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Rehabilitation Treatment of Gait in Patients with Parkinson's Disease with Freezing: A Comparison Between Two Physical Therapy Protocols Using Visual and Auditory Cues with or Without Treadmill Training

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Abstract: Freezing is a disabling symptom in patients with Parkinson's disease. We investigated the effectiveness of a new rehabilitation strategy based on treadmill training associated with auditory and visual cues. Forty Parkinsonian patients with freezing were randomly assigned to two groups: Group 1 underwent a rehabilitation program based on treadmill training associated with auditory and visual cues, while Group 2 followed a rehabilitation protocol using cues and not associated with treadmill. Functional evaluation was based on the Unified Parkinson's Disease Rating Scale Motor Section (UPDRS III), Freezing of Gait Questionnaire (FOGQ), 6-minute walking test (6MWT), gait speed, and stride cycle. Patients in both the groups had significant improvements in all variables considered by the end of the rehabilitation program (all $P = 0.0001$). Patients treated with the protocol including treadmill, had more improvement than patients in Group 2 in most functional indicators ($P = 0.007$, $P = 0.0004$, $P = 0.0126$, and $P = 0.0263$ for FOGQ, 6MWT, gait speed, stride cycle, respectively). The most striking result was obtained for 6MWT, with a mean increase of 130 m in Group 1 compared with 57 m in Group 2. Our results suggest that treadmill training associated with auditory and visual cues might give better results than more conventional treatments. Treadmill training probably acts as a supplementary external cue. © 2009 Movement Disorder Society

Key words: Parkinson's disease; freezing; rehabilitation; treadmill training

Parkinson's disease is a neurodegenerative disorder due to the depletion of dopamine in the basal ganglia, with progressive reduction in the speed and amplitude of movements. Freezing of gait is a disorder in which patients are unable to initiate or continue locomotion. This phenomenon is frequent in patients with Parkinson's disease and can be very disabling because it impairs mobility and restricts independence. Freezing is one of the causes of falls in patients with Parkinson's disease and occurs in various situations: when starting to walk, during turning, when approaching a narrow space, and just before reaching destination.

The freezing phenomenon is very difficult to treat. The pharmacological treatment is usually disappointing: whereas patients with freezing in "off" states can gain benefit from an increase in levodopa dosage, this was not observed in patients with freezing in "on" states.[1,2]

Rehabilitation is a possible treatment for gait disorders in patients with Parkinson's disease. Many studies have shown the efficacy of rehabilitation at improving specific impairments and functional limitations in individuals with Parkinson's disease. In particular, they have shown the efficacy of auditory (musical beats) and visual (white lines) cues.[3-7] Treadmill training, with or without partial body-weight support, also seems promising in the restoration of gait patterns.[8-10]

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However, there are no published studies on the use of treadmill training in association with auditory or visual cues. We, therefore, developed a rehabilitation protocol for gait disturbances and freezing that uses treadmill training associated with auditory and visual cues.

The aim of this study is to evaluate the efficacy of our protocol and compare its results with those of a traditional rehabilitation protocol using only auditory and visual cues.

PATIENTS AND METHODS

Study Protocol

Forty patients with a diagnosis of "clinically probable" idiopathic Parkinson's disease according to Gelb et al.,[11] admitted to our hospital for rehabilitation treatment, were enrolled into the study. The study was approved by the local Ethical Committee and all subjects gave their written informed consent before participation.

Inclusion criteria were: ability to walk without any physical assistance, visual and hearing capacity sufficient to perceive the cues, freezing of gait at the time of peak medication effect ascertained by clinical examination, Hoehn-Yahr stage 3, no cognitive impairment (mini-mental state examination score >26),[12] stable pharmacological treatment.

Subjects were excluded if they had neurological conditions other than idiopathic Parkinson's disease, postural hypotension, cardiovascular disorders, musculoskeletal disorders, or vestibular dysfunction limiting locomotion or balance.

The same neurologist examined the patients in the morning, one hour after they had taken levodopa, at baseline and at the end of the rehabilitation treatment.

Subjects were randomly assigned into two groups, each composed of 20 patients. Patients in Group 1 underwent a rehabilitation protocol for gait disturbance and freezing that used treadmill training associated with auditory and visual cues. A motorized medical treadmill (Locomotor Training, Biodex, IL) was used. Subjects assigned to this group received training for 20 minutes every day for 4 weeks (28 sessions in all). The patients were observed during treadmill training by a physiatrist. Maximum tolerated walking speed was determined before the training session. This speed was reduced (−40%) and used for a 2-day warm-up period. After that, the belt speed was increased every 3 days by 0.05 stride cycles/second. During the training a visual cue and an auditory cue were used. The visual cue was a target, displayed on a screen that the patient had to reach with the stride. The shapes of right and left feet were shown alternatively on the screen. When the patient's stride fell within the set standard deviation (SD), the footfalls were synchronized with the target shapes and "well done" appeared on the screen. When the stride fell outside the SD, the footfalls and target shapes were out of synchronization and the patient was informed, on the screen, of which footfall was outside of the SD and prompted to take a longer or shorter step with the respective foot. The auditory cue consisted of musical beats synchronized with the visual cues with a frequency of 0.5 c/s.

Patients in Group 2 followed a traditional rehabilitation protocol using only auditory and visual cues. Subjects assigned to this group also received training for 20 minutes every day for 4 weeks (28 sessions in all). The visual cue used during the gait training in this group consisted of lines spaced according to individual stride length. These lines were separated by a further 0.05 m per stride every 3/4 days. The auditory cue was a musical beat with the same frequency as that used for Group 1 (0.5 c/s).

The rating scales used for the clinical evaluation were the Unified Parkinson's Disease Rating Scale Motor Section (UPDRS III)[13] and the Freezing of Gait Questionnaire (FOGQ),[14] which is compiled by the same neurologist at the start and at the end of the rehabilitation program.

Gait was assessed by meters walked during a 6-minute walking test (6MWT), gait speed and stride length. All measurements were performed at the start and at the end of the rehabilitation program. The 6-minute walking test was conducted following a standardized procedure: the patient was first familiarized with the test by letting him/her go once forward and backward along a straight 30-m line on the level in a gymnasium. Then, after 15 minutes rest, he/she was instructed to walk from end to end of the line for 6 minutes and to cover as much distance as possible. No encouragement was offered during the test and no cues were used.

The gait speed and stride length were evaluated using the motorized medical treadmill endowed with four strain gauges under the belt sensitive to the bending of the belt itself caused by the weight applied by the patient walking. These gauges are connected to software that enables an evaluation of the various parameters under investigation. All patients were familiarized with the motorized treadmill before performing the evaluation at the start of the rehabilitation program, while only patients from Group 2 were again familiarized with the treadmill before performing the evaluation at the end of the rehabilitation program. The gait

TABLE 1. *Demographic and clinical characteristics of the patients in Group 1 and Group 2, at baseline and after the rehabilitation program*

	Group 1 baseline	Group 2 baseline	Group 1 after training	Group 2 after training
Age	71 (8)	71 (7)		
Duration of the disease (yr)	13.2 (4.1)	12.9 (4.6)		
Male/female	8/12	9/11		
Levodopa (mg)	685 (246)	720 (232)		
UPDRS III score	21.6 (5.6)	23.6 (5.2)	14.5 (3.7)*	17.8 (4.3)*
FOGQ score	11.6 (3.0)	11.4 (2.4)	6.5 (1.9)*	7.7 (1.8)*
6MWT (m)	221 (89)	226 (70)	351 (125)*	283 (77)*
Speed (m/S)	0.6 (0.2)	0.5 (0.1)	1.0 (0.3)*	0.8 (0.2)*
Stride cycle (cycle/S)	0.6 (0.2)	0.6 (0.1)	0.8 (0.2)*	0.7 (0.1)*

The data are expressed in mean (SD).
*$P \leq 0.0001$ compared with baseline.

speed and stride length of the patients in both groups were evaluated without the use of cues.

Statistical Analysis

Shapiro–Wilk statistic was used to test the normality of the distribution of all variables.

The effect of the rehabilitation strategy on each clinical variable considered was assessed by a two factor analysis of variance: training program (treadmill versus traditional treatment) and time (end of treatment versus baseline), with repeated measures in the time factor.

Within-group comparisons were carried out by paired t-test or by Wilcoxon's matched pairs test in case of violation of the normality assumption. Between group comparisons were carried out by unpaired T-test or by Mann–Whitney U-test if appropriate. Descriptive statistics are given as mean $\pm$ SD. A P value <0.05 was considered statistically significant.

All analyses were carried out using the SAS/STAT statistical package, release 8.02 (SAS Institute Inc., Cary, NC).

RESULTS

There were no drop outs and compliance was good and comparable in both groups.

The demographic and clinical characteristics of Group 1 and Group 2 patients, at baseline and after the rehabilitation program, are reported in Table 1. No statistically significant differences were observed between the two groups in any variable at baseline. The performance of both groups of patients improved significantly by the end of the training program. However, the results achieved by the treadmill treatment (Group 1) were better than those of the traditional rehabilitation protocol (Group 2).

Results from repeated measurements analysis of variance confirmed the overall improvement of all clinical variables in both groups, and showed significant time-treatment effect in favor of the patients in Group 1 in most considered variables ($P = 0.007$, $P = 0.0004$, $P = 0.0126$, and $P = 0.0263$ for FOGQ scores, 6MWT, gait speed, and stride cycle, respectively). No statistically significant time-treatment effect was observed for UPDRS III score ($P = 0.1466$).

Figure 1 is a graphical representation of these results for 6MWT, FOGQ, gait speed, and stride cycle. Differences in treatment effect on a given clinical indicator are reflected by differences in the slope of the lines joining the mean value of the clinical indicator at the baseline and after treatment in the two groups.

DISCUSSION

In this study of patients with Parkinson's disease who underwent two different types of rehabilitation programs, both groups of patients showed a significant improvement of gait and freezing after the rehabilitation treatment. These results are in agreement with those of previous studies on the use of rehabilitation protocols for gait.[10,15-18] However, patients treated with treadmill training and auditory and visual cues (Group 1) had better results at the end of treatment. In particular, patients in Group 1 showed statistically significant better improvements in FOGQ score, distance walked in the 6-minute walking test, gait speed and stride cycle.

Parkinson's disease is due to a depletion of dopamine production in neurons in the basal ganglia of the brain and patients have a disorder in sensory-motor integration.[19] Basal ganglia control the ability to perform well learned motor skills, such as walking and turning around, by sending to the cerebral cortex cues and sets able to regulate the speed and amplitude of movements.[20,21] Because of an imbalance of neurotransmitters in the brain, people with Parkinson's dis-

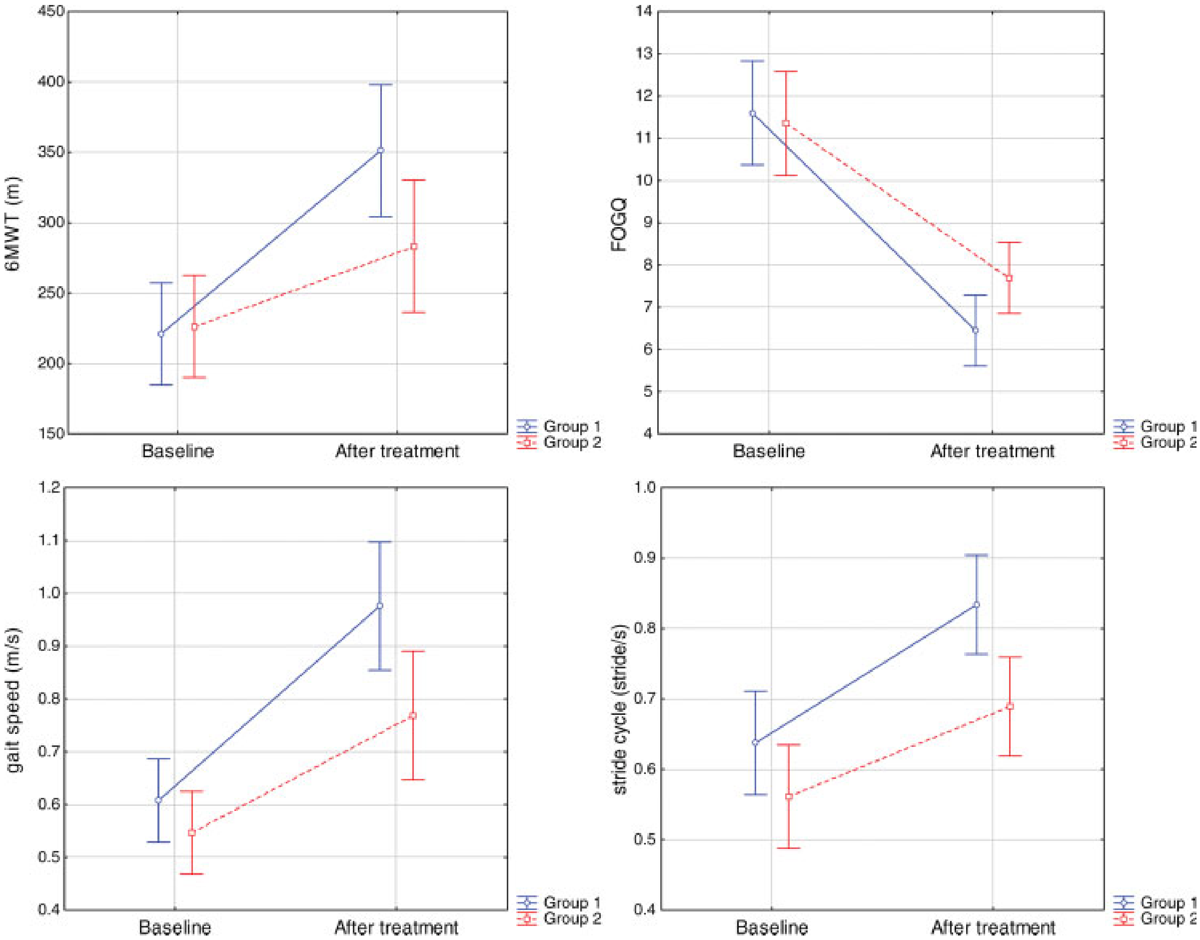

FIG. 1. Graphical representation of time-treatment interaction for the variables 6MWT (top left), FOGQ (top right), gait speed (bottom left), and stride cycle (bottom right). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

ease progressively lose flexibility and adaptability in their locomotor responses and walk with a stereotypical short-stepped, narrow-based shuffling gait. They also experience difficulty in modulating gait parameters in response to tasks demanding changes.[22] Freezing may be a manifestation of a problem with maintenance of the internal gait rhythm.[16,23]

The efficacy of auditory and visual cues in rehabilitation treatment of gait disorders in Parkinson's patients is well known.[4,16,24] The auditory cues provide an external rhythm, which is able to compensate for the defective internal rhythm of the basal ganglia.[25] People with Parkinson's disease do not lose the ability to generate a healthy stepping pattern, but have difficulty in activating the motor control system. Visual cues help to fill in for the motor set deficiency by providing visual data on appropriate stride length.[21] The visual cues generate an optical flow that may activate a cerebellar visual-motor pathway.[26]

In addition, it has been shown that treadmill training is effective in reducing falls and improving gait parameters in patients with Parkinson's disease.[16,17] Finally, Herman and Frenkel-Toledo hypothesize that treadmill training also acts as an external cue, setting the walking pattern and reinforcing neuronal circuits that contribute to gait pacing.[8,27] Several researchers have reported that treadmill training is effective in improving mobility[8-10] and Miyai hypothesized that cortical reorganization, especially in the supplementary motor area, might be a possible mechanism underlying the improvement.[18]

Our data suggest that treadmill training associated with auditory and visual cues can be more effective than conventional treatment with auditory and visual cues alone. Treadmill training probably imposes external pace and focuses attention on gait. In this sense it might act as a supplementary external cue able to improve the efficacy of the traditional auditory and visual cues.[27]

Study Limitations

This study considered only the acute effect of the treadmill rehabilitation protocol, but whether the treatment has prolonged clinical efficacy without the need to change pharmacological treatment remains unexplored. Future studies following a group of patients treated with treadmill training for a suitable period is devised to assess the long-term effects of this rehabilitation protocol.

Finally, it may be questioned whether the better improvement in patients treated with treadmill may be due to the habituation to treadmill walking. We used the software of the motorized treadmill only to evaluate gait speed and stride cycle. It should be noted that the patients treated with treadmill training and auditory and visual cues had better results at the end of treatment with significant improvements also in FOGQ score and that the functional indicator which showed the most impressive improvement was the distance walked in the 6-minute walking test, a result which cannot be attributed to habitual use of a treadmill. Hence, we think that habituation to treadmill walking did not play a relevant role in our results and their interpretation.

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