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Effects of Repeated Bouts of Segmental Vibration Therapy on Balance in Parkinson's Disease

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Abstract

Background: One of the cardinal features of Parkinson's disease is postural instability. This instability is believed to be due to abnormalities in processing afferent information from the vestibular, somatosensory and visual systems. Whole body vibration has been shown to improve balance in older adults. The goals of this study were to determine how sensory information affects balance and to examine if multiple sessions of segmental vibration therapy improved balance in individuals with Parkinson's disease.

Methods: Balance in healthy older adults and in individuals with Parkinson's disease was assessed using the modified Clinical Test of Sensory Integration and Balance. After initial assessment, individuals with Parkinson's disease were randomized into a control or segmental vibration therapy group. The segmental vibration therapy group completed twelve sessions, over four weeks, and was re-tested after that period.

Results: Subjects with Parkinson's disease showed the highest overall level of sway in the eyes closed soft surface condition, when compared to healthy older adults. However, repeated bouts of segmental vibration did not result in significant improvement in the sway scores.

Conclusion: Although these individuals showed significant balance deficits, segmental vibration therapy did not promote improvements in balance, as measured with the modified Clinical Test of Sensory Integration and Balance test.

Keywords: Vibration; Proprioception; Movement disorders; Intervention; Neuroplasticity

Abbreviations: m-CTSIB: Modified Clinical Test of Sensory Integration and Balance; PD: Parkinson's Disease; WBV: Whole Body Vibration; SVT: Segmental Vibration Therapy; AHA: American Heart Association; ACSM: American College of Sports Medicine; EOFS: Eyes Open Firm Surface; ECFS: Eyes Closed Firm Surface; EOSS: Eyes Open Soft Surface; ECSS: Eyes Closed Soft Surface

Introduction

In 2005, the incidence of Parkinson's disease (PD) in the world's most populous nations was estimated to be 4.1 million people [1]. Furthermore, it is predicted that by the year 2030 more than 8 million people in these countries will develop this disease [1]. PD is progressive and, over time, symptoms can become increasingly severe. There are four cardinal symptoms including tremor at rest, rigidity, akinesia or bradykinesia and postural instability [2]. Common treatments include pharmacological (levodopa/carbidopa, Sinemet), surgical (deep brain stimulation), and physical therapy (exercise and functional training). With this increase in the incidence of PD, additional treatment options are required to enhance the quality of life in these individuals.

PD can lead to impaired balance and decreased postural control [3]. Balance is largely dependent on proprioceptive, visual and vestibular input which alters motor output in the postural muscles [4]. In PD, deficits in proprioceptive input can result in a decline in synchronized motor output and lead to poor balance [4]. Many studies have indicated that motor deficits in PD may be directly related to the underlying mismatch of proprioceptive feedback and peripheral discharge for adequate balance reactions [5-8]. However, there is conflicting evidence in the literature as to whether proprioceptive deficits in PD are due to faulty peripheral or central pathways [9]. In addition, physiological evidence has yet to show that proprioceptive disturbances exist because of defective muscle spindle sensitivity or discharge [10]. However, it has been suggested that these disturbances arise from defective integration of afferent signals once they reach the central command centers in the brain, specifically the basal ganglia [6,11,12]. With the reduction of proprioceptive input and/or processing, risk of falling often increases as the disease progresses. The latter can lead to further medical complications outside the normal progression of the disease [13,14]. To reduce the risk of falls and to potentially enhance daily activity, interventions are required to improve proprioceptive capabilities in PD.

Whole body vibration (WBV) interventions have been shown to improve gait and motor function in PD [15,16] and in older adults [17]. However, there is little research examining the effects of segmental vibration therapy (SVT) on balance in PD. SVT has significant advantages over WBV because it is focused on a single muscle group and can be done in a seated position. Previous studies in our lab have shown that acute sessions with segmental vibration can reduce tremor and bradykinesia in PD [18], but its effects on balance over the multiple sessions are unknown. The goals of this study were 1) to examine how sensory information affects balance in healthy older adults and in individuals with PD, 2) to compare balance capabilities between these two groups and 3) to determine if multiple sessions of upper and lower body SVT improves balance in individuals with PD. A modified sensory integration test (m-CTSIB) was used to examine balance in healthy elderly and older individuals with PD. We hypothesize that individuals

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with PD will show greater postural sway in balance conditions with altered sensory input and that long term SVT will improve balance in the PD population, specifically components of balance that require proprioceptive input.

Methods

Individuals with mild to moderate idiopathic PD and healthy older adults were recruited for this study from the community, PD support groups and local neurology clinics. Prior to enrollment, all individuals completed a comprehensive cardiovascular pre-screening (AHA/ACSM questionnaire) and an extensive health history questionnaire. Individuals with one or more major signs/symptoms of cardiovascular or pulmonary disease**,** personal history of cardiovascular or related diseases, treatment with drugs that can alter balance and individuals with levodopa-based dyskinesias were disqualified from participation in the study. Primary inclusion criteria for the PD group were: clinical diagnosis of idiopathic PD, age between 50-79 years, and Hoehn and Yahr stage I-III when off anti-parkinsonian medication [18]. Primary inclusion criteria for the healthy older adults included: age between 50-89 years and no history of neurological disease, as determined by the health history questionnaire. Primary exclusion criteria for both groups were: existing cardiopulmonary disease or stroke, dementia, and acute inflammation or blood clotting disorder. Written informed consent was obtained, by the lab director (AR), according to the guidelines of the Kent State University Institutional Review Board.

Healthy older adults (N=16) and individuals with PD (N=20) were assessed for balance at a single time point in a University Research Laboratory. Individuals with PD were then randomized into one of two groups: control (no therapy, N=10) or segmental vibration therapy (SVT, N=10). During the first session, PD subjects in both groups completed baseline balance testing. Post-testing of the PD subjects was completed after four weeks. The control PD group was asked to report to the lab only on testing days (baseline and 4 weeks) and did receive any intervention. The SVT group completed twelve sessions over a four week period (three times per week). SVT sessions started with a 10 minute aerobic warm-up followed by vibration of upper and lower body muscle groups, as well as core musculature (details outlined below).

Balance assessment

The Biodex Balance System (Biodex Medical Systems, Shirley, NY) and the modified clinical test of sensory integration and balance (m-CTSIB) were used to test sensory integration capabilities and balance (Fall Risk) in each subject. The four conditions used were: eyes-open, firm surface (EOFS); eyes-closed, firm surface (ECFS), eyes-open, soft surface (EOSS); eyes-closed, soft surface (ECSS). Sway index numbers, the standard deviation of the stability index, were extracted after each 30 second test condition. The stability index is the average position from center [19] and higher sway index scores indicate greater instability.

Segmental vibration therapy: The SVT intervention, using the Swiss Wing (Swiss TTP, Twinsburg, OH), focused on five lower body muscle groups, four upper body muscle groups and two core muscle groups. Each muscle group was stimulated for 2 minutes at 20 hertz, as recommended by the manufacturer and previous publications [18,20]. Lower body muscle groups were stimulated either seated or standing and included: gluteals - standing with buttocks resting on drum; hamstrings -standing with hamstring draped over drum; gastrocnemius–seated with belly of the calf draped over the drum; hip adductors- standing with side of thigh resting on the drum; hip flexors-standing with front of the hip touching the drum. All upper body muscle groups were stimulated with the participant seated in a chair and included: hands- hands placed palms down on the drum; forearm extensors- palms up and forearms on the drum, forearm flexors- palms down and forearms on the drum, upper arm- arm crossed in front of the body, deltoid on the drum. The core included two areas: abdomen and lower back.

Statistics

Independent samples *t*-tests were used to compare ages of the healthy and PD groups and to compare the demographic variables of the control PD and SVT PD groups. A one-way ANOVA was used to compare the sway scores among the four m-CTSIB conditions for each group independently, followed by Bonferroni's post-hoc comparisons tests. A one-way 2 group (healthy elderly and PD) multivariate analysis of covariance (MANCOVA), with age as a covariate, was used to analyze the difference in sway scores between the healthy elderly and PD groups. A repeated measures ANOVA (2 time X 2 group) was performed to examine changes in sway index and fall risk scores between the control PD and SVT PD groups. An alpha level of 0.05 was set for all comparisons.

Results

The first aim of this study was to examine if individuals with PD showed deficits in balance and sensorimotor integration when compared with healthy older adults without PD. Twenty mild to moderate adults with idiopathic PD and sixteen healthy older adults were assessed. One subject with PD was eliminated from the data analysis due to severe kyphosis which prevented upright posture during the balance testing. In both the healthy older adults ($F=72.3$, $p<0.001$) and the individuals with PD ($F=41.32$, $p<0.001$), there was a significant difference in sway scores across the four conditions (Figure 1). Specifically in healthy older adults (Figure 1A), there was a significant increase in sway index score between the EOFS and ECFS (1.05, $p<0.001$), EOFS and ECSS (3.11, $p<0.001$), EOSS and ECSS (2.56, $p<0.001$), ECFS and ECSS (2.06, $p<0.001$). In PD (Figure 1B), there was a significant increase in sway index score between the EOFS and ECSS (3.41, $p<0.001$), ECFS and ECSS (2.81, $p<0.001$), EOSS and ECSS (2.68, $p<0.001$).

Baseline sway index scores from each of the m-CTSIB conditions were compared between the healthy older adult group and the individuals with PD. Due to the fact that there was a significant difference in age ($t=3.5$, $df=33$, $p=0.001$) between the healthy older adult group (74.4 ± 1.9 years, 10 males, 6 females) and the individuals with PD (66.1 ± 1.4 years, 14 males, 5 females), age was used as a covariate for the sway index score analysis which compared the two groups. Individuals with PD showed significantly greater sway index scores than the healthy older adults (Figure 1) in the EOFS ($F=7.5$, $p=0.01$), EOSS ($F=12.3$, $p=0.001$) and ECSS conditions ($F=4.7$, $p=0.038$).

The second aim of this study was to examine the effects of a four week SVT intervention on balance scores in individuals with Parkinson's disease. Subjects were randomly allocated into either the intervention group (n=10) or control/no intervention group (n=9). No significant differences were found for gender, age, height, weight, or BMI (Table 1) between the two groups. Fall risk and m-CTSIB sway measurements were collected at baseline and after 4 weeks of SVT or no intervention. There was no significant interaction between group and time for fall risk or m-CTSIB sway index scores ($p>0.05$; Table 2). However, there was a significant time effect in the EOSS condition ($F=8.1$, $p=0.011$) and in the fall risk scores ($F=7.3$, $p=0.015$; Table 2).

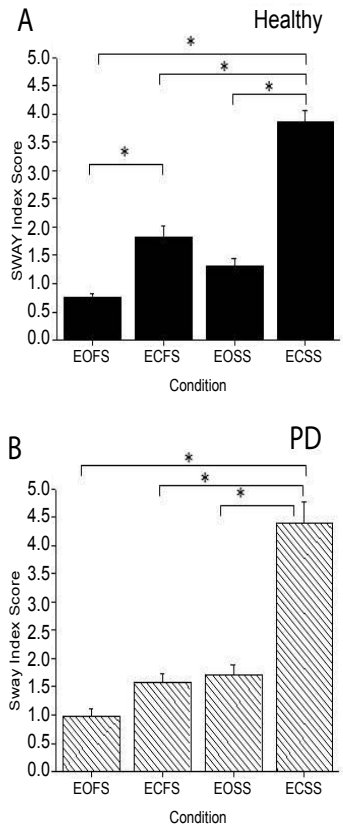

Figure 1: Sway index scores for healthy older adults and individuals with Parkinson's disease. **A.** Healthy older adults showed increases in sway with eyes closed and when standing on a soft surface. The greatest change in sway score occurred between EOFS and ECSS. **B.** Individuals with Parkinson's disease showed similar changes in sway scores as healthy older adults. However, these subjects showed higher sway than the healthy group in the eyes closed and soft surface conditions. *= p<0.001

Variable	Control PD	SVT PD	p value
Age	66.7 ± 6.9	66.9 ± 6.2	0.947
Gender (female/male)	2/8	4/6	-
Height (m)	1.73 ± 0.09	1.68 ± 0.1	0.274
Weight (kg)	90.1 ± 41.5	79.2 ± 21.6	0.479
BMI (kg/m^2)	29.2 ± 11.7	27.6 ± 5.4	0.693

Values are mean ± SD. No significant differences were seen between control and SVT groups

Table 1: Subject demographics.

Discussion

The purpose of this study was to document balance deficits in individuals with PD and older adults under different sensory conditions and to determine if multiple sessions of upper and lower body SVT is an effective intervention to improve balance. Both healthy older adults and those with PD showed greater sway scores when visual information was absent or when the surface was unstable. This finding is consistent with other studies [4,17,21] and suggests that deficits in sensory function that occur with age and with PD could increase the risk of falls.

PD subjects showed the highest overall level of sway in the ECSS condition. The degree of sway in this population was well outside that of normal healthy controls. This suggests that sensory deficits were greater in the PD individuals. Previous studies have reported that proprioceptive deficits in the PD population have a large effect on gait, balance and posture [4]. Sensory feedback, specifically proprioceptive control, is a deficit that can promote reduced balance and increased risk of falling as the disease progresses. Although we did not physiologically determine what causes this impairment, we were able to support the presence of an overall balance deficit in the PD population when compared to a healthy elderly population using the Biodex Balance testing system. Overall sway index scores were significantly higher in PD under each condition.

Vibration therapy may promote improvements in balance because mechanical stimulation is transmitted to the vibration-sensitive primary muscle spindle endings [17]. This stimulation should then activate the alpha motor neurons in postural muscles and lead to improved balance reactions. This theory is supported by studies involving healthy older adults who participated in WBV interventions [16,17]. Haas et al. [16] documented a 25% decrease in tremor and bradykinesia after five treatments of WBV. Using dynamic computerized posturography, Bogaerts et al. showed that 12 months of WBV significantly decreased fall frequency when the platform moved and visual input was altered [17]. A recent meta-analysis also concluded that WBV promotes dynamic balance improvements in frail older adults [22].

WBV has also been studied as an intervention for improved motor performance in the PD population [23-27]. Although the methods of applying WBV among these studies are variable, short-term improvements in balance and motor function were documented after WBV. The mechanisms of these improvements are unknown but it possible that vibration stimuli enhance sensory processing in individuals in PD [8,9,26]. Another possibility is that WBV promotes activation of dopaminergic neurons, as has been shown in animal models [28].

Despite previous studies using WBV, we found that SVT had no effect on balance after 12 sessions in individuals with PD. There are several possible reasons for lack of improvement. First, we stimulated each muscle group for a period of two minutes. This length of stimulation could have saturated the receptors and decreased feedback to the muscles. Brief vibration (10-20 seconds) has, previously, been shown to enhance Ia neuronal discharges in lower extremity muscles involved in balance reactions [23]. Furthermore, vibration stimuli greater than 30 seconds have been shown to decrease afferent discharge frequency by 73% [23]. Second, the length of the study was four weeks. This may not be enough time to see neuroplastic effects and re-organization within the nervous system for improved balance and proprioceptive feedback. Third, the timing of our balance assessments relative to bouts of SVT may have not been optimal. Previous studies in our lab have documented improvements in tremor and bradykinesia immediately after acute bouts of SVT. Therefore, it is possible that balance improvements were present immediately after the intervention

Variable	Control PD		SVT PD		p values	
	Baseline	Post	Baseline	Post	Time	Time X Group
Fall Risk Score	1.46 ± 0.5	1.14 ± 0.4	1.61 ± 0.4	1.42 ± 0.5	0.01*	0.48
EOFS- Sway	1.0 ± 0.5	0.95 ± 0.3	0.95 ± 0.7	0.97 ± 0.5	0.88	0.78
ECFS- Sway	1.52 ± 0.4	1.68 ± 0.7	1.61 ± 0.9	1.64 ± 0.8	0.50	0.65
EOSS- Sway	1.74 ± 0.8	1.34 ± 0.3	1.7 ± 0.6	1.29 ± 0.5	0.01*	0.98
ECSS- Sway	4.28 ± 1.8	4.44 ± 1.4	4.47 ± 1.6	4.13 ± 1.6	0.77	0.44

Values are mean ± SD., * - p<0.05

Table 2: Fall risk and m-CTSIB scores in control PD and SVT PD intervention groups.

but were not maintained over time [18]. Lastly, the small sample size is a limitation. However, the P-values for the interaction effect were between 0.4 and 0.9 (Table 2) so it is unlikely that additional individuals would result in significant statistical changes. Segmental vibration may be a clinically advantageous form of vibratory intervention because it is easy and safe to implement within a clinically-based balance program. However, further study is needed to determine optimal timing and length of segmental vibration interventions in the PD population.

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