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Short-term effects of vibration therapy on motor impairments in Parkinson's disease

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Abstract. Recent studies have suggested that vibration therapy may have a positive influence on motor symptoms in individuals with Parkinson's disease (PD). However, quantitative evidence of these benefits is scarce, and the concept of "whole-body" vibration in these studies is vague. The objectives of the current study were to evaluate the influence of vibration on motor symptoms and functional measures in PD by delivering sound waves to the entire body. We delivered whole body sound wave vibration to 40 individuals with PD using a Physioacoustic Chair, a piece of equipment with speakers spaced throughout the chair permitting a series of programmed low frequency sound waves through the body. Using a parallel cross-over design we utilized the Unified Parkinson's Disease Rating Scale (UPDRS), quantitative gait assessments, and a grooved pegboard for upper limb control. Improvements were seen in all symptom, motor control and functional outcome measures at the time of assessment. Specifically, a significant decrease in rigidity, and tremor were shown, as well as a significant increase in step length and improved speed on the grooved pegboard task. Results of this initial investigation provide support for vibration therapy as a non-pharmacological treatment alternative. Long-term benefits of vibration therapy will require further research.

Keywords: Vibration therapy, Parkinson's disease, rehabilitation, gait, motor control

1. Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder characterized by several motor symptoms including, tremor, rigidity, bradykinesia, and postural instability. PD is typically treated pharmacologically, but over time patients experience an increasingly shorter period of symptom relief and develop a wide array of psychiatric and physiological problems [15]. As well, there has been insufficient evidence to assert or refute the efficacy of both occupational and physiotherapy in Parkinson's disease [4,5]. Thus it is important to investigate alternative non-pharmacologic strategies to improve the symptoms of PD.

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Evidence has supported vibration therapy as a prospective approach for relief of symptoms in PD by influencing the abnormal neural rhythms associated with the disease [8]. In the basal ganglia , this neural synchrony is critically dependent on the level of dopamine available [3]. The subthalamic nucleus (STN) has a powerful influence on neuron activity in the basal ganglia. Levy and colleagues hypothesized that the characteristic over-stimulation of the STN that occurs in PD may cause the basal ganglia to be held abnormally in a 15–30 Hz oscillatory rhythm [13]. Therefore the mechanical perturbations of vibration therapy may disrupt these hypersynchronized rhythms. Several studies have examined vibration as a potential therapeutic intervention for motor symptoms of PD. Jöbges and colleagues [9] administered local vibration to single upper limb muscle groups in individuals with PD experiencing moderate resting tremor, and subsequently found reductions in tremor. The authors suggest that tremor frequency is influenced by manipulating local

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sensory feedback to the limb. Haas et al., also investigated the effects of vibration using variable stimuli on the whole body of PD participants rather than single muscle groups [8]. The justification for variable stimuli comes from work by Schultz [18] in a series of investigations showing that unpredictability of a stimulus is directly related to dopamine release. By logical extension, if random vibration causes small supplementary releases of dopamine, it may enhance activity of the affected brain circuits. In the experiment by Haas et al, random unsynchronized vibration (varying in amplitude) was delivered to the feet of PD participants from a platform with the assumption that the effects would be experienced throughout the whole body. Haas et al. [8] found a highly significant improvement of 16.8% in the Unified Parkinson's Disease Rating Scale (UPDRS) motor score (tremor and rigidity scores improved by 25% and 24% respectively). In the current study, the influence of whole body vibration was evaluated in a cross-over design by delivering sound waves to multiple sites across the body surface. The present study employs the use of physioacoustic vibration, to ensure uniform delivery of stimulation to the entire body, and is a comfortable alternative to other methods of delivering vibration. Studies using low frequency waves with the physioacoustic method improved movement and personal autonomy in individuals with Parkinson's disease as measured by subjective assessments made by the patients themselves [17,19]. This is the first study to quantitatively test the effects of the physioacoustic method on motor symptoms associated with PD participants. Particularly unique to the current study is the variety of outcome measures used in addition to the motor impairment section of the UPDRS. Quantitative measures included gait analysis and upper limb targeting and coordination tasks.

The most frequently targeted symptoms of PD in current neurological rehabilitation paradigms are gait dysfunction and postural instability, as available strategies have shown to be less effective against bradykinesia and tremor [10]. The current study is a trial of a therapeutic technique that could potentially combat several or all symptoms of PD.

2. Methods

2.1. Participants

Forty individuals diagnosed with idiopathic Parkinson's disease participated in this study with their informed consent. Participants were subdivided into groups according to primary symptom. Hence, there were 20 slow/rigid dominant participants, and 20 tremor dominant participants. The mean ($\pm$ standard deviation) age was 65.4 ± 9.9 years, and the mean duration of the disease was 6.8 ± 4.8 years (for further detail, please see Table 1). Diagnosis was established by the primary care neurologist. Participants with dementia or other diseases impairing gait or coordination were not admitted to the study, and all subjects had normal or corrected-to-normal vision. To represent their typical day-to-day state, subjects were not withdrawn from their medication and were determined to be in an "on" state by the UPDRS assessor. Some individuals were unable to complete all tasks due to physical incapabilities and/or technical difficulties, which accounts for the different n values of the assessments. Ethics approval was obtained from the Wilfrid Laurier University Research Ethics Board.

2.2. Treatments

The vibrations were delivered using a method called the physioacoustic method [11,12]. An arm chair run by software that produced and controlled sound vibrations from its six strategically placed speakers, allowed the whole body to experience its effects (see Fig. 1). Because sound changes in air pressure, the method is reliant on the external distribution of tactile receptors throughout the body, and the internal resonance of vibrations in the body's tissues. To ensure correct resonance frequencies, the software uses frequencies to cause the sound to vary about a fixed pitch, a technique called scanning. This results in a pulse-like sensation that causes a traveling sound pressure in the body facilitating circulation [12]. Vibration treatments were administered in 5 consecutive series lasting one minute each, with one minute rest periods between each delivery of vibration. When sitting in the chair, participants were instructed to close their eyes and relax as much as possible with their legs reclined and uncrossed. Lower legs, thighs, buttocks, lower back, and upper back were to be in contact with the surface of the chair at all times.

2.3. Assessments

Participants were first assessed using a segment of the motor section of the Unified Parkinson's Disease Rating Scale (UPDRS). The UPDRS is a standardized diagnostic tool that gauges the nature of the disease progression and effectiveness of treatment plan [6]. The

Fig. 1. The Physioacoustic Chair.

scale is categorically organized by mental effects, limitations in activities of daily living, complications of treatment, and motor impairments. Only a subset of the motor impairment scale was used and then rated by an experienced evaluator. Videotaping the assessments allowed the rater to be completely blinded to the treatment status of each participant, with no cues as to which experimental group the individual belonged. For the videotaped assessment, participants were rated for tremor, finger tapping, leg agility, posture, and ability to arise from a seated position, corresponding to items 20–23 and 26–28 on the UPDRS. The only subset that could not be rated with videotapes was the rigidity component which was also completed by the same blinded rater for each assessment. The overall rigidity score is a sum of UPDRS rigidity scores for all four limbs and the neck.

The assessment segment was two-fold. First, each participant was required to walk in a straight line at a normal pace down a pressure-sensitive carpet that was run by software (GAITRite®, CIR Systems, Inc., Clifton, New Jersey). This carpet measured several parameters regarding the gait of the individual and five trials were completed for each assessment block. The dependent measures of interest were velocity and step length for both right and left feet. The second assessment was the timing of a grooved pegboard task to indicate the severity of the bradykinesia. This grooved pegboard is a manipulative dexterity test consisting of 25 holes with randomly positioned slots. Pegs with a key along one side must be rotated to match the hole before they can be inserted. Participants were timed for the placement and the removal separately, and these were added together for a total time of task. Both placement and removal tasks are considered to be fine motor tasks, however the placement of pegs requires more precision. Therefore, while removal is considered a primary measure of motor speed, the placement task better represents a measure of visual-motor speed [2]. This task is an efficient way to represent several reach, place and grasp tasks encountered with common daily living.

2.4. Procedure

In each test session, two participants were studied in a parallel crossover design and were randomly assigned to one of two treatment groups. All participants were assessed at baseline, after vibration treatment, and after the control period. The difference between the groups was the order of the vibration treatment and control period, in which group A received the vibration session first, and the rest period second, while group B received the rest period first and the vibration session second.

The parallel crossover design was used for the purpose of counterbalancing practice effects and fatigue across assessments. In addition the crossover design allows us to gauge the duration of the benefit given the treatment's effectiveness. In group A, the participant receives the vibration treatment first and the rest period second, the expected result would be for improvement in the second assessment. If this effect were to last longer than approximately 30 minutes, we would expect to see a carry over effect in the third assessment which is completed after the rest period. However, in group B when participants receive a rest period first and a vibration session second, there should only be an improvement in the third assessment.

2.5. Statistical analysis

Group A and group B results were submitted to separate repeated measures ANOVAs for each parameter of assessment. Whether it be tremor-dominant or slow/rigid-dominant, the participant's dominant symptom was also included as a between groups variable in

Table 1
Participant Demographics

Patient #	Group	Age	Symptom	Gender	Disease Duration	Medication
1	A	61	R	m	4	sinemet 100/25 3x/day
2	A	49	R	m	2	12 mg requip,rasagaline
3	B	72	R	f	6	none
4	A	55	T	m	14	100 mg amantadine
5	B	62	R	m	8	sinemet (12 × 100/25),3 mirapex, comtan
6	B	70	R	m	10	sinemet (1.5, 4x/day)
7	B	59	T	m	1	none
8	B	61	T	f	7	mirapex
9	B	65	T	f	1	none
10	A	75	T	f	4	sinemet, 6/day, mirapex 3 mg /day
11	B	61	T	f	3	none
12	B	72	T	f	6	none
13	A	65	R	m	5	sinemet 18x/day, mirapex 4x/day
14	A	72	R	m	10	sinemet 1.5 × 4; comtan × 4
15	B	79	R	f	3	sinemet 5/day;
16	A	71	T	m	16	sinemet 8/day, mirapex × 3, sinemet SR 1 × 200/50
17	A	73	R	m	7	sinemet 16.5
18	A	63	T	f	2	none
19	A	74	R	m	6	10 sinemet, 12 requip (24 mg)
20	B	33	R	m	1	rasagaline
21	A	66	R	m	5	3 sinemet, 2 100 mg amantadine
22	B	63	T	f	7	requip 2 mg × 3 = 6 mg
23	B	50	T	m	2	requip 0.75 mg × 3 = 2.25mg
24	A	70	T	f	9	mirapex × 3
25	B	72	T	f	13	sinemet, 3 comtan, 3 mirapex, 2 amantadine
26	A	79	T	f	7	10 sinemet, 5 comtan
27	B	77	R	f	16	1 sinemet, 3 sinemet CR, 3 200 mg comtan, 25 mg mirapex
28	A	69	T	f	14	5 × 1.5 sinemet; 5 × 200 mg comtan
29	B	80	T	m	2	apo-trihex, 4 × 10 sinemet, 2.5 mg
30	B	65	T	m	2	1mg rasagaline
31	A	56	R	m	9	requip × 4pills × 3 times = 0.25 mg each
32	B	66	R	m	5	8 sinemet, 4 comtan
33	A	61	R	m	15	sinemet CR × 7, permax × 3(1 mg), amantadine 3 × 100 mg)
34	B	77	T	m	15	sinemet 4x/day
35	A	57	R	m	7	mirapex × 8
36	A	62	T	f	2	mirapex × 3
37	B	81	R	m	5	4 × sinemet
38	A	64	R	m	15	sinemet × 6.5, 3 comtan, 4 requip
39	B	60	T	m	1	none
40	A	51	R	m	5	6 mg, 4x/day requip

each ANOVA in the event that individuals were affected differently by the treatment because of their dominant symptom. In the analyses for step length and velocity, trial number was included as a within-subjects variable in the event that it contributed to the overall variance between assessments. ANOVAs for UPDRS scores of tremor, finger-tapping, leg agility, posture, sitting-to-standing ability, and rigidity, as well as pegboard times were conducted as follows: 2 Dominance (tremor, rigid) X 3 Assessment (Baseline, Post Vibration, Post Rest Period). Step length and velocity were submitted to repeated measures ANOVAs as 2 Dominance (tremor, rigid) X 3 Assessment (Baseline, Post Vibration, Post Rest Period) X 5 Trials. For main effects, Tukey's Honest Significant Difference post hoc tests were conducted to determine if the effects of vibration treatment differ significantly from the effects of the rest period with an alpha level of 0.05%.

3. Results

All participants tolerated the treatment well with no report of pain, dizziness, or discomfort. Symptom category namely, tremor-dominant or slow/rigid-dominant was included as a between groups variable, but showed no comparable differences in any assessment category.

3.1. Rigidity

Figure 3 shows the mean UPDRS scores for rigidity in the group that received vibration first and a rest pe-

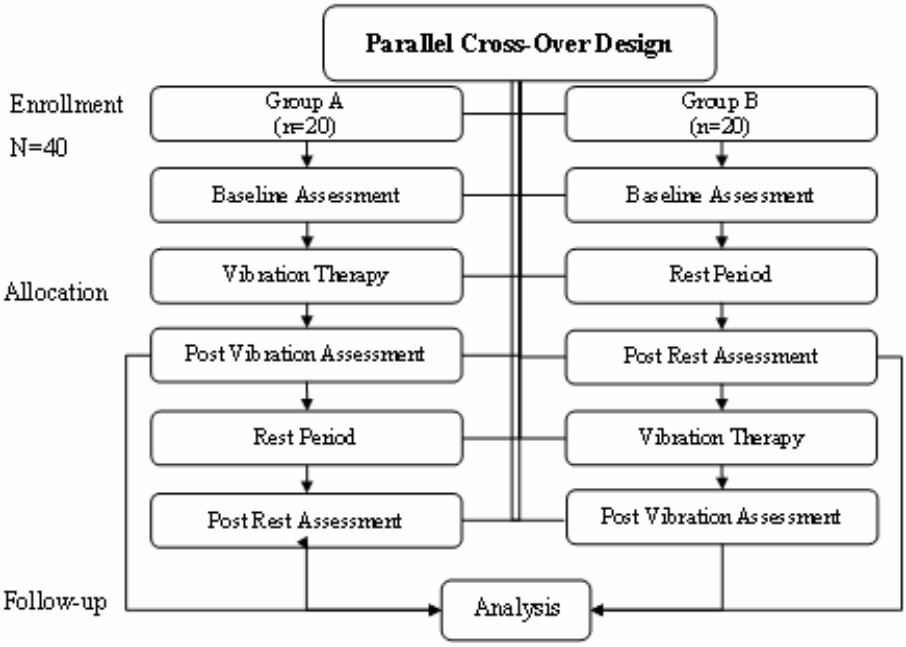

Fig. 2. The parallel cross-over design.

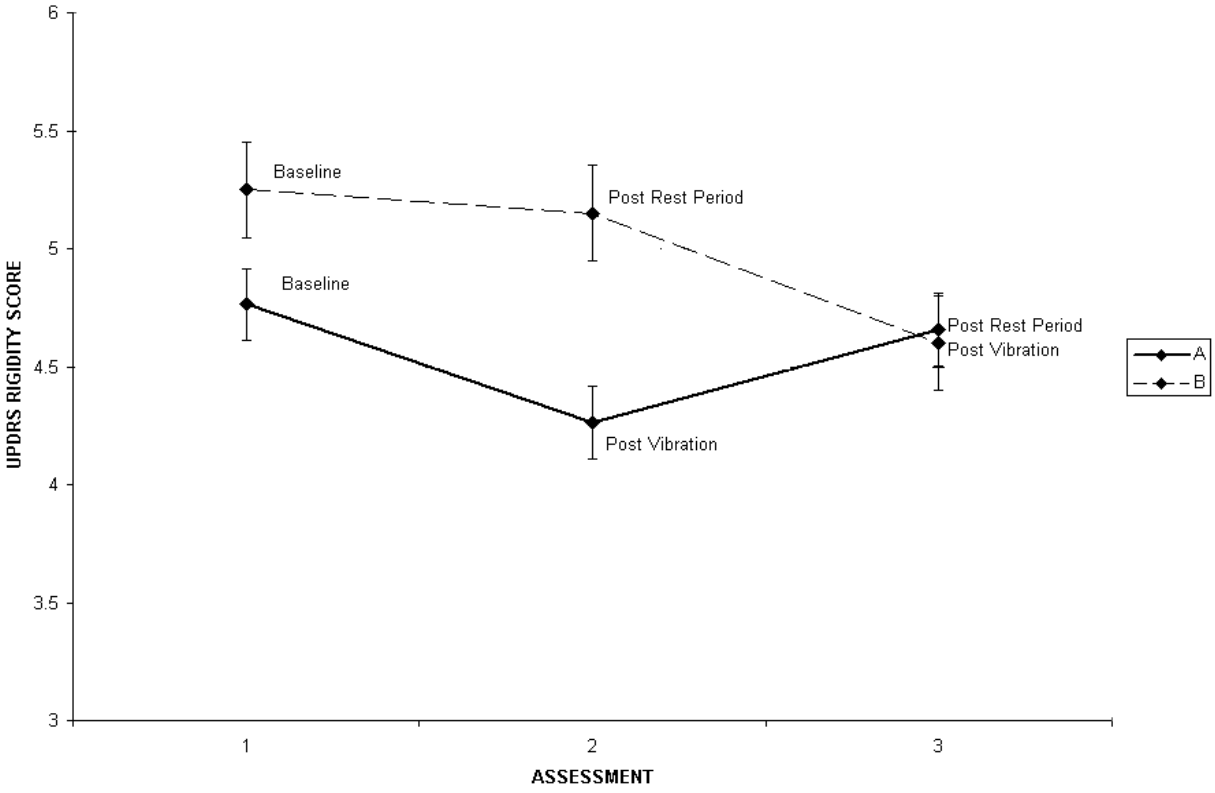

Fig. 3. Rigidity scores in group A improved after vibration treatment with some carry over effects in the post rest period assessment. Rigidity scores in group B had negligible changes after a rest period but decreased significantly after vibration treatment.

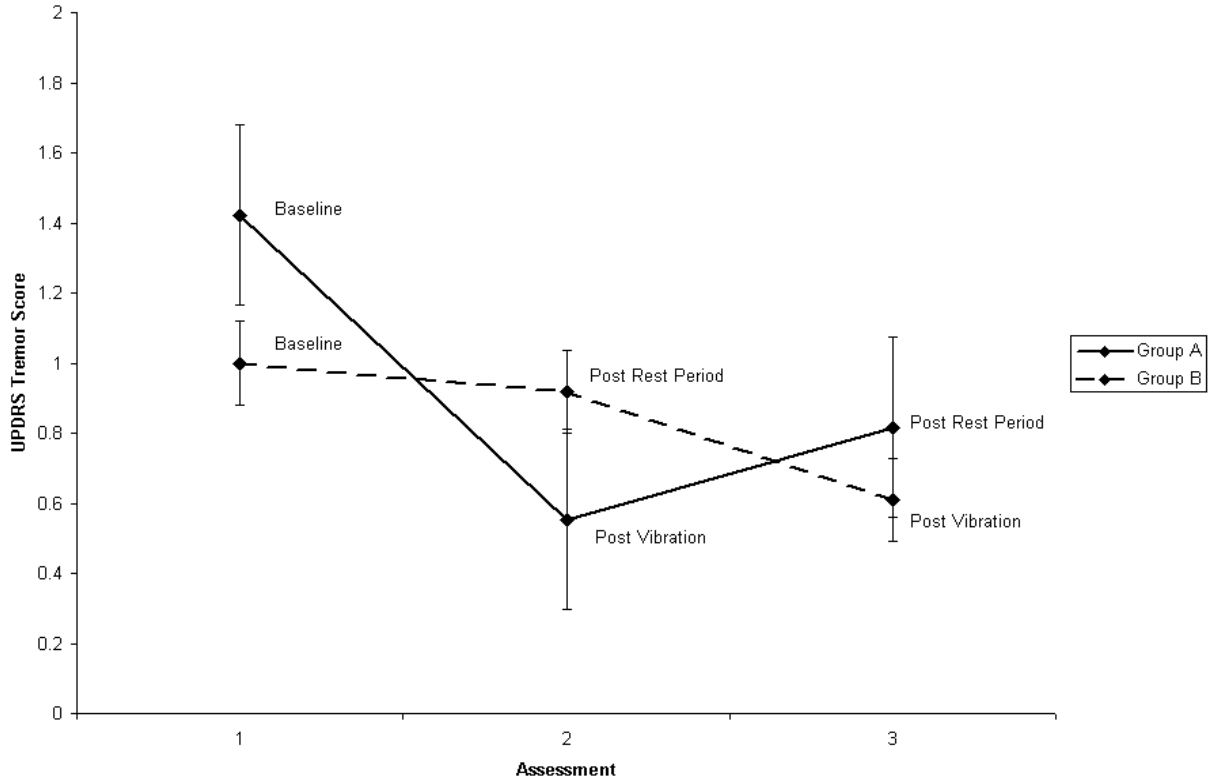

Fig. 4. Tremor scores in group A improved after vibration treatment with some carry over improvement effects in the post rest period assessment.

riod second (group A). There was a significant effect of treatment status (F(2,34) = 3.36; $p = 0.046$) for the UPDRS score such that rigidity decreased for both post-vibration and post-rest period assessments. Post-hoc confirmed that there were rigidity improvements similar in both the post-vibration and post-rest period conditions. Rigidity scores were also significantly different between the treatments in group B, the group that received a rest period first and a vibration session. The UPDRS rigidity score decreased significantly in the post vibration assessment (F(2,36) = 10.35; $p < 0.001$). Post hoc analyses show that post vibration assessments in group A are significantly different from baseline ($p = 0.049$) but did not differ from post-rest period assessments ($p = 0.141$). In group B, post vibration assessments differed significantly from both baseline ($p < 0.001$) and post rest period assessments ($p < 0.003$).

3.2. Tremor

Figure 4 shows the mean UPDRS scores for tremor in the group receiving treatment before rest. There was a significant effect of treatment ($F(2,34) = 8.3$; $p = 0.002$) for the UPDRS score, such that it decreased in both post-vibration and post-rest period assessments. Tremor UPDRS scores failed to reach a level of significance between assessments in group B ($F(2,32) = 2.38$; $p = 0.109$). Post hoc analyses show that baseline assessments in group A were significantly different from post vibration assessments ($p < 0.001$) and from post-rest period assessments ($p < 0.021$). In group B, there were no significant post hoc analyses.

3.3. Other UPDRS measures

The UPDRS measures for finger tapping, leg agility, posture, and arising from a seated position all failed to reach a level of significance.

3.4. Bradykinesia

Figure 5 shows the mean time in seconds for the peg task completion in group A by assessment. There was a significant effect of treatment status (F(2,32) = 5.24; $p = 0.011$) for the peg board task such that completion time decreased for both post-vibration and post-rest period assessments. Peg task completion time was also

significantly different between the treatments in group B (see Fig. 5) with the peg board task time decreasing in the post vibration assessment ($F(2,36) = 11.2$; $p < 0.001$).

Post hoc analyses show that post vibration assessments in group A were significantly different from baseline ($p = 0.008$) but did not differ from post-rest period assessments ($p = 0.565$). In group B, post vibration assessments differed significantly from both baseline ($p < 0.001$) and post rest period assessments ($p = 0.039$).

3.5. Step length

Step length was not significantly different across the assessments in Group A ($F(2, 36) = 0.386$, $p = 0.982$), however, group B did show a significant effect of treatment status ($F(2,32) = 4.26$; $p = 0.023$) for the step length such that it was increased for the post-vibration assessment (see Fig. 6).

Post hoc analyses show that post vibration assessments in group B are significantly different from baseline assessments ($p = 0.033$). The post vibration assessment only differed slightly from post-rest period assessments ($p \approx 0.05$) which indicates a high variation in scores. In group A, there were no significant post hoc analyses.

3.6. Velocity

The other parameter of interest in gait analysis was velocity, in which there was no main effect of treatment. Velocity was the only quantitative measure to not reach a level of significance.

4. Discussion

Our objective was to complete a thorough, quantitative analysis of the effectiveness of whole body vibration as a potential treatment for motor symptoms of PD. Although previous investigations have also supported the idea that vibration therapy is an effective mode of symptom relief, the thoroughness in quantitative gait and functional upper limb assessments of the current study is unprecedented. The current method permitted effective delivery of vibration throughout the whole body. The parallel crossover design we employed allowed us to counterbalance the effects of fatigue and practice in our assessments, as well as determine if there was a difference between vibrating in the chair and simply sitting in the chair.

For several motor symptoms, significant improvements were linked to the vibration treatment, while the control condition (post-rest) led to small, insignificant changes as compared to the baseline assessment. In light of this evidence, the beneficial effects of vibration therapy have not been more apparent. Vibration therapy in general is a relatively untouched area of research, and the current study has unprecedented efficiency and accuracy through biomechanical analyses and a parallel cross over design. Despite being the gold standard for PD assessments, the UPDRS carries with it a high degree of subjectivity. By videotaping as much of the assessment as possible, and having the recordings rated at another date, the rater is entirely blinded from the biases of knowing the participant's treatment status. In addition, quantitative testing using GAITRite technology and the grooved peg board test largely enhances the ability to detect functional outcomes that may be more relevant to activities of daily living rather than evaluating a change in only symptoms of participants.

In summarizing the results, no major symptom category is left untouched. UPDRS scores for tremor and rigidity both improved. The other subsets of the UPDRS scales namely posture, sitting to standing scores, and leg agility did not reach a level of significant improvement. However, this is likely because these scores were naturally less severe initially. Therefore, unlike tremor and rigidity, there was little room for improvement in the first place.

The GAITRite carpet was able to provide the study with accurate and unbiased parameters indicating the improvement in step length. Both practice effects and fatigue can be factors in the quality of the walking. However, the crossover design controls for these effects by reversing the order of the vibration session and rest periods in group A and B. Step-to-step variability may be of interest to look at in future studies as this may be an important diagnostic tool in evaluating impaired gait [1]. A large step-to-step variability may reduce the experimenter's ability to detect improvements in step length as a trend in a large group of participants. Also, the grooved peg board test requires more complex visual-motor coordination than most bradykinesia assessments. Although practice and fatigue may play a role in the participant's completion speed, it is ultimately one of the most efficient assessments for bradykinesia available. Even with the crossover design, the pegboard completion times were shown to decrease in post vibration assessments, in correspondence with the decrease in bradykinesia.

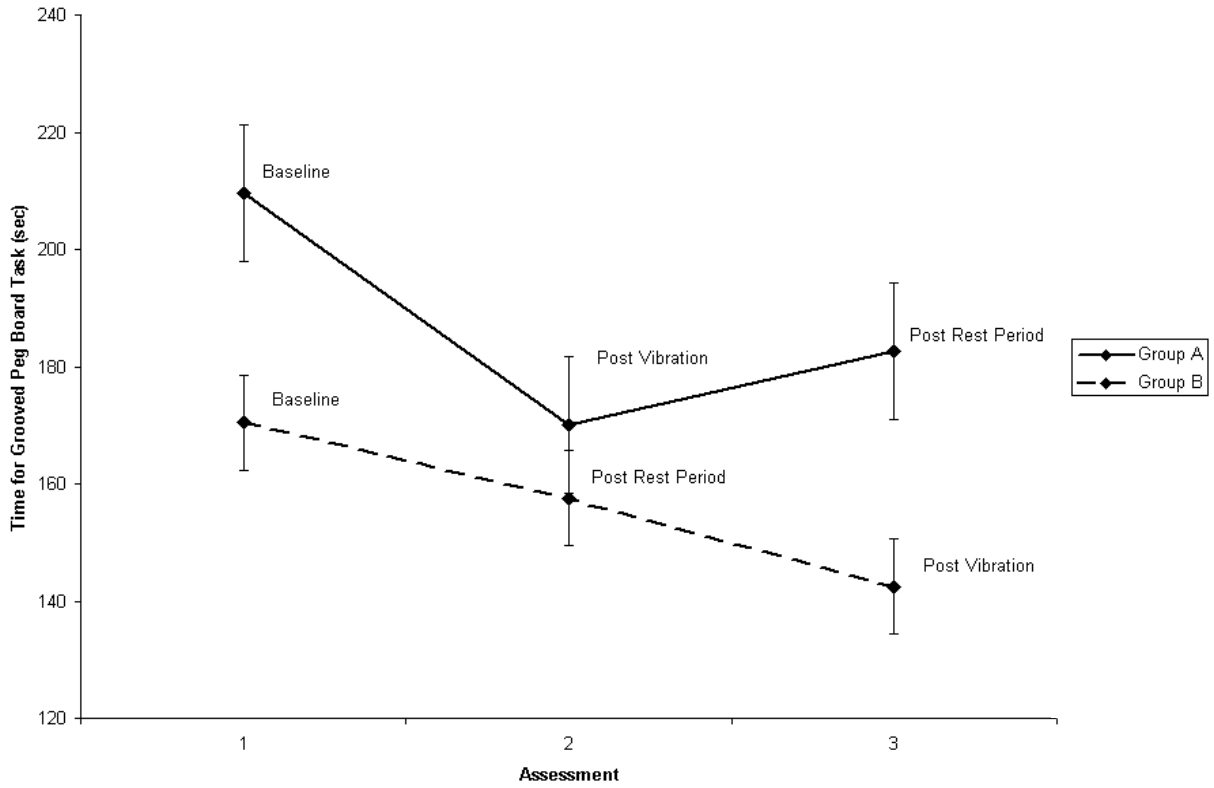

Fig. 5. Peg task completion times in group A improved after vibration treatment with some carry over effects in the post rest period assessment. Peg task completion times in group B changed negligibly after a rest period but showed significant improvements after vibration treatment.

These findings may contribute to the aforementioned model of abnormal basal ganglia function, in which 15–30 Hz beta oscillations potentially gain an abnormal access route to the basal ganglia through the cortical subthalamic pathway [9]. As mentioned, this promotion of oscillatory synchronization in the basal ganglia may initiate the majority of symptoms of PD. While administration of dopaminergic medication seems to suppress these beta oscillations in the basal ganglia, it can be speculated that the mechanism for vibration's benefits may also have to do with resetting or perturbing these neural rhythms [7]. Furthermore, the closed loop structure of the cortex, basal ganglia, and muscle networks, suggests that normal basal ganglia oscillations are the result of proprioceptive feedback [16]. The importance of proprioception in motor control is well represented in the literature. One theory is that sound wave vibration resonates throughout the body and stimulates a greater ability to sense the position, location, and orientation of the body and its appendages in relation to each other. Apart from neural rhythms and proprioception, it is also apparent that vibratory stimuli affect a variety of physiological functions, particularly neurotransmitters and the endocrine system [18,14].

The most significant limitation associated with the study was the unexpected duration of benefits and the timescale for assessments. It was obvious in group B that the post rest period assessments should not differ significantly from the baseline assessments, and that post vibration assessments should be significantly different from both baseline and post rest period assessments. However, in group A it was unknown as to whether there would be carry-over effects of the treatment into the post rest period assessment since the vibration therapy was administered beforehand. Evidently, in all tests that showed significant effects of the treatments in group A, namely bradykinesia, rigidity and tremor, post hoc analyses revealed carry over effects of the treatment in each post rest period assessment. In response to this finding, the long-term benefits of vibration therapy are worth looking into in future studies.

Several possibilities present themselves with respect to future investigations. The rationale for choosing the frequencies and durations for this study were based on a very limited selection of previous studies as well as in-

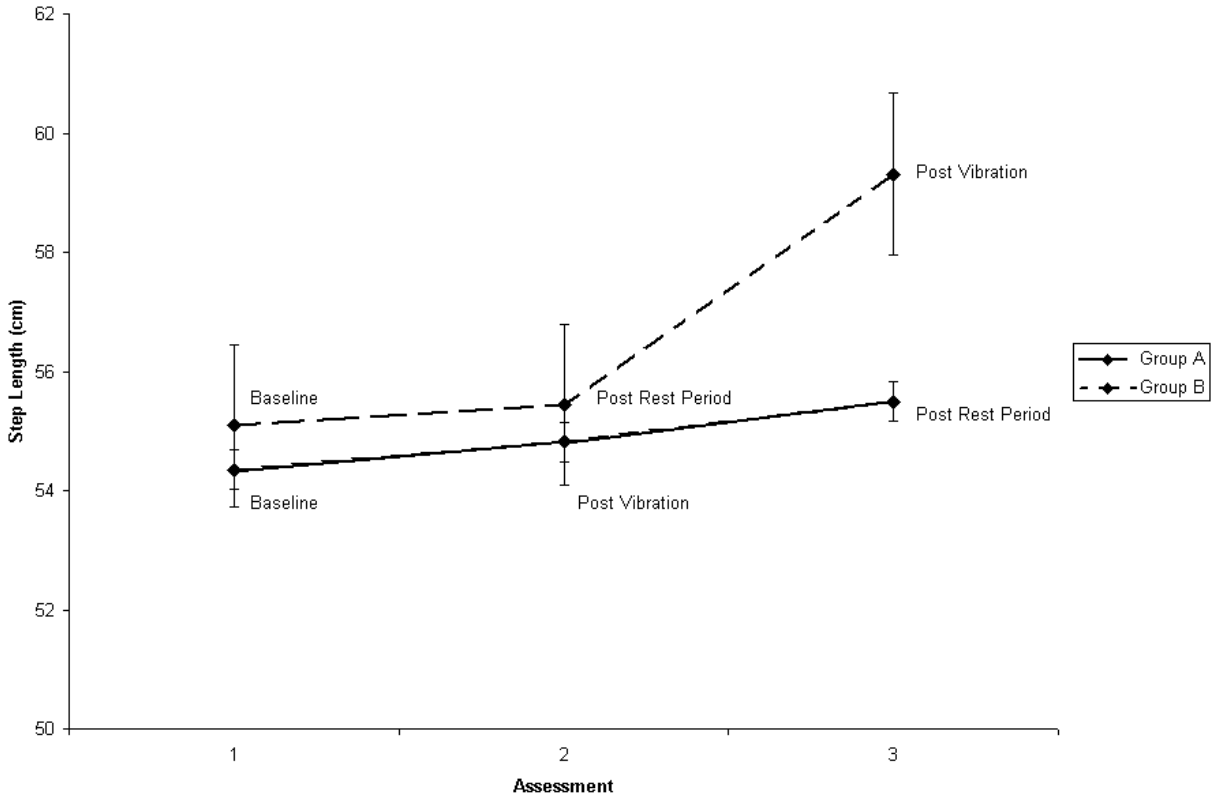

Fig. 6. In group B, negligible changes in step length were shown after the rest period, however the post-vibration assessment revealed significant increases.

dividual testimony. Since this is the first study to quantitatively test the effects of the physioacoustic method on PD participants, it is important to realize that there are a number of other frequencies and durations that could be chosen for a treatment plan. In planning the study, it was also unknown how long benefits would last in the event of treatment success. Future studies should seek to measure the benefits over a longer time scale, and subsequently work to lengthen this benefit. Since participants were subjected to only ten minute treatments, by logical extension increasing the duration of treatment sessions, and possibly the number of treatments may be the next step in lengthening the beneficial effects.

Finally, the current study attempted to compare subjects based on their dominant symptom, however there was no apparent relationship between greater treatment success and primary symptom. Studies involving individuals with PD are limited by the fact that PD is pathologically heterogeneous across participants, and the variation in how participants responded to the treatment is currently beyond the scope of explanation for a study of this nature. Sources for this variation should be explored in greater detail.

In summary, although vibration therapy may not be at the stage in which it can be regarded as an exclusive treatment for PD, the results of the study strongly suggest its application as an important adjunct to medication.

Acknowledgements

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