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Interval, Active-Assisted Cycling Improves Motor Function but Does Not Alter Balance in Parkinson's Disease

Original Research

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Abstract
Introduction: Previous work in our lab has demonstrated that a single bout of active-assisted cycling improves tremor and bradykinesia associated with Parkinson's disease. The purpose of the present study was to determine if an interval, active-assisted cycling intervention improves motor function and balance in individuals with Parkinson's disease. **Methods:** Twenty-seven individuals (8 females, 19 males) with Parkinson's disease volunteered to participate in the study. Subjects were randomly assigned to either a cycling or control group. The cycling group completed 40 min of interval, active-assisted cycling three times per week for four weeks. The Unified Parkinson's Disease Rating Scale (UPDRS Motor III scale) and the modified Clinical Test of Sensory Integration and Balance test were completed at baseline and following the four-week intervention. **Results:** The UPDRS scores (upper body motor function, lower body motor function, tremor, bradykinesia, posture and gait) improved ($p = 0.01$) following the intervention while balance remained unchanged. **Conclusions:** These data demonstrate that a four-week interval, active-assisted cycling program improves motor symptoms, specifically tremor and bradykinesia, in the upper and lower extremity but does not alter balance in individuals with Parkinson's disease.

Key Words: tremor, balance, exercise

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Introduction

Parkinson's disease (PD) is a progressive neurodegenerative disorder that results in tremor, rigidity, bradykinesia and mobility deficits[1]. Despite medical and surgical intervention, as PD progresses individuals often experience loss of balance and postural instability leading to an increased risk of injury and inactivity[2,3]. Furthermore, medication-based therapy (levodopa) has been shown to increase postural sway which can increase fall risk[4]. Thus, it is critical to examine rehabilitative interventions that can improve balance in these individuals.

Balance and postural control require integration of the vestibular, visual, auditory, motor and pre-motor systems. Research has demonstrated that proprioceptive integration is altered in PD and this may, in part, explain the postural instability experienced by individuals with PD[5,6]. Rehabilitation methods utilizing external sensory cues (proprioceptive, visual or auditory) can improve motor function, gait and balance in PD[7-11]. Therefore, it is recommended that rehabilitation strategies should focus on retraining nervous system to optimize postural reactions considering sensory deficits in PD.

Previous work has demonstrated that intensive exercise training programs promote improvements in gait and stability in individuals with PD[10,12-17]. However, gait-based therapies require specialized safety equipment and are limited to individuals who can maintain upright posture. Further, while investigators have recently demonstrated that training on a stationary cycle at low[18] and moderate-to-high[19] intensity improves motor performance in the early stages of PD, this training paradigm may not be a viable option for patients with more advanced disease. We recently developed a rehabilitation paradigm called active-assisted cycling (AAC)[20]. This paradigm utilizes a stationary motorized cycle to assist individuals with PD to actively pedal at a cadence (revolutions per minute) faster than they can achieve on their own. The high-speed rhythmic rotation of the legs during AAC may provide high-frequency sensory input that could alter motor function and posture.

A previous study in our lab has demonstrated that tremor and bradykinesia are improved after a single 30 minute bout of active-assisted cycling at a rapid cadence[20], but these effects are likely short-lived. Furthermore, the effects of an interval based, high cadence cycling intervention on balance have not been examined. The purpose of the this investigation was: 1) to examine if an interval, active-assisted cycling (I-AAC) intervention improves motor function, as measured with the Unified Parkinson's disease Rating Scale (UPDRS) Motor III test, and 2) to determine if this intervention improves balance, as measured with the modified Clinical Test of Sensory Integration and Balance (CTSIB). We hypothesize that four weeks of I-AAC will result in significant improvements in overall motor function and balance.

Methods

Participants

Twenty-seven individuals (8 females, 19 males) with idiopathic PD were recruited from local support groups. All volunteers were interviewed over the telephone with the American Heart Association/American College of Sports Medicine pre-screening questionnaire. Individuals at moderate risk of cardiovascular disease were cleared prior to participation by their primary care physician. Participants were excluded from the study if they report current cardiovascular, metabolic or respiratory disease. Written informed consent was obtained from each subject prior to participation according to the guidelines of the University's Institutional Review Board. All participants were asked to complete a four-page health history and were assessed using the Hoehn & Yahr score for a more complete health assessment to confirm that they qualified for the study. The same researcher performed all initial assessments. Participants levodopa equivalent dosage was calculated. Training and testing were completed while participants were 'on' Parkinson's medications.

Experimental Testing

The intervention was four weeks in length with one day for pre-testing and one day for post-testing. Individuals were randomized into one of two groups: Interval, active-assisted cycling (I-AAC) or control (no exercise). Individuals in the I-AAC group cycled for 40 minutes three times a week for the four weeks. Each cycling session began with 5 minutes of warm up. Participants then completed 30 minutes of interval, active-assisted cycling followed by 5 minutes of cool down on a motorized semi-recumbent cycle (Motomed Viva 2 Parkinson). Interval, active-assisted cycling combines short bouts of high-cadence cycling (90 revolutions per minute) with slower cadence periods (Table 1). During the 30-minute main set, the motor was set at a specific speed (revolutions per minute) and the subjects were asked to overpower the motor to maintain the cadence and were given visual feedback from the monitor. Participants heart rate was maintained within the range of 40 – 70% of their estimated VO_2max as calculate by the baseline fitness test. This I-AAC paradigm was developed to examine if short bouts of high-cadence cycling was sufficient to improve motor symptoms. Heart rate (Polar Accurex Plus, Polar Electro, Inc., Woodbury, NY) and Ratings of Perceived Exertion (RPE 6-20 scale) were recorded every two minutes during each cycling bout [21]. The control group only came to the lab for two assessments (baseline and 4 weeks).

Table 1. Exercise Paradigm

	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7	Phase 8	Phase 9	Phase 10
Gear	20	20	0	0	0	0	0	0	20	20
Time (mins)	2:30	2:30	5:00	4:00	6:00	8:00	3:00	4:00	2:30	2:30
RPM	55	70	90	75	65	90	65	90	60	45
Passive/Active	Passive	Passive	Active	Active	Active	Active	Active	Active	Passive	Passive

PD motor symptom severity was assessed using the UPDRS Motor III; the overall score was calculated by summing all measures. Greater UPDRS scores suggest more severe PD symptoms. The subcomponents of upper body motor function, lower body motor function, tremor, bradykinesia, posture, and gait were also examined. Balance was assessed using the Biodex Balance System SD. The Biodex Balance System quantifies the ability to maintain postural stability on an unstable surface and as well as during 'eyes closed' conditions using the CTSIB [22,23]This test includes four conditions: CTSIB-1, eyes open, firm surface; CTSIB-2, eyes closed, firm surface, CTSIB-3, eyes open, dynamic surface; CTSIB-4, eyes closed, dynamic surface.

Statistical Analysis

Demographic variables between the two groups were analyzed with an independent samples t-test. A repeated measure analysis of variance (ANOVA), with time as the within-group factor (Pre, Post) and group as the between-subject factor (I-ACC, CON), was performed to test the effects of I-AAC on variables of motor function and balance. Significant main effect or interactions were further analyzed with a paired samples t-tests with Bonferroni adjustments. All data were analyzed using SPSS 18.0 software.

Results

Participant characteristics are presented in Table 2. There were no significant differences in age, Hoehn and Yahr score, or levodopa equivalent dosage (LED) between the two groups. There was a difference between the baseline UPDRS motor III scores. Individuals in the I-AAC group showed a higher score (greater impairment) than the control group at baseline. However, data analysis examined the changes from pre-intervention to post-intervention using a repeated measure design to minimize the effect of this difference.

Table 2. Participant Characteristics

Variable	I-AAC (N= 13)	Control (N=14)	P value
Age (years)	70.6 ± 5.1	65.1 ± 9.3	0.084
Gender (Male/Female)	9/4	10/4	-
Hoehn & Yahr score	2.2 ± 0.7	2.1 ± 0.9	0.697
LED	362.7 ± 243.3	377.8 ± 273.3	0.582
Baseline UPDRS Motor III	35.2 ± 5.1	65.1 ± 9.3	0.084

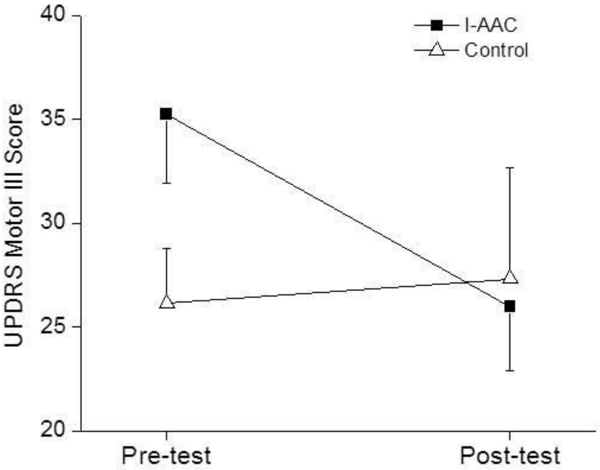
Abbreviations: LED, Levodopa equivalent dosage; UPDRS, Unified Parkinson's disease Rating Scale; Mean ± Standard deviation,

I-AAC Intervention

All thirteen individuals in the I-AAC group completed 12 sessions. The average heart rate was 79± 1.6 bpm and RPE was 10.1± .58 during the main set of the exercise sessions.

UPDRS Motor III Score

In order to assess overall motor function, UPDRS Motor III total scores pre (week 0) and post (week 4) for the I-AAC (N= 13) and control (N= 12) groups were compared (Figure 1). There was a significant interaction (power = .767, F= 7.876, p=.010) and main effect of time (power = .643, F= 5.897, p=0.023) in the total UPDRS motor III score. Post-hoc analysis using paired sample t-test with Bonferroni adjustments demonstrated that individuals in the I-AAC group improved their motor function score (decrease in the score) by 26% (t=8.106, df= 12, p<.001) while the control group did not change (t= -.193, df= 11, p=.851).



Each individual component of the UPDRS score was assessed to determine which motor function variables exhibited the greatest changes. The individual components were summed in order to examine lower body motor function, upper body motor function, tremor, bradykinesia, gait and posture, individually. Significant interactions were present in subscores of the UPDRS Motor III (Table 3) including lower extremity (UPDRS lines 20c, 22c, 26-31), upper extremity (20b,22b, 23-25), tremor (20-21) and bradykinesia (23-26, 31). There was a slight, but non-significant, improvement (26%) in posture (28, 30) after the I-AAC intervention.

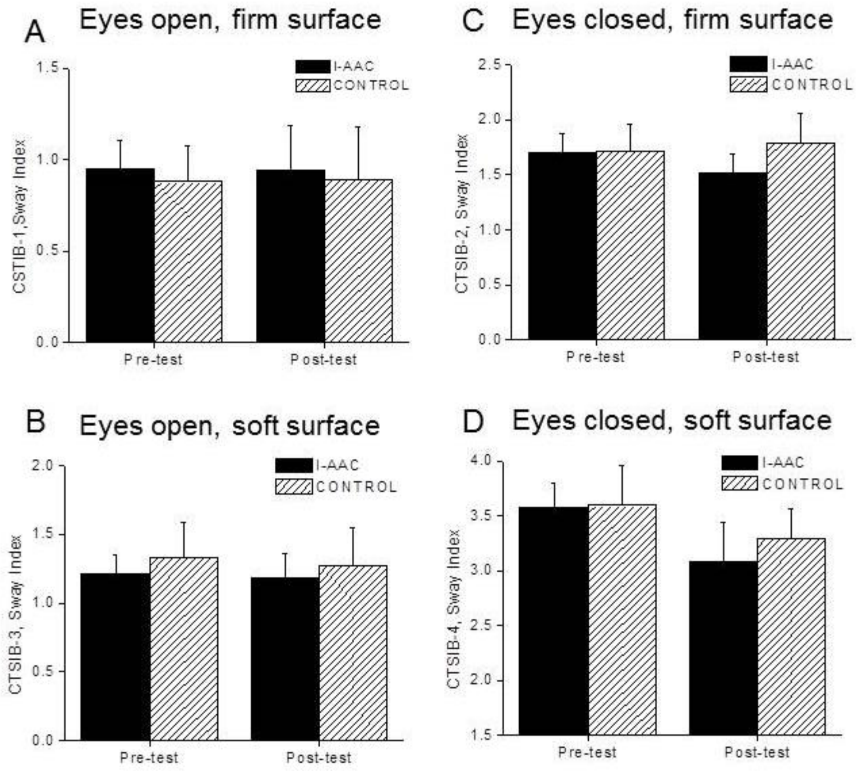
Table 3 UPDRS Motor III scores subgroups

	I-AAC				CONTROL			
Variable	**Pre**	**Post**	**% change**	**P value**	**Pre**	**Post**	**% change**	**P value**
Lower extremity UPDRS	12.5 ± 1.4	9.3 ± 1.7	-25	.001	9.1 ± 1.5	8.6 ± 1.8	-5	.693
Upper Extremity UPDRS	15.8 ± 1.4	11.5 ± 1.9	-27	.001	13.5 ± 1.5	14.1 ± 1.9	+4	.751
Tremor	9.1 ± 1.3	5.6 ± 1.8	-38	.001	9.7 ± 1.4	11.3 ± 1.8	+15	.370
Bradykinesia	13.0 ± 1.0	9.5 ± 1.7	-27	.001	12.1 ± 1.1	12.5 ± 1.7	+3	.811
Rigidity*	6.7 ± 1.0	5.1 ± 1.2	-	N.S	8.5 ± 1.1	9.4 ± 1.2	-	N.S
Posture*	6.1 ± 1.0	4.5 ± 1.5	-	N.S	8.8 ± 1.1	9.6 ± 1.0	-	N.S
Gait*	3.1 ± 1.3	2.2 ± 1.7	-	N.S	8.2 ± 1.4	8.8 ± 1.7	-	N.S

P values represent post-hoc paired samples t-test in cases of a significant interaction. Negative % change= improvement, positive % change = worsening in Parkinson's disease symptoms. Abbreviations: N.S., not significant; Mean ± standard error of the mean; *- no significant interaction, no further statistics required.

Balance Assessment

There were no differences in the two groups in either eyes-open conditions (CTSIB-1, CTSIB- 3, Fig. 2A,B). Eyes-closed conditions (CTSIB-2 and CTSIB-4) demonstrated slight, but non-significant, improvements in the I-AAC group. CTSIB-2 showed 11% improvement in I-AAC and 5% worsening in control (Fig. 2C). CTSIB-4 (Fig. 2D) showed 13% improvement in I-AAC compared with 7% improvement in control. In addition, the mean change in the I-AAC group is two-fold greater (0.48) than the control group (0.24). When individual data are examined, 69% (9/13) of participants decreased their CTSIB-4 sway score after I-AAC and 43% (6/14) of the control individuals showed a decrease.



Discussion

This study examined changes in motor function and balance after a four-week interval, active- assisted cycling exercise intervention in Parkinson's disease. Significant improvements in overall UPDRS Motor III scores suggest that symptoms of PD were decreased after this intervention. Specifically, we noted improvements in upper extremity motor function, tremor and bradykinesia. One of the most interesting findings of this study is that improvements in upper extremity motor function were documented after a lower extremity intervention. This is in agreement with other studies from our lab[20,24,25] and further supports the contention that high-cadence cycling may alter central motor control processes. Our findings are unique as the use of an interval, active-assisted cycling paradigm could be helpful for individuals with significant cardiovascular or musculoskeletal disability.

The advantages of both I-AAC and body weight supported treadmill training are that individuals are able to perform at higher intensity over an extended period of time. Previously, researchers have postulated that treadmill training (task repetition) may have induced a motor learning effect[13,14]. These theories of mechanisms of improvement can be carried over to the current study. The rhythmic pattern of high-cadence cycling could produce a motor learning effect that promotes improvements in overall motor function, as measured with the UPDRS Motor III score. However, the current study showed no improvements in resting and kinetic tremors in the exercise group. This could be due to the low baseline values of the tremor scores signifying that the individuals in this study do not have significant tremor symptoms.

Although there were no significant changes in the overall balance scores in this study, there were greater improvements in the two eyes closed conditions (CTSIB-2, firm surface; CTSIB-4, soft surface) in the I-

AAC group compared to the control group. Individuals with PD rely heavily on vision to maintain upright posture[26] due to proprioceptive deficits[27]. These findings suggest that I-AAC could increase the role of the vestibular and/or proprioceptive feedback in maintaining upright posture. Studies that have utilized balance training[28,29] interventions have shown similar results.

There are several limitations in this study. First, there was no follow-up testing session right after exercise and in the few weeks following the exercise training program. This would help to determine how long the effects of the training program would ultimately last in an individual with PD. Second, there was a wide variety of PD symptom severity in our study population. This variability resulted in a large standard deviation in the dataset and may have contributed to the lack of significant improvement between pre and post. Lastly, the PD subjects were "ON" their medications for training and testing. While participants were "ON" medication we did not track the timing of the medication. It is possible that we would have shown larger effects of the active-assisted cycling intervention if we tested individuals "OFF" their medications. However, we wanted to examine the effects of I-AAC while individuals were medicated to mimic "real-world" conditions.

Although we documented significant improvements in UPDRS Motor III scores after 4 weeks of I-AAC, there were no significant changes in balance as measured with the modified CTSIB test. Future studies should narrow the inclusion criteria of PD subjects to help control for the variability. Further, investigators could specifically focus on individuals who showed balance deficits and examine the effects of a longer intervention program to maximize improvements in motor function and balance in individuals with PD.

Media-Friendly Summary

Our study demonstrated that active-assisted cycling (like tandem cycling) improves movement in individuals suffering from Parkinson's disease.

Acknowledgements

None

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