4 months later (Fig. 1B). MDRT showed no significant change in any direction for both participants (Fig. 2). BBSD postural stability showed a slight increase post-intervention for PDB01 and no change for PDB02, seen in Figure 3. Limits of stability, as measured by BBSD, showed no change for either participant (image not shown).

Gait Measures. PDB01 showed a decrease in endurance on the 6MWT after the BIG intervention, but PDB02 showed an increase immediately after BIG. Unfortunately, this increase did not carry over to the 4 month follow up (Fig. 4A). In the FGA, PDB01 did show an improvement in score post-BIG, but it was not statistically significant. PDB02 showed significant increases at both post-BIG and 4 months post (Fig. 4B). Using the GaitRite, gait velocity showed a slight decrease post-intervention for PDB01 and no change for PDB02 (Fig. 5). Gait initiation relative anticipatory response time for PDB01 showed a slight increase and absolute anticipatory response times also showed a small increase; however, PDB02 showed a significant change in relative anticipatory response time at post that increased some after 4 months, but was still decreased from baseline. There was no significant change in absolute anticipatory response times (Fig. 6). Force generated by the anterior tibialis muscles as measured

by EMG showed a decrease in both participants (Fig. 7A). Integrated EMG representing muscle work showed a slight decrease in work for PDB01. PDB02 had an initial decrease post-BIG, but increased again at the 4 month follow-up (Fig. 7B). Step length also decreased from baseline to post-treatment, moving from an average of 52.88 cm on the left and 52.47 cm on the right to 50.85 cm on the left and 49.62 cm on the right for PDB01. PDB02 had a similar result, moving from an average of 47.12 cm on the left and 41.26 cm on the right to 40.65 cm on the left and 36.51 cm on the right. At baseline, PDB01 was in left single limb stance (SLS) 39% of gait cycle (GC) and right SLS 40% of GC, while double limb stance (DLS) comprised of 20% of GC. At post-treatment, left SLS increased to 40% of GC and all other measurements stayed the same. At baseline, PDB02 was in left SLS 33% of GC and right SLS 36% of GC, while DLS comprised of 30% of GC. At post-treatment, no change was made in time spent during SLS or DLS. Figure 8 displays these results in terms of normal gait versus the participants' gait.

DISCUSSION

The intent of this study was to determine the efficacy of LSVT BIG on PD while using multiple clinical and instrumented measures. While there were subjective reports of improvement from the participants, the data showed little evidence regarding change in balance and functional mobility. The clinical and instrumented data provided comparable results, suggesting that the clinical measures are effective for showing change in participants with PD in the clinical setting without the high price of the instrumented measures. The FGA and Brief-BESTest are the two measures that showed significant improvement even 4 months after the intervention stage. These are both functional measures determining gait, balance, and fall risk. PDB02 improved significantly in these measures while PDB01 did not.

PDB01 showed no significant change in functional mobility from baseline to post-intervention, and in fact showed slight decreases in performance in most of the outcome measures. Unfortunately, her post-intervention measures were taken when there were many hindrances in personal life affecting her physical ability and health that may have affected her performance. Fall risk was determined by cut off values provided in the outcome measures section. She demonstrated no change in fall risk status according to the measures provided. She was still a fall risk according to the FTSTS, but was not considered one on the Brief-BESTest, MDRT, or FGA. According to the MCID, PDB01 demonstrated a significant decrease in endurance on the 6MWT. Also, she already demonstrated a normal SLS/DLS gait cycle, and it did not change throughout the intervention.

PDB02 showed a significant improvement in FGA and Brief BESTest, demonstrating improvement in balance and gait; however, there were no other significant improvements in outcome measures even though there were trends showing small improvement in many measures. She was highly motivated and engaged in LSVT BIG, and seemed to gain the most benefits. She also received tips on preventing falls when she was in her dyskinetic stage. She showed improvement in fall risk measures with an improvement from baseline to 4 months post in FTSTS, Brief-BESTest, MDRT, and FGA. According to the MCID, PDB02 demonstrated a significant increase in endurance on the 6MWT. She had an extended DLS and decreased SLS at baseline, demonstrating decreased dynamic balance. No change was seen post-BIG or 4 months post-BIG in DLS/SLS. Unfortunately, the investigators were unable to truly determine if the improvements in mobility and stability were due to the effects of LSVT BIG or if the follow-up measures were simply taken at a time of her medication cycle where she was least affected by her PD symptoms. Also, the investigators were unable to determine whether the changes were

due to BIG specifically, or if the participant simply reached "critical threshold" resulting in central processing changes as Petzinger et al suggests.[5]

At the 4 month follow-up, PDB02 reported that she had not kept up with the BIG exercises at home as often as she wanted to, but was still doing them a few times each week. She reported that she noticed a decrease in number of episodes of loss of balance compared to before completing BIG. She also reported that while she had multiple falls in the months leading up to BIG, she had only one fall in the 4 months since treatment that she referred to as "unavoidable" as her healthy sister-in-law fell at the same time. She was pleased with the tasks that she learned and the tips she received that were specific to problems she reported having.

The results of this study relate to the changes that the Argentine tango[6] and tai chi[7] had on participants with PD as there were improvements in balance and gait. This leads to the assumption that large amplitude movements to the limits of stability and with many directional changes improve balance and gait ability; however, it is difficult to identify clinically meaningful changes in the outcome measures provided due to variations in data between the two participants. There were many variables that existed during the time of data collection including effects of medication, sickness, and weather changes. The decrease in desirable outcomes on many of PDB01's post-intervention measurements can be attributed to sickness, making her feel "weaker" and allowing for a decrease in endurance and strength during data collection.

Unfortunately, multiple limitations and errors affected the conclusion of the research. Due to the nature of the disease, it is very difficult to have a standard time to test the participant. Only two data collections days were scheduled and completed before and after the treatment session due to time constraints. Because the participants were kept on medication throughout the research, they were susceptible to differences in symptoms based on time medicine was taken,

diet, fatigue level, and time of day. PDB02 had significant dyskinesias where there was a narrow window of time between when her medicine kicked in and when her dyskinesias began. The data was affected based on what stage of the medication cycle she was in. Because of the severe dyskinesias of PDB02, the data varied significantly in the first two baseline days, as illustrated in Figure 9. These images were from the Biodex limits of stability test. Both days were completed at approximately the same time in the afternoon, 3 days apart, but while one day showed relatively smooth movements, the next data collection the participant was experiencing dyskinesias throughout the entire session causing her to have very little control over her movements.

The study was also affected by the limited participant pool in San Angelo. There is a small PD population, limiting the number of volunteers available. With only three volunteers, a small group study was still feasible; however, with two dropping out of the study the research design was not set to accommodate a single participant design. This limits the ability to make firm conclusions regarding cause and effect. Also, because BIG is a one-on-one treatment requiring a significant amount of time with each participant, it is very difficult accommodate many participants at once in an academic setting. In addition to the extended time requirement of the intervention, the data collection sessions were time intensive, limiting the number of data collection sessions before and after treatment and preventing weekly data collection during the intervention stage. This limited number of data collection days affected the standard deviations, especially since "outlier" data was unable to be determined and removed, causing the conclusions to show less change than there may have truly been.

Future research options include using determining whether LSVT BIG has any effect on people with other neurodegenerative disorders, such as multiple sclerosis or dementia with Lewy

bodies. Many clinicians already apply some of the principle of BIG to many different neuro participants, so it is important to do a controlled trial to provide evidence-based treatment to clinicians regarding efficacy of this treatment. Another research option would be determining whether BIG is most effective during "off" or "on" stage of medication cycle. This preliminary study shows that a larger subject pool is necessary for future studies. Also, because the participants were interested in techniques to improve opening bottles and managing buttoned shirts, it would be wise to include upper extremity outcome measure, such as a 9-hole peg test or block-and-box test. Finally, because of the similarities in our results to the results of Li's tai chi study[7], an interesting future research would examine whether the slow, smooth movements of tai chi or the fast movements of BIG are more effective in addressing balance and gait in PD.

CONCLUSIONS

This research study showed that LSVT BIG was somewhat effective in improving functional gait and balance; however, there were too any limitations to determine a firm conclusion regarding the efficacy of LSVT BIG on PD. The clinical measures and instrumented measures resulted in similar conclusions, demonstrating that the clinical measures are effective outcome measures for PD participants in the clinical setting.

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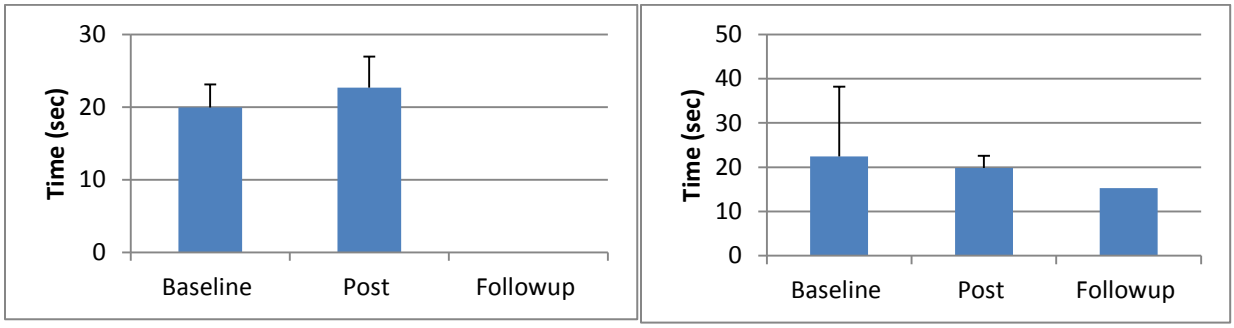
FIGURES

A. PDB01 PDB02



B. PDB01 PDB02

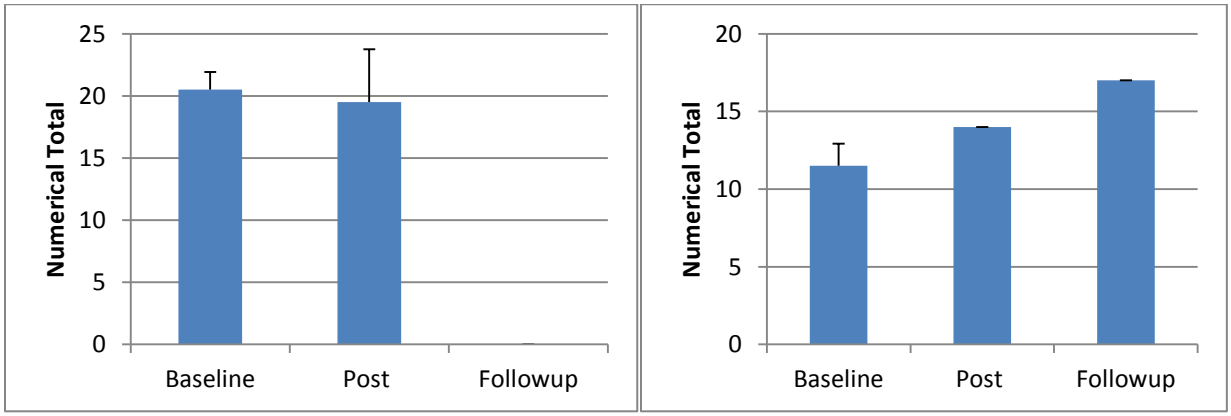


Figure 1: Balance Measures

A. Five Times Sit to Stand (FTSTS) With this measure, decreasing time indicates improvement. PDB01's results on the right show an increase in time to perform the activity at post-intervention. PDB02's results on the left show no significant change in speed in the participant's performance. There is, however, a trend demonstrating a small decrease in time.

B. Brief-BESTest The Brief-BESTest provides results demonstrating a change in functional balance and mobility. The higher the score, the better. On the right, PDB01 demonstrated a decrease in score post-intervention. On the left, PDB02's results demonstrate an improvement greater than two standard deviations at both post-intervention and the 4 month follow-up, indicating significant changes.

*PDB01 was lost to follow up and will not be seen on any graphs.
**Note that the scale is different for the two participants throughout the figures.

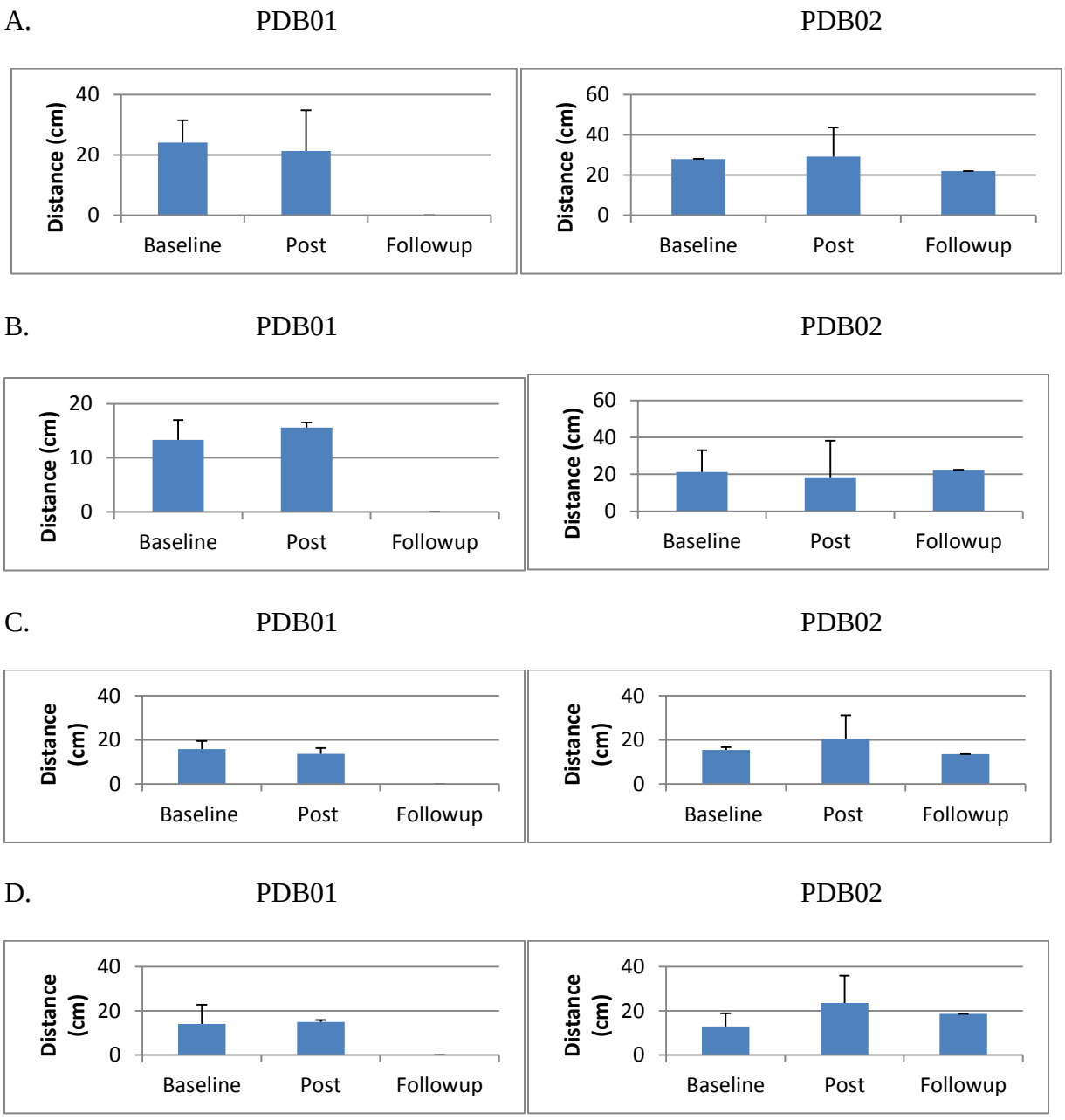


Figure 2 Limits of Stability Distribution of reach scores for the Multi-Directional Reach Test (MDRT) are shown in the above images. An increase in distance represents improvement.

A. **MDRT Forward** PDB01 demonstrated a decrease in distance post-intervention. PDB02 demonstrated no significant change from baseline after intervention. At the 4 month follow-up, there was a significant decrease in distance reached.
B. **MDRT Backward** PDB01 demonstrated increased distance post-intervention, but the change was not significant. PDB02 demonstrated a decrease in distance post-intervention, but an increase at the 4 month follow-up from baseline, although the change was not significant.
C. **MDRT, Lateral, Left** PDB01 demonstrated decreased distance post-intervention. PDB02 demonstrated improvement in distance from baseline after intervention, however, at the 4 month follow up, retention was not observed and a decrease in distance from baseline was observed.
D. **MDRT, Lateral, Right** PDB01 demonstrated slight improvement in distance post-intervention, however the change was not significant. PDB02 demonstrated an increase in distance post-intervention, but did not retain the improvement in the 4 month follow-up.

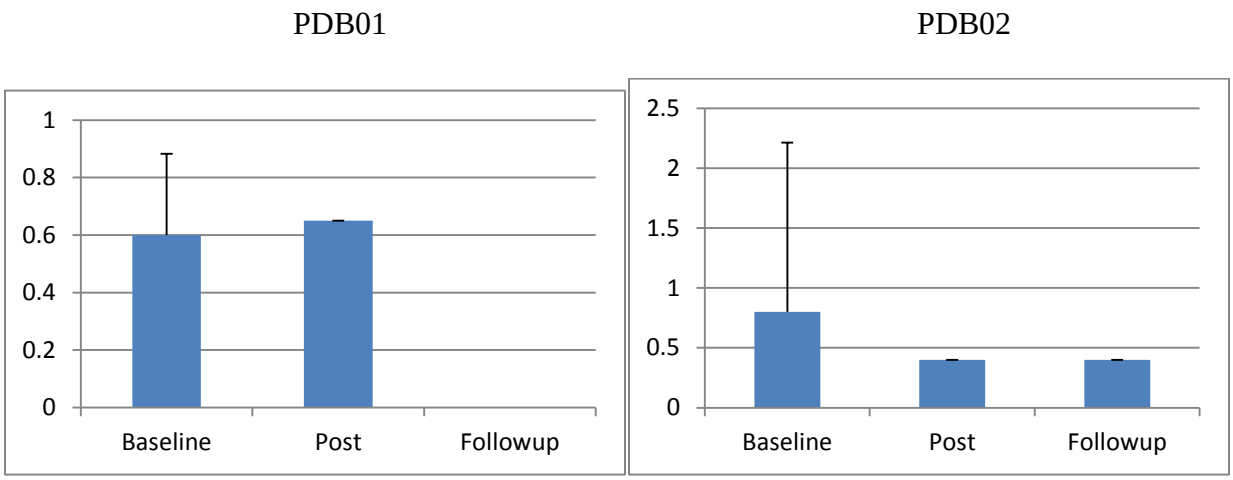
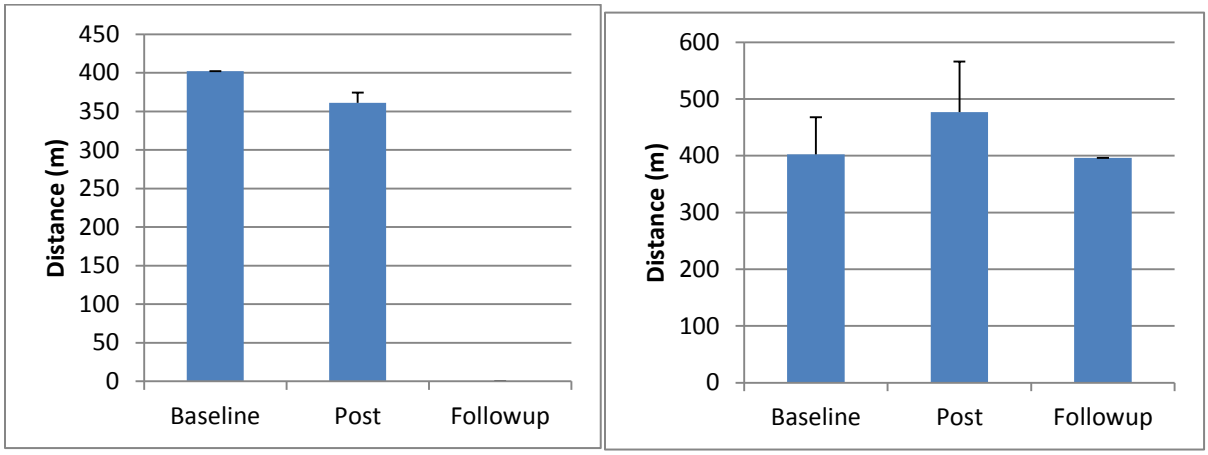


Figure 3: Postural Stability A greater "sway" in body movement is associated with an unstable posture, producing a high stability index (SI). A lower SI indicates a more stable posture. PDB01 demonstrated an increased SI post-intervention, indicating an increase in sway. PDB02 demonstrated a large difference (0.3 and 1.4) in their SI between the two days of baseline measurements, resulting in a large standard deviation. Therefore, although a large decrease in SI was seen at post-intervention as well as at the 4-month follow up, we cannot say the change is truly significant.

A. PDB01 PDB02



B. PDB01 PDB02

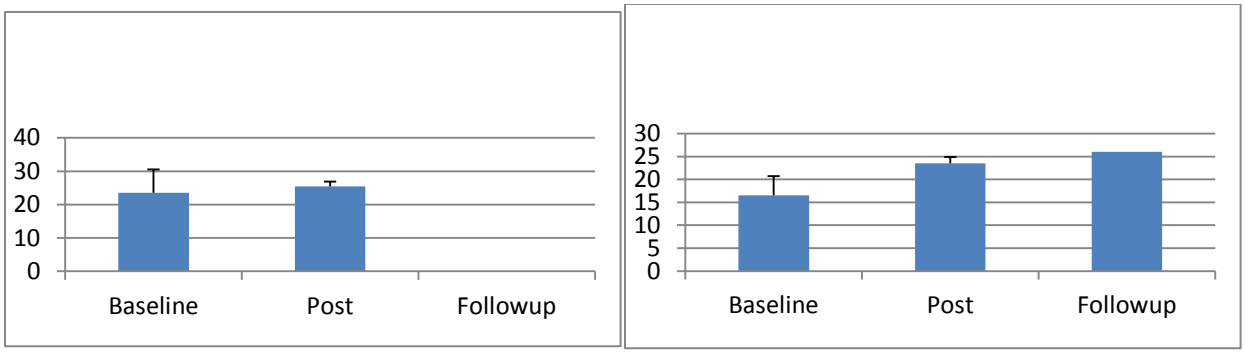


Figure 4: Gait Measures

A. 6 Minute Walk Test (6MWT) The 6MWT reports changes in participant endurance. Increased distance covered signifies increased endurance. PDB01 demonstrated decreased distance covered post-intervention, demonstrating a decrease in endurance. PDB02 demonstrated a significant increase in distance covered post-intervention, followed by a return to baseline at the 4 month follow-up.

B. Functional Gait Assessment (FGA) The FGA is an ambulation-based balance test to assess higher-level balance in individuals. A higher score indicates improvement. PDB01 demonstrated a slight increase in score post-intervention but the change was not significant. PDB02 demonstrated a significant increase from baseline, with a continued increase at the 4 month follow-up.

PDB01 PDB02

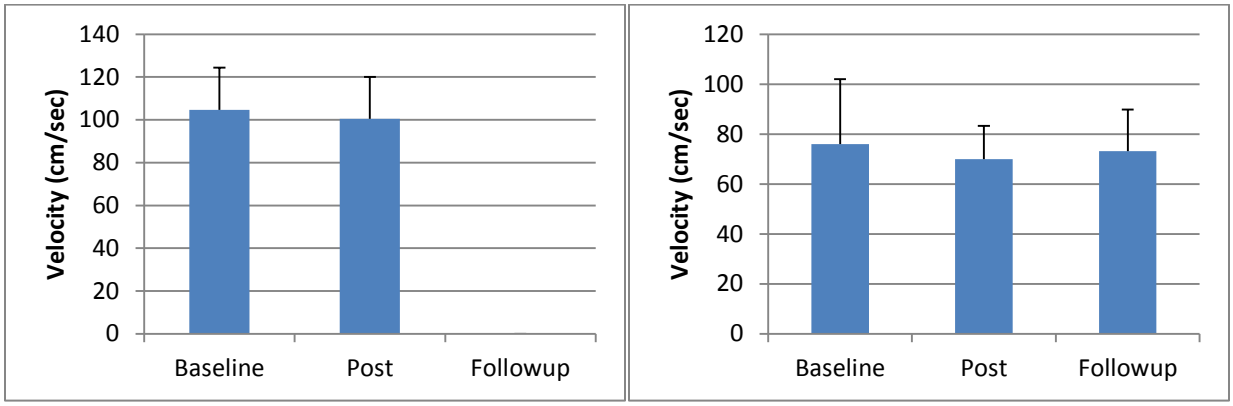


Figure 5: Gait Velocity (GV) The GaitRite was used to calculate GV in the participants. A decrease in GV can be a good predictor of increased fall risk. PDB01 demonstrated a slight decrease in GV at post-intervention. PDB02 demonstrated a slight decrease post-intervention, followed by a return to baseline at the 4 month follow-up. No significant changes were identified in either participant.

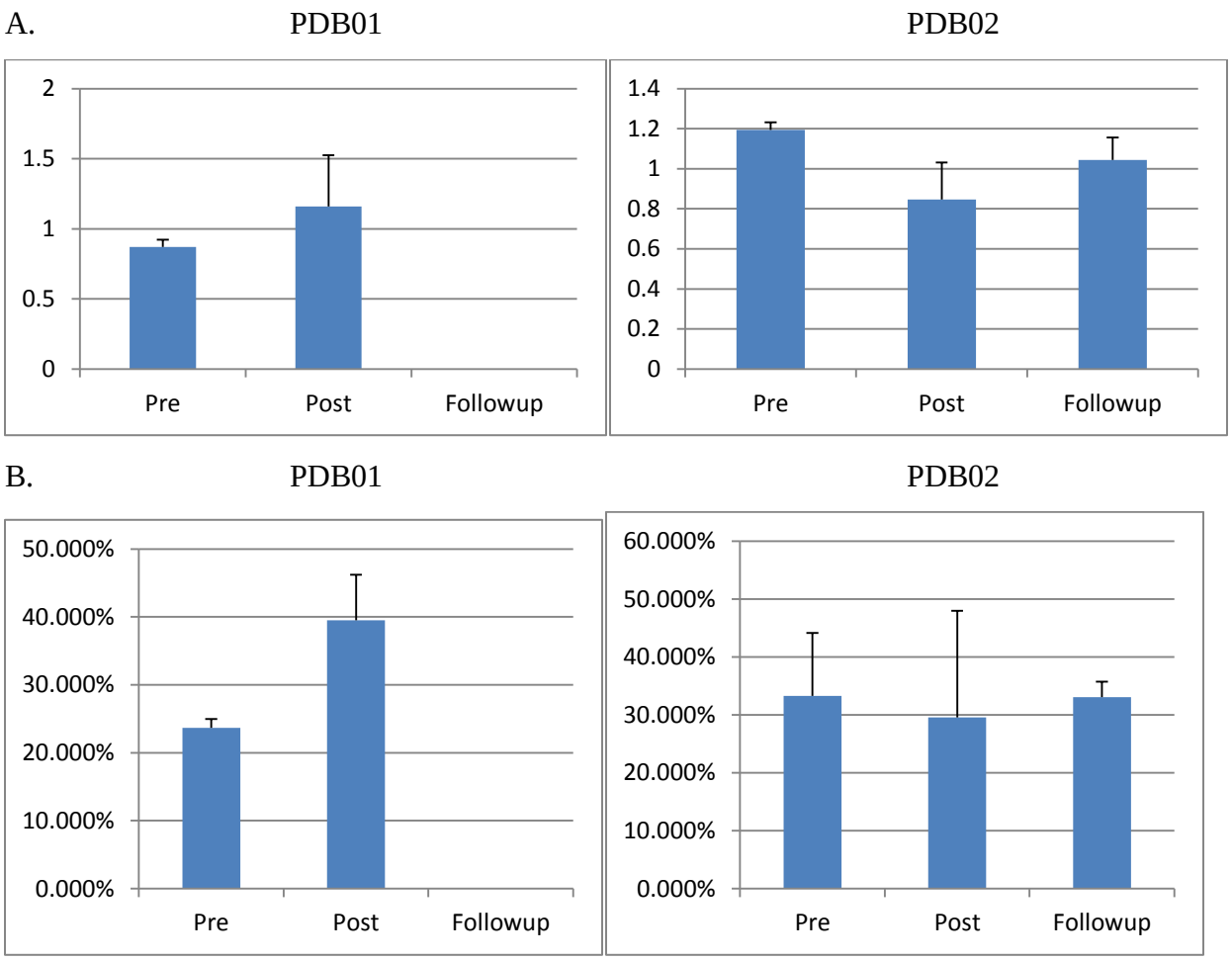


Figure 6: Gait Initiation

A. Anticipatory Response-Absolute Time This measure refers to the entire gait initiation (GI) process. That is, from initiation of movement of swing limb to complete toe off of stance limb. Decreasing numbers indicate improvement. PDB01 demonstrated an increase in absolute time post-intervention. PDB02 demonstrated a significant decrease from baseline at post-intervention. At 4 month follow-up PDB02 demonstrated a trend leading back to baseline, however, the change continued to be significant.

B. Anticipatory Response-Relative Time This measure refers to the % of GI that makes up the initiation of heel off of swing limb to complete toe off of swing limb. Decreasing numbers indicate improvement. PDB01 demonstrated a significant increase post-intervention, which was not a desirable outcome. PDB02 demonstrated a slight decrease (not significant), followed by a return to baseline at the 4 month follow-up.

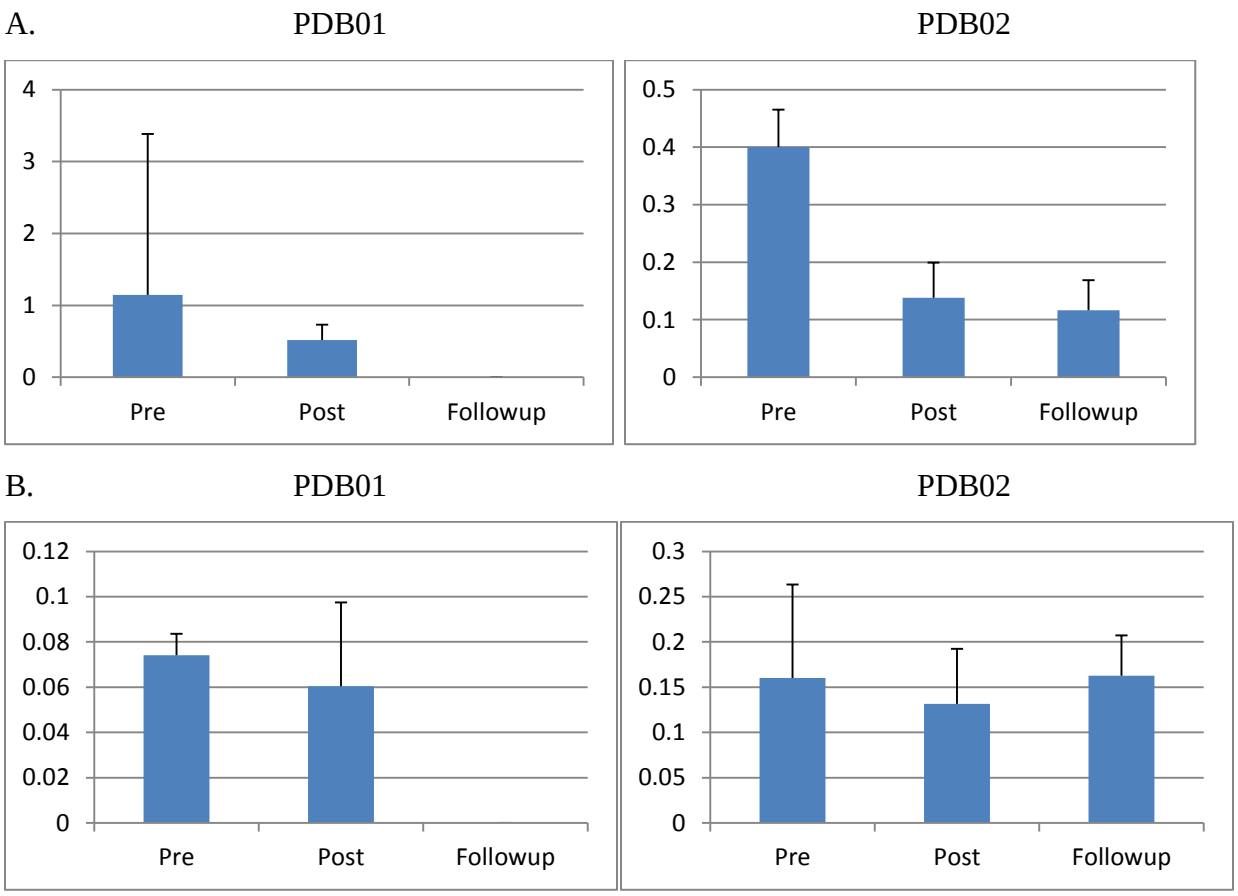


Figure 7: EMG

A. **Force Generated** This measure refers to the increase in force generated to reach the desired amount of muscle work to achieve gait initiation. An increase in force generated indicates improvement. PDB01 demonstrated a decrease in force generated at post-intervention. PDB02 demonstrated a significant decrease in force generated, followed by a further decrease in force generated at the 4 month follow-up.

B. **iEMG (Muscle work)** This measure represents the efficiency of muscle work needed to achieve the force generated. A decrease in numbers indicates improvement. PDB01 demonstrated a decrease post-intervention, indicating increased efficiency of muscle work. PDB02 demonstrated a similar increased efficiency from baseline to post-intervention. However, PDB02 demonstrated a regression back to baseline at the 4 month follow-up. No significant changes were identified in either participant.

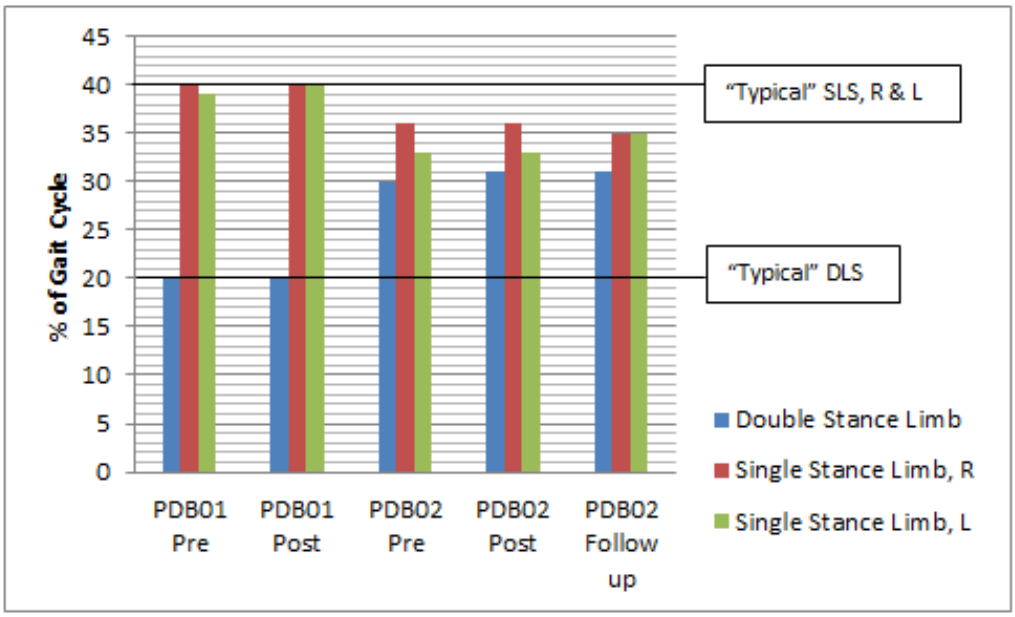


Figure 8: Percentages of Double Limb Stance (DLS) and Single Limb Stance (SLS) in the Gait Cycle (GC). The SLS should consist of 40% of the GC while DLS makes up 20% of the gait cycle in normal, generic gait. A black marker at both levels has been added to the graph to indicate percentages of "typical gait". Both participants stayed consistent with DLS and SLS at baseline, post-intervention and at 4 month follow-up. No significant changes were observed.

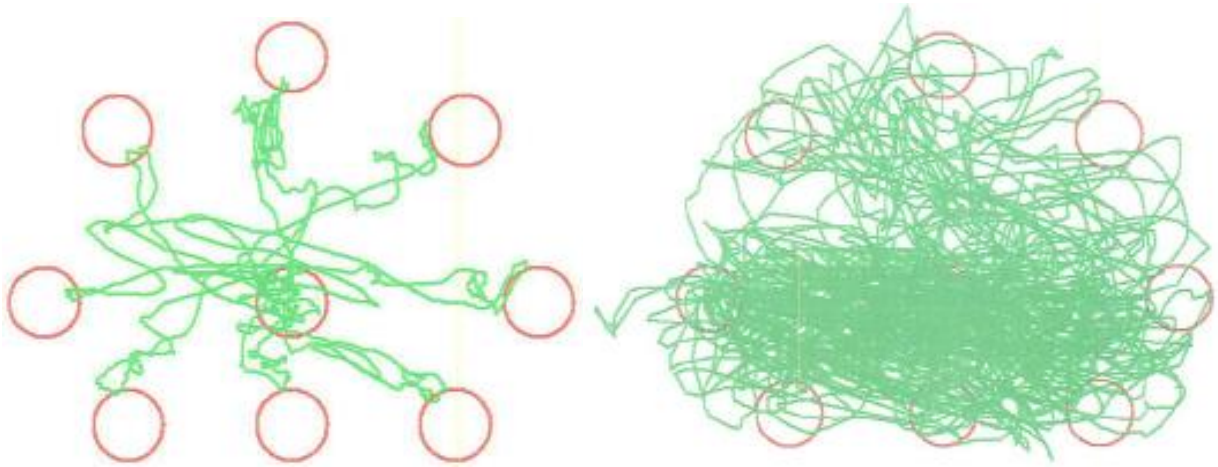


Figure 9: Limits of Stability and Dyskinesias. The two images shown above depict the participant's two baseline measures of limits of stability on the Biodex SD. They were taken 3 days apart at approximately the same time in the afternoon. The image on the left demonstrates smooth motions, while the image on the right shows very poor control of weight shifting. At the time of the image on the right, the participant was reaching the peak of her medication and demonstrating dyskinetic movement. This image shows how different a participant's movement pattern can be when dyskinesias are present and gives the reader a visual of how difficult it can be to get conclusive data.

TABLES

	Age	Gender	Years since Diagnosis	Assistive Devices	Falls	Rigidity	Bradykinesia	Postural Instability	Tremor	Dyskinesias
PDB01	76	Female	9	none	none	no	yes	yes	yes	slight; neck
Meds: carbidopa-levodopa 25/100mg, 3x daily; carbidopa 25mg, 3x daily; entacapone (COMT) 200mg, 2x daily										
PDB02	63	Female	19	cane	year:5, 3mo:2	no	yes	yes	yes	severe; trunk
Meds: ropinirole extended 4mg, daily; carbidopa-levodopa 150mg, 5x daily; rasagiline 1mg, daily; venlafaxine 37.5mg, daily										
PDB03	76	Male	10	wheelchair	none	BUE	yes	yes	yes	yes; extremities during sleep
Meds: carbidopa-levodopa with entacapone 150mg 2x daily, carbidopa-levodopa extended release 50-200mg 1x daily; memantine HCl 10mg 2x daily; quetiapine 25mg 1x daily; donepezil HCl 10mg 2x daily										

Table 1. Background Information about Participants.

Attendance	Baseline	BIG Sessions	Immediate Follow-up	Long Term Follow-up
PDB01	2	16	2	0
PDB02	2	16	2	1
PDB03	1*	12**	0	0

Table 2. Attendance Information. PDB01 completed all required sessions; however after the death of her spouse, she dropped out before the 4 month follow-up session. PDB02 completed all BIG sessions including the 4 month follow-up. PDB03 completed only one baseline measurement day as it became apparent that he was not physically capable of completing the measures at this time. He missed 4 days of BIG, dropping below the 80% attendance requirement causing him to be removed from the study.

APPENDIX A

Inclusion/Exclusion Criteria

Individuals were eligible for participation if they had a medical diagnosis of Parkinson's Disease. Willingness to participate in the study and to abide by the protocol guidelines were also eligibility factors. Emphasis was made on benefits of LSVT BIG when the primary clinical manifestations included bradykinesia and rigidity. Other inclusion criteria included the ability to participate in an exercise program, stable medications, no history of cardiac limitations secondary to heart attack, no congestive heart failure or other cardiac disorders, no history of fractures or orthopedic surgeries in the past year, no history of stroke, ability to understand and follow instructions, and the ability to walk independently 30 meters with or without an assistive device such as a cane or walker. Exclusion criteria included placement of a deep brain stimulator, cardiac or respiratory issues that may limit participation in the exercise protocol, and cognitive impairments that prevent the participant from following instructions.

APPENDIX B

Outcome Measures

Activity Monitor: The StepWatch Activity Monitor (SAM) is a research grade instrument for long-term assessment of ambulatory activity during day-to-day life. The SAM was worn 24 hours a day (with the exception of bathing and other activities involving water) around the ankle for one week before and after the 4-week LSVT BIG protocol. It records the number of strides taken every minute. The participants were asked to keep an activity log during the time of wearing the activity monitor as well. This allowed us to monitor their activity level as well as identify how many steps were taken each day in anticipation that both would increase post-BIG intervention. Step detection accuracy exceeds 98% both for unimpaired gait and for movement styles that have traditionally been difficult to monitor accurately such as geriatric shuffling, hemiparetic gait, and dyskinetic gait. This was removed from the study due to the lack of sensitivity and the high variability of results in this population.

Five Times Sit to Stand (FTSTS): Participants began this test sitting in an armless chair that was 42 centimeters from the ground with the instructions to cross their arms over their chest and sit with their back against the upright back rest of the chair. The investigator then demonstrated the correct technique of task performance, including coming to a full stand, defined as an upright trunk with the hips and knees fully extended followed by sitting down with their back making full contact with the back of the chair. This timed task began when the investigator said 'go' and stopped when the participant's back had reached the chair back after the fifth stand. Participants completed three trials of the FTSTS each day of data collection. A study by Duncan indicated an excellent test-retest reliability (ICC = 0.960) as well as excellent interrater reliability (ICC = 0.99) within the PD population.[12]

6 Minute Walk Test (6MWT): The 6MWT is a measure of endurance. The test was performed on a level tile floor in a straight hallway. One hundred feet were marked off by a cone at each end. Participants were instructed to walk at a safe, comfortable pace while trying to cover as much ground as possible while given specific words of encouragement at timed intervals, following the protocol referenced in a study by Steffen and Seney. [21] The total distance walked was measured and any stops/rests were noted. A study performed by Steffen et al determined that there was a high test-retest reliability (ICC = 0.96) in individuals with PD.[22]

Functional Gait Assessment (FGA): This outcome measure assesses postural stability during various walking tasks. It consists of 10 activities with standardized instructions and scoring provided by Wrisley et al.[23,24] The ten activities include: gait on a level surface, change in gait speed, gait with horizontal head turns, gait with vertical head turns, gait and pivot turns, step over obstacles, gait with narrow base of support, gait with eyes closed, ambulating backwards, and steps. The highest score in this outcome measure is a 30. The standard distance is 20 feet for all activities with items being scored based on performance and/or the time it took to complete the task. Excellent test-retest reliability was established whether performed by a PT (ICC = 0.91) or by a student (ICC= 0.80) within the community dwelling adults with PD population. Excellent interrater reliability (ICC= 0.93) within community dwelling adults was PD was determined as well.[18]

Multi-directional Reach Test (MDRT): This outcome measure was chosen in order to measure the limits of stability in all 4 directions. This is a clinical measure that approximates the Limits of Stability (LOS) Test on the Biodex Balance SD described below. The participant stood with feet shoulder width apart and with one arm raised to 90 degrees of flexion adjacent to but not touching the chalkboard. The body was perpendicular to the chalkboard and the arm parallel. The

investigator placed a mark on the chalkboard at the location of the 3rd metacarpal joint. The investigator instructed the participant to reach as far forward as he/she could while maintaining his/her balance and not moving his/her feet. The investigator made a second mark. Next the participant was asked to lean backwards as far as he/she can without losing balance or moving feet and a third mark was made. All participants used their right arm to reach with. The participant then turned so that his/her back was now parallel to the chalkboard. The investigator asked him/her to raise the right arm to the side. The investigator made a mark as above. The participant was then asked to reach to the right as far as he/she can without moving feet or taking a step. Another mark was made by the investigator. The process was then repeated with the left arm. The distances were recorded in centimeters on the data sheet. Holbein-Jenny et al determined that test-retest reliability in personal care home residents was excellent in both forward reach (ICC= 0.75) and left reach (ICC= 0.83), and adequate in both backward reach (ICC= 0.71) and right reach (ICC = 0.66).[25]

Brief BESTest: The brief BESTest is a 6-item balance assessment containing 1 item from each of the 6 subsections of the full BESTest but takes 10 minutes to perform rather than 45 minutes. The 1 item from each specific section of the BESTest with the strongest correlation to that total section was included in the Brief-BESTest (Duncan, 2013).[13] The 6 sections include: Biomechanical Constraints, Limits of Stability, Anticipatory Postural Adjustments, Reactive Postural Response, Sensory Orientation and Stability in Gait. We used the standardized instructions and scoring provided by Padgett et al. The Brief BEStest has good reliability and sensitivity for fallers (100%) and good specificity for non-fallers (95 to 100%). In a study performed by Padget et al, excellent inter-rater reliability (ICC= 0.994) was determined in a population with balance deficits.[26]

Biodex Balance SD (BBSD): The base of the Balance SD has a platform that has sensors underneath that detect the movement of a person's center of gravity. The platform was stable (immobile) for the two tests. A small monitor providing visual cues about the desired test was placed at eye level. A hand rail that participants were able to use when stepping up onto the platform and at any time they felt unsteady was available. Prior to the testing, paper was taped to the surface of the platform. The participant's feet were placed in the standardized position (shoulder width apart and the anterior ankle centered anteriorly/posteriorly on the center line of the platform). The first time on the platform, the participants feet placement were traced to maintain consistency for all data collection sessions on the BBSD. A study performed by Karimi et al indicated a high reliability(ICC= 0.97) in balance test indices measured by using BBSD in a population standing with double legs, eyes open, and no back pain.[27]

Postural Stability: The postural stability test emphasizes the participant's ability to maintain center of balance for 20 seconds. A screen is used to prompt the participant with visual cues as to how they are performing, with instructions to keep the "dot" in the center of the cross hairs. The dot moved in response to the participant's postural sway. The Balance SD recorded the amount of sway in all directions and compared the amount of sway to norms by age of participant.

Limits of Stability: This test is designed to challenge the participant's ability to move and control their COG within their BOS through weight shifts in multi-directional planes. It is a measure of dynamic balance. During each trial, participants must shift their weight to move the cursor from the center target to the blinking target (1 of 8 targets) and back as quickly with as little deviation as possible. This task is often difficult for person with PD.

Instrumented Sit-to-Stand, Gait Initiation and Gait Analysis:

Sit-to-stand. The participant began by sitting in the standard 42 centimeter chair used in the FTSTS. Feet were placed shoulder width apart parallel to each other in the middle of the Tekscan mat that was used to measure the movement of the center of mass as the participant moves from sitting to standing.

Gait: Once gait was initiated, the participants continued walking forward to walk across the GaitRite mat. The GaitRite mat is a rubberized surface with embedded pressure sensors that track the interaction of the feet with the surface. The GaitRite provided information such as step length, gait velocity, and double and single limb stance in the gait cycle. The trunk rotation goniometer provided information about trunk rotation during gait.

APPENDIX C

LSVT BIG Protocol

Participants were expected to complete 80% of all intervention days in order to remain in the study. This comes out to missing no more than 2 or the BIG intervention days. The participants were also expected to be fully engaged during the 75 min intervention session.

Maximal daily exercises: floor to ceiling x8 reps, side to side x8 reps, forward step x8 reps, sideways step x8 reps, backward step x8 reps, forward rock and reach x10 each side, sideways rock and reach x10 each side; functional component tasks x5 reps each; hierarchy task; walking BIG). Functional component tasks included tasks such as sit to stands, opening water bottles, getting in/out of vehicle, etc.

Hierarchy tasks were participant identified tasks that provided the participant to incorporate the BIG principles into real world participant-driven tasks such as getting in/out of shower and donning/doffing sweater. The complex aspects of these tasks were broken down with a new component added regularly to slowly build up to the given task across the span of the 4 weeks of intervention. Distance and time varied with walking BIG due to subjective reports given, fatigue of participant, and the participant's performance that day. BIG walking included forward, backward, and side steps as well as BIG turns, sudden start/stops/pivots, and walking across various types of terrain.