Asian Biomedicine Vol. 5 No. 5 October 2011; 649-654 DOI: 10.5372/1905-7415.0505.086

**Original article**

# Treadmill training with music cueing: a new approach for Parkinson's gait facilitation

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***Background:*** It has been pointed that cueing techniques may have influence upon gait training in Parkinson's disease (PD).
***Objective:*** Study the effects of music cue on treadmill training in PD patients.
***Subject and methods:*** A randomized single-blind controlled trial was conducted. Thirty male PD patients, aged 60 to 80 years with Hoehn and Yahr stage 2-3 were allocated into three groups (each 10 patients). Group A: treadmill with music three days and home walking three days/week, Group B: treadmill three days and home walking three days/week, and Group C: home walking six days/week. Each group received four weeks training followed by self-practice for other four weeks. Gait performances at pre-program, fourth, and eighth week were compared.
***Results:*** The results showed that A, B, and C, stride length gained 12%, 5.2%, and 6.7% (p=0.042), walking-speed gained 8.6%, 6.5%, and -2.4%, six-minute walk distance gained 10.2%, 5.4%, and 2.9%, and Timed Up and Go (TUG) gained 14.2%, 12.5%, and 7.6%.
***Conclusion:*** Music cue enhanced gait training in mild to moderate PD patients.

***Keywords***: Cueing technique, music cue, Parkinson's disease, treadmill training

Parkinson's disease (PD) is an important cause of chronic disabilities in the elderly. Abnormal gait, hypokinesia, balance impairment, and slow reaction time lead to risk of falling. Rehabilitation is essential for restoring function, improving quality of life, and preventing complications for these patients [1-3]. The core components include physical therapy exercise programs, activities of daily living and coordination training. The management principles for ambulation training are daily stretching exercise to maintain proper posture and flexibility, gait and balance training to reduce the fall risk. However, walking ability and response to training are limited by the disease's impact upon the motor system that progressively worsens with the degree of disease severity and advanced age [4]. Therefore, rehabilitation program should be introduced as early as possible, followed by long-term maintenance program, for maximizing functional outcomes and minimizing complications.

Regarding the gait training, treadmill is the most used equipment. Previous studies reported the effectiveness of treadmill training in PD as increasing in step length, speed, cadence, balance, and quality of life [5-7]. Most studies recommended four to six weeks of hospital-based training course, which may be inconvenient to attend and maintain in long-term.

During the last two decades, cueing techniques for neurorehabilitation have been introduced. Sensory cues via visual, auditory, and somatosensory pathways were used to guide regular pace and increase walking speed [8]. These beneficial effects were shown in both short-term [9-13] and long-term [14-16]. In this study, we developed a new technique of gait training for PD patients by using music cueing with treadmill. We proposed that, appropriate rhythmic music could enhance the treadmill effects, and in addition, could carry on the same regular pace when practiced during a home walk program.

This article was presented at the 6th World Congress of Neurorehabilitation at Vienna, Austria, March 21- 25, 2010.

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## Methods

Preliminary study of a randomized single blind controlled trial was conducted at the Department of Rehabilitation Medicine, King Chulalongkorn Memorial Hospital between October 2008 and July 2009. This study was approved by the Ethics Committee of the Faculty of Medicine, Chulalongkorn University.

PD patients were recruited from Chulalongkorn Comprehensive Movement Disorders Center, King Chulalongkorn Memorial Hospital. Only male patients were enrolled. The inclusion criteria were male PD patients aged 60 to 80 years diagnosed by neurologists as idiopathic PD, Hoehn and Yahr stage 2-3, with good cognitive function on Thai Mental State Examination (TMSE) score >23 [17], stable symptoms with unmodified anti-parkinsonian medication throughout the study, independent walking without using any gait aids. Furthermore, patients should have no other medical conditions that could interfere with the training program and did not participate in any training program during the previous two months. Finally, good vision and hearing was required to ensure that the patient could follow the program.

The patients were allocated into three training groups (each 10 patients) as follows.

**Group A**: treadmill with music cue three days/ week and home walking program three days/week.

**Group B**: treadmill training three days/week and home walking program three days/week.

**Group C**: home walking program six days/week.

If the PD patients attended less than 80% of the training course, or their medication was changed during the study, they would be excluded from the study. When completing the four-week training program, the participants were assessed for the second time. Then they were assigned to practice home program for another four weeks, and the assessments were done again after the end of the eighth week. Fall incidence was also recorded at every follow-up appointment.

In each group, all participants were instructed to practice stretching exercise, breathing exercise, and balance training.

All participants were assessed by two physicians and one research assistant, who were blinded to group assignment. The assessments were performed during "on" state of each patient, in the same time of day as follows.

1) Interviewed on medical history including fall(s) within the past six months.

2) Assessed gait and balance performance with Timed Up and Go test (TUG) [18], Expanded Timed Up and Go test (ETUG) [19], single leg stance test (SLST), and six-minute walk test (6-MWT). The TUG, ETUG, and SLST were performed for three times in each participant, the means and standard deviations (SD) of measured parameters were calculated. The 6-MWT was performed once along the 20-meter hall way.

3) Step length and stride length during the patients' preferred comfortable speed were identified from six-meter walking sections of the 10-meter path in ETUG test. These were determined by strapping a small color marker at the center of each shoe heel, and covering the 6-meter walking way with paper. After ETUG test, the distances between color dots stamped on the paper were measured. The distance between color dots from right and left foot=step length, between the same foot of one gait cycle=stride length. Step lengths and stride lengths from four gait cycles were measured and calculated for mean and SD.

4) Walking speed was calculated from the time spent during 6-meter walking sections of the ETUG test.

5) The mean walking speed and step length were used to calculate step frequency (cadence).

### *Training program*

*Treadmill training*: the program started with 10 minutes of stretching exercise, followed by 20-minute treadmill walking. On the treadmill, participants were instructed to take long steps at their preferred speed. After getting familiar with the treadmill, the speed would be gradually raised about 5%-10% to the point where the participants could still regularly step without difficulties or developing gait deviations.

*Music cue*: five relaxing green music pieces were chosen and modified (stretching or retracting) into different rhythmic frequencies by using a music computer program manager. As for group A, after treadmill speed was set, the step frequency would be identified by adjustable electrical metronome. The prepared music with the same rhythmic frequency was chosen. Then the participants were trained to walk synchronized with the matched music rhythm on the treadmill. This music would be recorded in MP3 for the participants to take home and listen during their home practice.

*Home program*: the home program consisted of 10-minute stretching exercise, and 20-minute walking. Stretching handbook and walking diary were used as a program monitoring tool.

***Statistical analysis***

Main gait parameters (step length, stride length, cadence, and walking speed) are the primary outcomes, and the results of balance performance tests, and walking endurance are secondary outcomes. All data were analyzed with SPSS software for Windows version 17. Continuous data were expressed as means±SD. The categorical data were presented in frequencies and percentages as appropriate. The outcome measures were compared within group with repeated measures for analysis of variance (ANOVA), and compared between groups with analysis of covariance (ANCOVA). Statistical significance was accepted at $p < 0.05$.

## Results

Thirty patients completed the assignment without any adverse event. The three groups had similar demographic and medical characteristics at baseline as shown in **Table 1**.

All patients in groups **A** and **B** could appropriately walk on the treadmill within the first or second session. They were adjusted to walk with the speed slightly higher than their comfortable ground speed, but with longer step and lower cadence. Most frequently used cadences on the treadmill were around 80-100 steps/minute. Gait performances at baseline, at fourth week and at eighth week are shown in **Table 2.**

Repeated measures ANOVA analysis revealed significant improvement of step length and stride length only in group A. Compared between groups with ANCOVA analysis, group **A** gained step length and stride length more than group **B** and **C** at p=0.037 and 0.042, respectively. Interestingly, these improvements still maintained to the end of the eighth week.

From start through the 8$^{th}$ week, walking speed increased without change of the cadence. Six-meter walking time significantly improved in group **A** ($p < 0.001$) and group **B** (p=0.029). Calculating walking time into walking speed, the increasing speeds of both groups did not show statistical significance (p=0.06). The six-minute walking distance also increased more in group **A**, but without significant difference between groups. Balance function assessed by TUG test improved in group **A** and **B** more than group **C** at fourth week (p=0.039). Static balance test with SLST slightly improved without statistical significance.

During the study, one patient in group **A** fell at home. The fall took place in his bedroom while he was turning backward. No injuries resulted from the accident and the patient could complete the assigned program.

**Table 1.** Characteristics of the patients displayed in mean±SD, number, and percent

| Characteristics | Group A (Treadmill+music) | Group B (Treadmill) | Group C (Home program) |
|---|---|---|---|
| Age (year) | 67.1±4.0 | 67.9±6.3 | 68.6±5.2 |
| Height (meter) | 1.63±0.06 | 1.63±0.05 | 1.60±0.03 |
| Body mass index (kg/m$^2$) | 24.5±2.8 | 24.5±4.5 | 22.7±3.3 |
| Thai Mental State | 28.0±1.3 | 28.6±0.9 | 27.9±1.6 |
| Examination PD onset (year) | 3.7±4.1 | 7.4±3.4 | 4.4±2.3 |
| Hoehn and Yahr stage (2:2.5:3) | 7:1:2 | 5:0:5 | 9:0:1 |
| ***Gait and balance parameters*** | | | |
| Step length (cm) | 62.2±7.3 | 62.6±11.5 | 59.1±7.3 |
| Stride length (cm) | 124.3±15.0 | 125.1±23.0 | 117.8±14.1 |
| Cadence (step/minute) | 116.1±10.0 | 114.4±12.8 | 118.8±11.3 |
| 6-meter walk time (sec) | 5.0±0.4 | 5.2±1.0 | 5.4±0.9 |
| Walking speed (m/s) | 1.24±0.20 | 1.18±0.21 | 1.16±0.21 |
| Six-minute walk test (m) | 426.6±110.9 | 426.8±90.1 | 449.3±107.5 |
| Timed up and go (second) | 11.2±1.8 | 12.1±2.8 | 12.0±2.1 |
| Right single leg stance (second) | 21.1±21.4 | 31.6±26.4 | 24.0±17.6 |
| Left single leg stance (second) | 13.1±8.2 | 15.4±11.6 | 24.9±22.5 |
| ***Fall within 6 months:number (%)*** | 2 (20%) | 1 (10%) | 3 (30%) |

**Table 2.** Comparisons of mean±SD of walking parameters at baseline, 4th week, and 8th week

| | Group A (Treadmill+music) | Group B (Treadmill) | Group C (Home program) | P-value |
|---|---|---|---|---|
| ***Step length (cm)*** | | | | |
| Baseline | 62.2±7.3 | 62.6±11.4 | 59.1±7.3 | |
| 4th week | 69.1±7.7* | 66.7±12.2 | 61.7±7.7 | 0.169 |
| 8th week | 69.6±5.8** | 65.7±9.1 | 63.1±6.4 | 0.037[a,b] |
| ***Stride length (cm)*** | | | | |
| Baseline | 124.3±14.9 | 125.1±23.0 | 117.8±14.1 | |
| 4th week | 138.2±15.7* | 133.3±24.5 | 123.3±15.4 | 0.165 |
| 8th week | 139.2±11.6** | 131.6±18.0 | 125.6±14.1 | 0.042[a,b] |
| ***Cadence (step/minute)*** | | | | |
| Baseline | 116.1±10.0 | 114.4±12.7 | 118.8±11.3 | |
| 4th week | 116.1±10.3 | 115.1±14.6 | 114.6±8.4 | 0.366 |
| 8th week | 120.7±15.0 | 115.4±8.5 | 117.3±6.7 | 0.426 |
| ***6-meter walk time (second)*** | | | | |
| Baseline | 5.0±0.41 | 5.2±0.97 | 5.4±0.89 | |
| 4th week | 4.5±0.60* | 4.9±0.90* | 5.2±0.63 | 0.155 |
| 8th week | 4.5±0.34** | 4.8±0.69** | 4.9±0.53 | 0.131 |
| ***Speed (m/sec)*** | | | | |
| Baseline | 1.24±0.20 | 1.18±0.21 | 1.16±0.20 | |
| 4th week | 1.29±0.15 | 1.27±0.23 | 1.17±0.14 | 0.259 |
| 8th week | 1.35±0.09 | 1.26±0.17 | 1.13±0.40 | 0.283 |
| ***6-minute walk distance (m)*** | | | | |
| Baseline | 426.6±110.9 | 426.8±90.1 | 449.3±107.5 | |
| 4th week | 453.0±55.5 | 459.0±93.4* | 455.3±112.4 | 0.662 |
| 8th week | 470.2±49.6 | 449.9±90.3** | 462.3±103.8 | 0.561 |
| ***Timed up and go (second)*** | | | | |
| Baseline | 11.2±1.8 | 12.1±2.8 | 12.0±2.1 | 0.620 |
| 4th week | 10.0±0.7 | 10.8±2.1* | 11.8±2.1 | 0.039[b,c] |
| 8th week | 9. 6±0.8** | 10.6±1.5** | 11.1±2.4**,+ | 0.177 |

Significance between groups, a: Group **A** *vs.* Group **B**, b: Group **A** *vs.* Group **C**, **C**: Group **B** *vs.* Group **C**.
Significance within group, *Baseline *vs.* 4th week, **Baseline *vs.* 8th week, + 4th week *vs.* 8th week.

## Discussion

The present gait and balance performances of the PD patients were lower than those in the healthy older male population and the fall rate was higher [20]. These findings confirmed the impacts of PD upon walking function and fall rate.

Morris et al. [21] postulated that the abnormal gait resulted from the defect of higher center in regulating normal step length, while the ability to adjust step frequency was still intact. The patient's attempt to maintain normal speed without ability to take longer steps may result in the increase in cadence. When the patients focus on walking with longer steps, their cadences decrease. This attentional strategy depends on the patient's cognitive function, which requires considerable effort and is difficult to maintain for a longer period. Therefore, in our study, external cues were introduced to help modulating gait pattern by bypassing the basal ganglia pathway. Despite few randomized clinical trials [9, 14-16], auditory cue seems to show most effective, possibly via the lateral premotor cortex [8]. Previous studies used metronome and rhythmic musical instruments to guide pacing [14, 16]. We aimed to develop a new gait training technique, using music cue to facilitate treadmill walking for PD patients. It was our strategy to instruct longer steps on the treadmill, maintaining proper steps with musical rhythm and continue walking with music at home.

Treadmill functioned as an external motor cue to control regular steps during gait training [5]. Herman et al. [6] assigned a 30-minute session x 4 sessions/

week of 6-week intensive treadmill training for mild to moderate PD patients, and reported 6.8% gained in stride length, and 13.5% gained in walking speed. Our study used only 20-minute session of treadmill walking x 3 sessions/ week x 4 weeks, with additional home practice program. The increment of treadmill speed was adjusted based on each patient's ability in walking adaptation to the treadmill. The preferred speed for the patients to maintain appropriate large steps without difficulties were assigned individually. Therefore, the protocol was equivalent to low-level aerobic training.

After four weeks, the treadmill group (group **B**) gained 6.5% in stride length, which was comparable with the six-week intensive program, while the treadmill with music cue group gained 11.2% stride length and 4.3% speed. These findings reflected the effectiveness of our program on stride length more than speed. The less speed gain resulted from the lower intensity and shorter duration of treadmill training. However, after another four-week walking at home, group **A** continued improving their walking speed to +8.6%, while group **B** and **C** slightly declined from their previously gained speed.

Group **A** improved the most, probably because of the synergistic effect of motor (treadmill) and auditory (music) cue, while group **B** received only motor cue with occasional verbal instruction. In addition, group **A** used music cue during home walking. The unchanged cadence reflected that PD patients could successfully walk with preferred speed by increasing step length without changing step frequency.

Evidence indicates that dual tasks could interfere with the functional performance and gait in PD [22]. Recently, Baker et al. [23] reported equal effectiveness of attentional strategy alone and the combination of rhythmic auditory cue and attentional strategy. Our program of combined motor and auditory cues might interfere with gait pattern in PD patients. Impressively, our patients, even though none ever walked on a treadmill, could follow the music-treadmill training without difficulties. Compared with metronome, though the metronome is more convenient in application, the sound of music has therapeutic effects more than tempo cueing alone. This was also demonstrated by Styns et al. [24], which reported that people could walk with music rhythm faster than on metronome stimuli. Human brain has a high level of music integration in the premotor cortex via auditory-motor interactions [25]. Even with limited explanations, music therapy has been practiced in many areas of medicine for a long time. Pacchetti et al. [26] used active music therapy for PD as choral singing, free body exercise, and integrating with specific task including gait and balance. Their studies revealed music effectiveness on motor and behavioral outcomes. Satoh et al. [27] used mental singing while walking as a cueing strategy. The positive results supported the usefulness of music in walking facilitation. Our study simply used music as pace guidance, which resulted in enhancement effects of music on treadmill training. In addition, music brings relaxation and promotes positive emotions, which is another important area of deficit in PD.

In addition to improving in dynamic balance, a low fall rate during the study confirmed the safety of our program. However, inadequate time for follow-up limited interpretation of the program effects on fall risk reduction.

In conclusion, application of rhythmic music as an additional auditory cue could enhance treadmill-training effects on gait and balance performance in early PD patients. Treadmill walking with music cueing may be another alternative method for gait training, with advantages in less OPD sessions, and more potential in improving mood and adherence.

## Acknowledgement

This study was supported by the Ratchadapiseksompotch Fund, Faculty of Medicine, Chulalongkorn University. There is no potential conflicts of interest involve in the study.

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