Resistance Training and Gait Function in Patients with Parkinson’s Disease

ABSTRACT

Objective: To determine whether patients with Parkinson’s disease who are enrolled in a resistance training program can gain strength similar to that of normal control subjects and whether these gains in strength would improve their gait function.

Design: Subjects included 14 patients with mild-to-moderate Parkinson’s disease of either gender and six normal control subjects of similar age. The training consisted of an 8-wk course of resistance training twice per week, focused primarily on the lower limbs. The primary outcome measures consisted of exercise performance monitoring and quantitative gait analysis before and after the training course.

Results: Both the patients with Parkinson’s disease and normal control subjects significantly increased their performance with resistance training. Subjects with Parkinson’s disease had gains in strength similar to those of normal elderly adults. Patients with Parkinson’s disease also had significant gains in stride length, walking velocity, and postural angles compared with pretreatment values.

Conclusions: Patients with mild-to-moderate Parkinson’s disease can obtain increases in performance or strength similar to that of normal adults of the same age in a resistance training program. Resistance training can produce functional improvements in gait and may, therefore, be useful as part of a physical rehabilitation and/or health maintenance program for patients with Parkinson’s disease.

Key Words: Resistance Training, Parkinson’s Disease, Rehabilitation, Gait
Parkinson’s disease (PD) is a neurodegenerative disorder which affects 1 in every 100 people >50 yr old; it is the second most common of the neurodegenerative diseases. The primary symptoms in patients with PD may include a coarse resting tremor in the digits (“pill-rolling tremor”) or other muscles of the limbs and posture, muscular (cogwheel) rigidity, bradykinesia, impaired postural reflexes, and associated disturbances in gait.

The symptoms of PD can be managed well with medication in the earlier stages of the disease. However, with time (5–10 yr), the patients’ symptoms become more difficult to manage with medication and complications of drug therapy become more prevalent. Symptoms continue to progress in severity to the point where patients become completely disabled. A major complication arising from the symptoms are physical injuries, generally resulting from an increasing frequency of falls. Fall-associated injuries such as fractured hips may result in lengthy hospitalization and increased mortality, typically from aspiration pneumonia.

The progression of symptoms in patients with PD is also associated with a deterioration in physical condition, not all of which is strictly related to the disease itself. Elderly persons with PD are characterized by poverty of movement, loss of muscular strength and endurance, and diminished functional capacity. The weakness may arise from various factors associated with the disease including inactivity arising from the basic disability as well as electrophysiologic changes in muscle activation involving alterations of the discharge patterns of muscle units during activation and coactivation of opposing muscle groups. Typically, when these patients become less confident in their coordination, many patients prefer to restrict their activity because of potential injury. This restricted activity results in muscular atrophy, similar to the condition of sedentary elderly individuals. The encouragement of such patients to perform various exercise and avoid the complication of muscle atrophy in addition to the underlying neurologic deficit is the rationale for physical rehabilitation methods in patients with PD.

Resistance training is recognized as a beneficial component of an exercise program designed to improve muscular strength and functional capacity in older adults. Data from intervention studies have demonstrated the beneficial effects of strength training on changes in physiologic variables. Resistance training has also been suggested to be of benefit for persons affected with PD, but it has not been emphasized as a major part of physical treatment. Studies in the application of physical therapy have suggested that strength can be improved in patients with PD, but these studies have not specifically emphasized methods to enhance muscle strength. Studies of electromyographic activity in patients with PD suggest that resistance training may be beneficial, based on the finding that similar appearing patterns (e.g., coactivation) can be ameliorated with resistance training. Resistance training has been shown to be beneficial in enhancing the physical functioning of elderly people and of individuals with decreased muscle strength resulting from disease or disability such as arthritis. This lack of muscular strength would be expected to effect the remaining function, regardless of the effectiveness of pharmacologic treatment. This technique could also be readily maintained by the patient and may be effective for maintenance exercises.

Although gains in muscle strength can be monitored by increased performance, the relationship between moderate increases in muscle strength in patients with PD and improvement in functional activities has not been investigated. The various parameters of the gait cycle are one set of quantitative measures for a functional activity important to daily living. Parkinsonian gait, which is characteristic of the disease, is described as festinating (shuffling) with decreased stride length, moderate decreased cadence, overall velocities of movement, and associated disturbances in range of motion. These aspects are presumably reflective of the Parkinsonian symptoms of bradykinesia, muscular rigidity, and disturbance of postural reflexes as expressed in walking movements. It is generally agreed that strength training will improve gait, although few quantitative measurements have been obtained to show that strength
training will improve gait for patients with PD. The objective of this study was to determine whether a resistance training protocol can produce increases in strength and improvements in functional gait in patients with PD.

METHODS

Subjects. Fourteen (8 women and 6 men) previously sedentary patients with PD (Hohen and Yahr stage 2-3), ranging in age from 48 to 78 yr (mean age, 65.5 yr) participated in this study. There were six normal (unaffected with PD) control subjects. The control subjects were typically caregivers (5 women and 1 man) with an age range of 58 to 67 yr. All subjects gave their informed consent. The study was approved by the Institutional Human Studies Review Committee. Before acceptance into the study, all subjects were administered stress tests to determine signs of latent heart disease or severe pulmonary impairment; such individuals were excluded from this study. None of the subjects had previous experience with resistance training.

Training. All 20 subjects submitted to a rigorous 8-wk resistance training schedule. Under qualified supervision, they trained twice a week during this period. The exercises were predominately geared toward the lower body. They included leg press, toe (calf) raise, leg curl, leg extension, and traditional abdominal crunches. For the toe (calf) raise, the patients held a dumbbell in each hand and lifted their heels off the ground. All other lower limb exercises were performed using Cybex selectored equipment. Initial resistance weight was determined as 60% of a one repetition maximum at the beginning of the study. One set (1 to 12 repetitions) of each exercise was performed to momentary muscular fatigue. A 2-min resting interval was provided between each exercise.

When patients achieved 12 repetitions at a given weight (resistance), the resistance settings were increased by 5 lb, unless this amount exceeded the initial starting weight or the subject could not achieve more than one repetition with the increase. In the latter case, smaller increments were determined by identifying a weight <5 lb at which the subject could do more than one repetition.

Gait Analysis. A computerized gait analysis was performed before and at the end of this study. The three-dimensional program (Peak Motus, Peak Performance Technologies, Englewood, CO) recorded the subjects as they walked along a 40-ft track. Before testing, all patients with PD were instructed to undergo a 12-hr washout of their medication. Before the computer can analyze the gait of the participants, the subjects were fitted bilaterally with 3M reflective markers. The markers were placed at the base of the second metatarsal of the foot, the most posterior aspect of the lateral heel, on the lateral malleolus, the lateral fibular head of the knee, greater trochanter, angle of the acromion process, lateral epicondyle, distal ulna, seventh cervical vertebral markers, sternum, each malleolus, and the forehead between the eyebrows. Gait parameters were derived from the digitized movements of the reflective markers recorded through the computer system as an average of three walking trials. The gait parameters measured consisted of stride length, cadence, and the average maximum velocity of the shoulder, wrist, hip, knee, and ankle achieved during each trial. Gait velocity was defined as the average maximum velocity of the hip marker during successive gait trials. Velocity of movements has been shown to be a sensitive indicator of change with physical treatment methods. The postural angle of the head relative to the floor was measured at midstride during the single limb support phase as an indicator of postural change. The angle was defined by a line between the forehead marker and cervical vertebral markers and a horizontal line defined by the floor. This parameter was used as an indicator of postural change rather than a simple measurement of the angle of the head relative to the body, because several aspects of body angle, including spinal column, pelvic tilt, and knee and ankle crouch, can contribute to altered posture in patients with PD.

Data Analysis. Changes in performance were measured using the formula: repetitions multiplied by the amount of weight in pounds. Standard statistical procedures were used to calculate means, standard errors, and standard deviations. Standard deviations were used as the expressed measure of variance unless otherwise noted. Analysis of variance was used to examine the differences between treatment groups with Fisher’s probable least significant difference as a post hoc test. A paired t test was used to detect differences within groups during the treatment period.

RESULTS

All subjects were able to successfully complete the strength training program without injury. Analysis of variance on measurements of performance at the beginning of the study showed no significant difference between normal subjects and those patients with PD, with the exception of abdominal exercises. Over the course of the exercise regimen, performance in the selected exercises improved in both groups.

Abdominal Strength. There was a significant ($P < 0.05$; paired $t$ test) increase in abdominal strength in both groups, as shown with an increase in the number of crunches that could be performed in a single trial (Table 1). The patients with PD improved significantly ($P < 0.03$ [paired $t$ test];
Table 1

Abdominal strength

<table>
<thead>
<tr>
<th>Group</th>
<th>Begin</th>
<th>End</th>
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<tbody>
<tr>
<td>Normal</td>
<td>23 ± 14</td>
<td>35 ± 17&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Parkinson’s</td>
<td>13 ± 8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>22 ± 10&lt;sup&gt;b&lt;/sup&gt;</td>
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Ad libbed strength as measured by the number of crunches a subject could do at one time. Both groups increased significantly during the training.

Mean ± SD values are expressed.

<sup>a</sup><sub>P</sub> < 0.05; paired t test. Patients with Parkinson’s disease could do significantly fewer crunches at the beginning and end of the study compared with the normal control subjects.

<sup>b</sup><sub>P</sub> < 0.05.

Figure 1: Performance before and after a course of resistance training in patients with Parkinson’s disease. Asterisks indicate points at which posttraining performance significantly exceeded pretraining (<sub>P</sub> < 0.05). Reps., repetitions; Norm., normal subjects; Park., patients with Parkinson’s disease.

Lower Limb Exercises. In general, all subjects began at similar levels of performance, and performance increased significantly (<sub>P</sub> < 0.05) during the training period (Fig. 1). Performance of patients with PD was either equal to or slightly greater than that of the normal subjects (Fig. 1). There were no significant differences between the patients with PD and normal control subjects at either the beginning or end of the study.

Gait. Patients with PD had a significantly shorter stride length compared with that of the normal group at the beginning (<sub>P</sub> < 0.014) and end of the study (<sub>P</sub> < 0.036). Cadence did not differ significantly between both groups at either time, but it showed a trend for a decreased cadence. With training, patients with PD showed a significant (<sub>P</sub> < 0.002, paired t test) increase in stride length (Table 2). Normal subjects showed no significant changes in either stride length or cadence (Table 2).

Velocity. There were significant differences (<sub>P</sub> < 0.008) between the initial hip-based gait velocity of normal subjects (1.33 ± 0.13 m/sec) and patients with PD (0.93 ± 0.32 m/sec; Table 2). This difference was reflected in most of the velocity parameters examined. By the end of training, the normal subjects showed no change (<sub>P</sub> = 0.9, paired t test) in basic gait velocity (1.35 ± 0.23 m/sec), whereas patients with PD showed a significant increase (1.0 ± 0.39 m/sec; <sub>P</sub> < 0.04, paired t test) in gait velocity. The gait velocity of the group with PD did not differ statistically from the normal group at the end of the study (<sub>P</sub> = 0.063; analysis of variance). The shoulder velocity of the group with PD also increased significantly by the end of the study (<sub>P</sub> < 0.023) as well as maximum knee velocity (<sub>P</sub> < 0.05, paired t test) (Table 2). Other parameters such as range of leg motion and velocities of lower limb markers showed similar trends, did not change significantly in either of the groups, although similar trends for improvement were present in the group with PD.

Head Angle. There was a significant difference between the normal group and the patients with PD in midstride postural head angle relative to the floor (<sub>P</sub> < 0.02; Table 2). Resistance training produced a small, but consistent increase (<sub>P</sub> < 0.002, paired t test) in postural head angle relative to the floor during midstride gait in the group with PD. The group with PD did not differ statistically from the normal group at the end of training. The normal group did not change.

Discussion

This study demonstrates that patients with mild-to-moderate PD have measurements of strength and performance which are similar to those of normal elderly subjects of similar age. It also showed that gains in performance are similar to those of a normal control group. Patients at the stage of disease used for subjects in this study begin to experience some disability, but they can generally ambulate and function independently or with minimal assistance. Patients with PD who have more severe symptoms and disability might...
be expected to show a poorer initial performance and less gain compared with the performance of normal subjects, because the more severe disease state contributes to increased disuse atrophy and interferes with the exercises themselves. Still, it was found that patients with PD can make significant gains in resistance training performance in this instance similar to those found in control subjects, and that this type of conditioning may be beneficial as part of a physical rehabilitation strategy and physical maintenance.

The gains in exercise performance in patients with PD were associated with significant improvements in quantitative assessments of gait including stride length and modest increases in peak velocity of movement, primarily in the net movement velocity during gait (e.g., shoulder and hip velocity). The increase in stride length and velocity were associated with no change or a trend for decrease in cadence for normal control subjects and patients with PD. This suggests that the increase in stride length is accompanied by increased movement velocity without an increase in cadence. This is in contrast with the results of other physical treatment methods, which suggest that more marked velocity changes in the lower limb are associated with significant increases in stride length and cadence. This may imply that resistance training alone is not the most effective method to improve movement velocity in these patients, although modest gains are achieved. This may be an important therapeutic management consideration, since bradykinesia is one of the major symptoms of PD.

In our study patient population with PD, the only significant initial deficit in strength or performance was associated with abdominal strength. As monitored by the number of crunches a subject could do, this measure was the only one which differed significantly at the beginning of the experiment between the patient and control groups. A significant difference was maintained even though both groups increased in performance over the course of the exercise regimen. Difficulty with proximal musculature is a prominent feature of PD, and may be associated with significant postural asymmetry and difficulty with transition movements when the disease is markedly unilateral. The identification and correction of abdominal weakness may be of importance in the design of physical treatment protocols for this patient population.

The results also indicate that postural head angle relative to the floor had also significantly changed. Although the total change was not uniform, an increase was consistent over the patient population. The origin of the change was not clear, but it may have resulted from a reductionof

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<tr>
<th>TABLE 2</th>
<th>Basic gait characteristics in normal subjects and in patients with Parkinson's Disease</th>
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<tbody>
<tr>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td>Cadence (steps/min)</td>
<td>Begin</td>
</tr>
<tr>
<td>Stride length (meters)</td>
<td>1.17 ± 0.18</td>
</tr>
<tr>
<td>Shoulder velocity (m/sec)</td>
<td>1.23 ± 0.16</td>
</tr>
<tr>
<td>Wrist velocity (m/sec)</td>
<td>2.01 ± 0.38</td>
</tr>
<tr>
<td>Hip velocity (m/sec)</td>
<td>1.33 ± 0.13</td>
</tr>
<tr>
<td>Knee velocity (m/sec)</td>
<td>2.25 ± 0.25</td>
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<tr>
<td>Ankle velocity (m/sec)</td>
<td>3.55 ± 0.27</td>
</tr>
<tr>
<td>Head angle (°)</td>
<td>33 ± 6</td>
</tr>
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</table>

Gait characteristics of subjects with Parkinson's disease compared with those of the normal control group before and after training. Cadence did not differ between groups or over time. Stride length was significantly less in patients with Parkinson's disease compared with normal subjects.

Mean ± SD values are expressed.
<sup>a</sup>P < 0.05 and remained so at the end of the study, despite a significant increase in stride length compared with before training.
<sup>b</sup>P < 0.0021; paired t test).
the increased knee and ankle flexion typical of patients with PD. These angle measurements were not monitored in the present study, but they may provide useful insights into the origin and management of postural problems experienced by patients with PD.

In summary, we have demonstrated that mild-to-moderately afflicted patients with PD can gain strength through resistance training similar to other elderly adults. This gain in strength is associated with significant quantitative improvements in gait. However, the observed alterations in gait and posture did not include marked increases in the velocity of movements which are desirable in the physical rehabilitation of patients with PD. We conclude that patients with mild-to-moderate PD can benefit significantly from resistance training, and that resistance training should be included as part of a rehabilitation program with other physical therapeutic techniques which have been shown to improve movement velocities in patients with PD.

REFERENCES

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