HHS Public Access

Author manuscript

Clin Rehabil. Author manuscript; available in PMC 2017 March 06.

Published in final edited form as:

Clin Rehabil. 2009 December ; 23(12): 1078–1085. doi:10.1177/0269215509337465.

AN EVALUATION OF SELF-ADMINISTRATION OF AUDITORY CUEING TO IMPROVE GAIT IN PERSONS WITH PARKINSON'S DISEASE (PD)

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Abstract

Objective—To evaluate a self-administration of auditory cueing on gait difficulties in persons with Parkinson's disease (PD) over a one week period.

Design—Single group pre- and post-test

Setting—Research lab, Community.

Participants—Twenty-one individuals with PD.

Interventions—Self-application of an auditory pacer set at a rate 25% faster than preferred cadence.

Main outcome measures—Self-selected gait speed, cadence, stride length, and double support time with and without the pacer at the initial visit and after 1-week of pacer use.

Results—During the initial visit, the auditory pacer improved gait speed (79.57 (18.13) cm/s vs. 94.02 (22.61) cm/s, p<.0005), cadence (102.88 (11.34) step/min vs. 109.22 (10.23) step/min, p= .036) and stride length (94.33 (21.31) cm vs. 103.5 (22.65) cm, p=.012). After one week, preferred gait speed was faster than the initial preferred speed (79.57 (18.13) vs. 95.20 (22.23) cm/s, p<.0005). Stride length was significantly increased (94.33 (21.31) vs. 107.67 (20.01) cm, p=.001). Double support time was decreased from 21.73 (5.23) to 18.94 (3.59) % Gait Cycle, p=.016.

Conclusion—Gait performance in persons with PD improved significantly after walking with the auditory pacer for one week.

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Keywords

Parkinson's disease; auditory pacer; gait; rehabilitation; cueing

INTRODUCTION

External, rhythmical auditory cueing has been reported in the literature to modify gait characteristics in persons with PD.[1,2] Most studies reported the effect of auditory cueing on PD gait after participants received gait training using the cue by therapists. We designed this study to demonstrate the actual influence of auditory cueing on gait in patients with PD without additional training provided by a clinician. The design allowed us to demonstrate gait modifications due to the influence of auditory cueing alone, not from any clinician feedback or verbal reminders, which usually occur during supervised gait training. Self-administered cueing may be more cost-effective than gait training with clinicians using an auditory cue. This is the first study to show gait modification in patients with PD by auditory cueing using a self-implemented method.

The PD gait pattern is characterized by reduced speed, short stride lengths, shuffling steps and, occasionally, freezing episodes. Walking becomes slow with a flexed posture and spontaneous arm swing is reduced, adding to the typical profile of the PD gait pattern.[3] The application of auditory cues to improve gait in persons with PD has been reported. [1,2,4,5,6] Auditory cues have included a metronome,[5,6] and a rhythmic auditory stimulator.[1] The provision of auditory cues to improve gait might be an adjunctive therapy to physical therapy gait training in persons with PD.

We used a pacing device in this study that is commonly used in sports training for runners and swimmers. The pacer enables swimmers to pace accurately at race-specific swimming speeds.[7] The device is small and can be mounted on a head strap or tucked in a cap whenever a person swims, walks or runs, thus it could easily be used while performing physical activities. Like a metronome, the pacing device emits a steady auditory beat to match a desired target walking, running, or swimming speed. The pacing device is commercially available and may enhance gait performance in persons with PD similar to its improvement of swimming performance. The application of the commercial pacing device in persons with PD to improve gait has not been reported. The use of the pacing device is clinically appealing because it is easy to handle, portable, and relatively inexpensive.

The aim of this study was to evaluate the effect of a commercial pacing device on gait performance in individuals with PD using a self-administered strategy. We investigated the effect of the pacer on gait parameters after initial application in the laboratory and after self-administration for seven days in the home and community.

METHODS

Subjects

Twenty-one participants (17 males, 4 females) with a diagnosis of idiopathic PD by neurologists who had expertise in PD and Movement Disorders. All subjects received anti-

parkinsonian medications and had no history of brain surgery for treatment of PD. Motor symptoms were assessed with the Hoehn and Yahr scale (HY)[8] and the Unified Parkinson's Disease Rating Scale (UPDRS).[9] Subjects were in HY stages 2 or 3 and were able to ambulate independently. They were recruited from the Michael E DeBakey Veterans Affairs Medical Center Parkinson's Disease Research, Education, and Clinical Center (PADRECC) and the Houston area. The study was approved by the Institutional Review Board for Human Subject Research for Baylor College of Medicine and Affiliated Hospitals.

Procedures

Subjects were tested following administration of their routine dose of anti-parkinsonian medications and during the period when subjects reported that their medication was at its most effective (clinical "on" state). All subjects were rated as at least a 2 (moderate difficulty, but requires little or no assistance) on the gait item of the UPDRS and at least a 1 (rare freezing when walking; may have start hesitation) on the freezing item of the UPDRS. Each subject received an explanation of all procedures and read and signed a consent form. Their cognitive status was screened by using the Mini Mental State Exam. A score of 24 or higher was required to participate.[10] The range of MMSE scores in this sample was from 25 to 30. Age, height, weight, duration of disease and motor score of the UPDRS were recorded.

Immediate effect of the pacer—For the baseline control condition (walking without the pacer), the subject was asked to walk at his/her preferred speed with any assistive device necessary on an instrumented, 3 m walkway (GAITRite, CIR Systems Inc., Havertown, PA) while the subject was guarded by a physical therapist to prevent falls. The patient completed 2 trials on the walkway and the average of the 2 trials was used in data analysis. In order to reduce acceleration and deceleration effects, the subject was asked to start a few steps before the gait recording began and continue walking a few steps beyond the walkway. Then, the subject was asked to walk again while wearing the pacer, which had been set at a rate 25% faster than the preferred pace.[6, 11] Gait at the preferred speed was always performed first to prevent the preferred cadence from being influenced by the pacer.

For each subject, a pacer rate of 25% faster than the preferred cadence was calculated based on the average of two trials at the subject's preferred speed. For example, if a subject walked at a cadence of 60 steps/min, which is equal to 1.00 sec/step, the pacer rate would be set to get a cadence of 75 (60 + 15) steps/min, which is equal to 0.80 (60/75) sec/step. Then, the pacer would be set to give a single beat every 0.80 sec. They were instructed to "Try to match your step with the pacer beat as much as possible" and were given a few minutes to get comfortable walking with the pacer before the gait record on the instrumented walkway. A short rest was given between the two trials and the two conditions if requested by the subject.

Self-administration of the pacer—All subjects were given a pacer to wear while walking at home for one week, and were asked to come back for follow-up gait measures. They were given written instructions on how to use the pacer as well as the oral instructions. The subjects were asked to turn the pacer on whenever they walked with the pacer for

approximately 30 minutes a day for seven days. The frequency of the pacer was set in the lab and subjects were instructed not to change the frequency. Phone contacts were made to assure compliance of each participant. After one week, the subject's gait was again measured in the laboratory on the GAITRite under two conditions--with and without the pacer when the subject indicated peak response to antiparkinsonian medications. On the testing day, subjects came to the lab for gait measure without using the pacer. They were asked to walk at their preferred speed without the pacer for two trials. After a few minutes of rest, the pacer was set to the same rate as was used during the initial testing and home use and the subjects were asked to walk with the pacer for two trials.

Instruments

The UPDRS and the modified HY scale were used to assess the symptomatic stage of parkinsonism. Cognitive performance was measured by the Mini Mental State Exam (MMSE).[10] The GAITRite system (GAITRite, CIR Systems Inc., Havertown, PA) was used to record gait characteristics.[12]

The auditory pacer—The auditory pacer is a round, light, electronic device with a diameter of 4 centimeters (Tempo Trainer, Finis Inc., Levermore, CA). It gives an audible sound with which to match the frequency of stepping. The frequency rate of the single beep can be adjusted in hundredths of a second from 0.20 seconds to 9.99 seconds by using two buttons in front of the pacer. This allows the pacer rate to be set for a range of 6 to 300 beeps per minute. The rate is digitally displayed in a small panel above the two buttons. A plastic clip is attached at the back of the pacer, which enables the user to clip the unit onto a cap, a head band, or a shirt collar. The cost of the pacer was $30.00 at the time of this writing.

Self-report questionnaire—All subjects were asked to complete a short questionnaire regarding their impressions about using the pacing device.

DATA ANALYSIS

All analyses were done using SPSS version 15.0. Planned comparisons with Bonferroni correction were used to compare significant differences in the dependent variables for gait performance. Two planned paired comparisons using *t*-tests were performed: 1) the initial walk without the pacer versus the initial walk with the pacer and 2) the initial walk without the pacer versus the post-one- week walk without the pacer. Our variables of interest for gait performance were gait speed (cm/s), cadence (steps/min), stride length (cm), double support time (% of the gait cycle time) and base of support (cm). Significance was set at $p \leq 0.05$.

RESULTS

Subject Demographic—Our sample consisted of 17 men and 4 women with PD. Mean age of the study sample was 72.00 (10.35) years. The mean of the UPDRS motor score was 35.57 (7.89). The average HY stage was 2.69 (0.43). The time since diagnosis was 6.60 (4.33) years. The average height was 173.93 (12.92) cm. The average weight was 76.27 (15.38) kg. The average body mass index (BMI) of the subjects was 25.17 (4.45) kg/m^2. The average MMSE score was 26.86 (2.06).

Immediate effect of the pacer—Displayed in Table 1 are the average cadence and the average pacer rate used in the study. During the initial visit, walking with the pacer increased gait speed ($t = 4.68$; $p<.0005$) and stride length ($t = 2.76$; $p=.012$) when compared to the usual walk at the preferred speed. There was no trial effect on gait speed or cadence when compared between two identical trials ($t = 1.76$, $p = .095$ and $t = .663$, $p = .515$; for gait speed and cadence, respectively).

Presented in Table 2 are the immediate effects of the pacer on gait performance including gait speed, cadence, stride length, double support time and base of support during the initial visit.

The effect of the self-administration of the pacer for one week—After using the pacer for one week, while walking without the pacer at the follow-up visit, gait speed ($t = 6.66$; $p<.0005$) and stride length ($t = 3.99$; $p=.001$) improved significantly. Double support time of the gait cycle ($t = 2.63$; $p=.016$) decreased significantly when compared to the usual walking parameters obtained at the initial visit. Cadence and base of support did not show significant change ($t= 1.514$, $p = .146$; $t = .949$, $p = .354$, respectively). Shown in Table 2 are the effects of the pacer on gait performance including gait speed, cadence, stride length, double support time, base of support and changes of score after one week of self-administration.

Responses to self- report questionnaire—Most subjects reported that they walked faster while wearing the pacer (Table 3). Ninety percent reported that the pacer was either very or somewhat helpful with their walking. The majority of the subjects indicated that the frequency of the pacer was suitable for their walking. Most of them reported that it was either very or somewhat easy to apply the pacer. Over three-fourths of them felt very comfortable while wearing the pacer. More than one-quarter reported that they were very likely to use the pacer for their walking if they owned it and nearly another half of the subjects reported that they would be somewhat likely to use it. Over all, most subjects reported that they felt the pacer helped with their walking.

DISCUSSION

This study demonstrated the feasibility of self-application of an auditory cue as a rehabilitation technique to improve gait in persons with PD. Both the immediate effect and the effect after one week of self-administration were studied.

The immediate effect of the pacer on gait performance—The results showed that the auditory pacer immediately improved gait performance in patients with PD. Increasing the rate of rhythmic auditory cues can elevate the cadence of walking in parkinsonian patients.[13,14] Previous studies demonstrated that 5%, 7.5%, 10%, 15%, and 25% increments in the auditory cue based on the pace of the usual walk increased gait speed in persons with PD.[5,6,11,15] We selected a pace that was 25% faster than the preferred gait speed of the subjects in order to maximize the possible effect size. Consistent with earlier studies, gait speed, cadence, and stride length in our subjects improved with the auditory pacer. In studies that investigated single sessions, rhythmic auditory cues have been associated with increases

in gait speed,[2,6,15,16] cadence,[2,6,15] and stride length.[1,16] An auditory cue provided by a metronome beat 25% faster than normal gait cadence improved gait speed in individuals with PD significantly while the subjects were “off” medication. The improvement of gait speed was approximately 28%.[11] From our results, the pacer set at the rate of 25% faster than the preferred speed immediately improved the gait speed significantly by approximately 18%, cadence by 6%, and stride length by 9% while the subjects were “on” medication. The discrepancy in percentage improvement (18% vs. 28%) between “on” and “off” medications can probably be attributed to the difference in gait speed during baseline conditions. Gait speed during “off” medication has been found to be slower than gait speed during “on” medication.[17]

Cadence did not increase immediately with pacer cueing at 25% faster rate than a preferred cadence. This experiment was a test for immediate effect of auditory cueing on gait patterns. The results showed that on average, subjects were not able to synchronize their cadence with the pacer by increasing their step frequency. The average pacer rate at 25% faster than the preferred cadence of the sample was 128.60 (14.18) steps/min, whereas the average cadence when wearing the pacer at the initial visit was 109.22 (10.23) steps/min. The increase in stride length when wearing the pacer suggested that subjects made longer steps when walking with the pacer. Our instruction was only ‘Try to match your steps with the pacer beats’. We did not instruct them to make longer steps or to step faster. Our results did not demonstrate that the subjects were able to synchronize their cadence with the pacer.

Normally, gait speed can be increased by either walking with a higher step frequency (i.e. increased cadence) or with longer stride lengths.[18] The immediate increase in gait speed when using the pacer in the present study appeared to be from an increase in stride length more than from an increase in cadence. The percentage of increase in cadence was lower than the percentage of increase in the stride length (6% vs. 9%). The immediate improvement in gait speed when using the pacer was in agreement with the results from previous studies that were done in laboratory settings and used other kinds of auditory cues (i.e. electronic metronome, a rhythmic auditory stimulation).[1,6,13,15]

The effect of the self-administration of the pacer on gait performance—In previous studies, long-term training with an auditory cue has been reported to be beneficial in persons with PD. After 3 weeks of home-based training under clinician supervision, subjects improved gait speed by 25%, cadence by 10%, and stride length by 12% compared to a control group who self-trained without the cue.[1] Our results showed increases in gait speed and stride length after self-administration with a pacer for one week. Thaut et al. reported a significant increase in gait speed, cadence, and stride length in subjects who had a daily, home-based gait-training program with rhythmic auditory stimulation of 1–2 Hz for three weeks compared to baseline before the training.[1] However, in our study, after one week, cadence was not different from baseline. Poor gait performance in persons with PD is directly attributable to an inability to internally generate sufficiently large steps.[19] Our results suggest that the subjects modified stride length as a compensatory mechanism instead of modulation of cadence after one week of self-walking with the pacer. Application of cues should preferably be aimed at enlarging the patient’s stride length to have a maximum impact on normalizing parkinsonian gait.[19, 20]

Gait speed, cadence, and step length were increased when using the pacer, and moved toward normative values from age-matched subjects walking at their normal speed. [18] These gait parameters were better than norms for a slow walk, but they were worse than norms for walking at the preferred speed.[18] Our findings are in agreement with earlier work, showing that the potential to generate a normal stepping pattern is not lost in persons with PD.[19] A more normal gait pattern can be elicited in persons with PD by applying external cues.

Cubo et al. studied the effect of auditory cues on freezing-of-gait problems and reported no effect. Nine patients walked with an audiocassette with a metronome recording daily for 1 week. Their freezing remained unimproved.[21] In the present study, two of our participants reported a reduction in the number of freezing episodes during the one week of walking with the pacer, but this was not systematically assessed.

Limitations—There are a number of limitations of the study, which need to be addressed. There was no control group with randomization to compare with the pacer group. We used only one frequency of the auditory pacer per subject and the device was used for only for one week. We do not know whether different frequencies or longer use would help maintain the gains made during one week, further improve gait parameters over time, or possibly even result in decreased gait performance. This self-application strategy needs to be evaluated more thoroughly in a randomized study with a sample size per group of approximately 9 subjects to demonstrate a reasonable effect on gait speed (power = .80, Cohen's *d* effect size of 1.56), 19 subjects to demonstrate a reasonable effect on stride length (power = .80, Cohen's *d* effect size of 0.97), 45 subjects to demonstrate a reasonable effect on double support time (power = .80, Cohen's *d* effect size of 0.60), and 100 subjects to demonstrate a reasonable effect on cadence (power = .80, Cohen's *d* effect size of 0.44).

The participants were instructed to turn the pacer on whenever they walked as a daily, self-implemented method for approximately 30 minutes a day. Mobility is best trained when persons with PD are at their best response to anti-parkinsonian medications. This study did not take into account the proportion of walking time during the one-week home trial done with the pacer when the participants had their best motor response to the medications. Therefore, the beneficial gains from using the pacer achieved by each individual might not have been maximized every day. There also might have been a positive effect as a result of being in the study, thus increasing attentional strategies on walking during the one-week study period by the participants themselves.

Acknowledgments

This work was supported by the National Institute on Disability and Rehabilitation Research (NIDRR) Grant # H133P020003-05. We thank the Michael E. DeBakey Veterans Affairs Medical Center (MEDVAMC) Parkinson's Disease Research, Education, and Clinical Center (PADRECC) staffs, and the Houston Area Parkinson Society (HAPS) for their cooperation in the recruitment of the participants.

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Clinical messages

- The simple pacer evaluated in this study was shown to increase step length and gait speed, but not cadence, after one week of self-administration.
- More than three-fourths of the subjects reported that the pacer was easy to use and helped with their walking.

TABLE 1

Cadence and Rate of Pacer Cueing (steps/min)

	Mean (SD)
Average Initial Cadence without pacer	102.88 (11.34)
Average Pacer Rate Setting	128.60 (14.18)
Average Initial Cadence with pacer	109.22 (10.23)
Average Post-One-Week Cadence without pacer	106.72 (7.57)

TABLE 2

Comparison of Gait Performance Before and After One Week of Walking with the Pacer

	Initial			Post One Week			Score Change[&]
N = 21	**W/O pacer Mean (SD)**	**W/Pacer**	**p-value**	**W/O pacer**	**W/Pacer**	**p-value**	
Gait speed (cm/s)	79.57 (18.13)	94.02 (22.61)	<.0005[*]	95.20 (22.23)	102.17 (30.23)	<.0005[#]	15.55 (10.76)
Cadence (step/min)	102.88 (11.34)	109.22 (10.23)	.036	106.72 (7.57)	120.46 (35.06	.146	3.84 (11.63)
Stride Length (cm)	94.33 (21.31)	103.5 (22.65)	.012[*]	107.67 (20.01)	102.76 (19.66)	.001[#]	13.33 (15.29)
Double support time (% GC) [a]	21.73 (5.23)	21.19 (4.15)	.582	18.94 (3.59)	21.06 (6.35)	.016[#]	−2.79 (4.87)
Base of Support (cm)	12.25 (5.31)	12.47 (5.03)	.69	11.78 (5.26)	11.95 (4.83)	.354	−0.47 (2.31)

[a]Double support time expressed as percentage of the gait cycle time (% GC).

[*]Pre W/O pacer vs. W pacer, significant at .025 with Bonferroni correction.

[#]Pre W/O pacer vs. Post one week W/O pacer.

[&]Change score over one week was calculated from scores changes between initial w/o pacer and post one week w/o pacer.

TABLE 3

Responses to Self-Report Questionnaire

Questions	Number	Percent
Did you walk faster while wearing the sound cueing device?		
Yes	18	85.7
No	3	14.3
How well did the sound cueing device help with your walking?		
Very helpful	5	23.8
Somewhat helpful	14	66.7
Not helpful	2	9.5
Was the frequency of the sound cueing device too fast/too slow for you?		
Too fast	0	0
Too slow	4	19.0
Suitable	17	81.0
How easy was it for you to apply the sound cueing device?		
Very easy	8	38.1
Somewhat easy	11	52.4
Somewhat difficult	1	4.8
Very difficult	1	4.8
Were you comfortable while wearing the sound cueing device?		
Very comfortable	16	76.2
Not very comfortable	5	23.8
Very uncomfortable	0	0
If you owned the sound cueing device how likely would you be to use it for your walking?		
Very unlikely	5	23.8
Somewhat likely	10	47.6
Very likely	6	28.6
Over all, do you feel that the sound cueing device helps with your walking?		
Yes	18	85.7
No	3	14.3