ORIGINAL ARTICLE

Tai Chi and Postural Stability in Patients with Parkinson's Disease

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ABSTRACT

BACKGROUND
Patients with Parkinson's disease have substantially impaired balance, leading to diminished functional ability and an increased risk of falling. Although exercise is routinely encouraged by health care providers, few programs have been proven effective.

METHODS
We conducted a randomized, controlled trial to determine whether a tailored tai chi program could improve postural control in patients with idiopathic Parkinson's disease. We randomly assigned 195 patients with stage 1 to 4 disease on the Hoehn and Yahr staging scale (which ranges from 1 to 5, with higher stages indicating more severe disease) to one of three groups: tai chi, resistance training, or stretching. The patients participated in 60-minute exercise sessions twice weekly for 24 weeks. The primary outcomes were changes from baseline in the limits-of-stability test (maximum excursion and directional control; range, 0 to 100%). Secondary outcomes included measures of gait and strength, scores on functional-reach and timed up-and-go tests, motor scores on the Unified Parkinson's Disease Rating Scale, and number of falls.

RESULTS
The tai chi group performed consistently better than the resistance-training and stretching groups in maximum excursion (between-group difference in the change from baseline, 5.55 percentage points; 95% confidence interval [CI], 1.12 to 9.97; and 11.98 percentage points; 95% CI, 7.21 to 16.74, respectively) and in directional control (10.45 percentage points; 95% CI, 3.89 to 17.00; and 11.38 percentage points; 95% CI, 5.50 to 17.27, respectively). The tai chi group also performed better than the stretching group in all secondary outcomes and outperformed the resistance-training group in stride length and functional reach. Tai chi lowered the incidence of falls as compared with stretching but not as compared with resistance training. The effects of tai chi training were maintained at 3 months after the intervention. No serious adverse events were observed.

CONCLUSIONS
Tai chi training appears to reduce balance impairments in patients with mild-to-moderate Parkinson's disease, with additional benefits of improved functional capacity and reduced falls. (Funded by the National Institute of Neurological Disorders and Stroke; ClinicalTrials.gov number, NCT00611481.)

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Movement impairments, especially loss of the ability to maintain standing balance, adversely affect function and quality of life in patients with Parkinson's disease.[1,2] With progression of the disease, patients lose postural stability and have gait dysfunction, difficulty managing activities of daily living, and frequent falls.[3,4] Although some motor dysfunction, such as tremor, may be alleviated with drug therapy, characteristics such as postural instability are less responsive to medication and require alternative approaches.[5,6]

Exercise is an integral part of the management of Parkinson's disease because physical activity has been shown to retard the deterioration of motor functions and to prolong functional independence.[7-9] Resistance-based exercises that address deficits in balance and strength have shown positive effects.[10-12] However, they require safety monitoring and are equipment-dependent. Research on alternative forms of exercise that could improve balance, gait, and function in patients with Parkinson's disease is scarce.

Tai chi, a balance-based exercise, has been shown to improve strength, balance, and physical function and to prevent falls in older adults.[13-15] Two pilot studies suggest that it may also improve axial symptoms of Parkinson's disease, such as postural stability.[16,17] However, there exist few data from large-scale randomized trials that have addressed the efficacy of tai chi in this context.

The primary aim of this study was to examine whether a tailored tai chi program could improve postural stability in patients with Parkinson's disease. Because the program emphasized rhythmic weight shifting, symmetric foot stepping, and controlled movements near the limits of stability, we hypothesized that tai chi would be more effective in improving postural stability in limits-of-stability tasks than a resistance-based exercise regimen or low-impact stretching (control).

METHODS

STUDY DESIGN

We designed a randomized clinical trial to compare the effects of exercise at 6 months in a group of patients assigned to tai chi classes with the effects in groups assigned to resistance-training or stretching classes. Each group participated in a 60-minute class that met twice weekly for 24 weeks. An expanded description of the methods is provided in the Supplementary Appendix, available with the full text of this article at NEJM.org. The trial protocol, also available at NEJM.org, was approved by the institutional review board of the Oregon Research Institute, and written informed consent was obtained from all participants. All authors vouch for the completeness and accuracy of the data and attest to the fidelity of the trial to the protocol.

STUDY PARTICIPANTS

Study participants were recruited from four Oregon cities (Eugene, Corvallis, Salem, and Portland) by means of newspaper advertisements, referrals from neurologists or physical therapists, and information distributed to local support groups for persons with Parkinson's disease. Eligibility criteria included a clinical diagnosis of Parkinson's disease, with a disease severity rating of stage 1 to 4 on the Hoehn and Yahr scale (which ranges from 1 to 5, with higher scores indicating more severe disease)[4]; an age of 40 to 85 years; at least one score of 2 or more for at least one limb for the tremor, rigidity, postural stability, or bradykinesia items in the motor section of the Unified Parkinson's Disease Rating Scale (UPDRS) III)[18]; stable medication use; ability to stand unaided and walk with or without an assistive device; medical clearance for participation; and willingness to be assigned to any of the three interventions. Exclusion criteria were current participation in any other behavioral or pharmacologic study or instructor-led exercise program, a Mini–Mental State examination[19] score lower than 24 (indicating some degree of cognitive impairment), debilitating conditions or vision impairment that would impede full participation in the study, and unavailability during the study period.

SCREENING AND RANDOMIZATION

Research staff screened patients by telephone. Those who met prescreening criteria underwent an in-person evaluation and baseline assessment. Eligible participants were randomly assigned to one of the interventions, in a ratio of 1:1:1, without stratification, with the use of permuted-block randomization once eligibility was confirmed and baseline assessments were completed. Outcome assessors were unaware of group assignments.

EXERCISE INTERVENTIONS

Tai Chi

The protocol consisted of six tai chi movements[17] integrated into an eight-form routine (see the Supplementary Appendix for more details).[20,21] Because the goal was to maintain balance through postural control, the protocol was specifically designed to tax balance and gait by having participants perform symmetric and diagonal movements, such as weight shifting, controlled displacement of the center of mass over the base of support, ankle sways, and anterior–posterior and lateral stepping. The first 10 weeks emphasized the mastery of single forms through multiple repetitions; later weeks focused on repetitions to enhance balance and increase locomotion. Natural breathing was integrated into the training routine.

Resistance Training

The protocol, developed from the exercise literature,[11,22-25] focused on strengthening the muscles that are important for posture, balance, and gait. Resistance (with weighted vests and ankle weights) was introduced at week 10. Weighted-vest resistance was initially set at 1% of body weight and was increased by approximately 1 to 2% of body weight, depending on each participant's tolerance, every fifth week until 5% of body weight was achieved. Ankle weights started at 0.45 kg (1 lb) per limb and were gradually increased to 1.36 kg (3 lb). The routine involved 8 to 10 exercises, including forward and side steps, squats, forward and side lunges, and heel and toe raises, performed in 1 to 3 sets of 10 to 15 repetitions. Progression was modified for participants with physical limitations. Natural breathing was emphasized during the training routine.

Stretching

This control condition was designed to provide a low-intensity exercise program with the social interaction and enjoyment inherent in the two other interventions but without similar training benefits in lower-extremity weight bearing, strength, or balance.[13,20] The core activities encompassed a variety of seated and standing stretches involving the upper body (neck, upper back, shoulders, chest, and arms) and lower extremities (quadriceps, hamstrings, calves, and hips), with the use of gentle joint extension and flexion and trunk rotation. Abdominal breathing, with an emphasis on inhaling and exhaling to maximum capacity, and relaxation of major muscles were also included.

PRIMARY OUTCOMES

Primary outcomes consisted of two indicators of postural stability — maximum excursion and directional control — as measured by computerized dynamic posturography (Balance Master System, NeuroCom). Maximum excursion is an assessment of the limits of self-initiated movements as patients shift or lean their center of gravity, without falling, toward the theoretical limit (100%) in each of eight target directions. Directional control, a measure of movement accuracy, is calculated by comparing the amount of movement toward the target with the amount of extraneous movement. Scores on both measures range from 0 to 100%, with higher percentages indicating better balance or control.

SECONDARY OUTCOMES

Gait (stride length and walking velocity) was quantified with the use of a computerized 4.3-m (14 ft) walkway (GAITRite, CIR Systems). Participants were instructed to walk at their normal pace for four trials; the results were averaged to derive a score for each measure, with higher scores indicating better gait ability. Strength of bilateral knee extensors and flexors was measured at an angular velocity of 60 degrees per second with the use of an isokinetic dynamometer (Biodex System 3, Biodex Medical Systems). Summary peak torque values (in Newton meters [Nm]) of five cycles of maximal extension and flexion were calculated from the average of measurements of both limbs. The functional-reach test[26] assessed the maximal distance a participant could reach forward beyond arm's length while maintaining a fixed base of support in a standing position, with higher scores indicating better balance. The timed up-and-go test[27] measured the time (in seconds) taken to rise from a chair, walk 3.1 m (10 ft), return, and sit down, with a shorter time indicating better mobility. Participants' motor symptoms were assessed with the 14-item UPDRS III[18]; scores range from 0 to 56, with lower values indicating less motor disability. Assessors were trained by a board-certified neurologist according to the standard protocol.[28] Interrater reliability was 0.96. Falls were monitored by means of daily "fall calendars" that were maintained by the study participants[13] and collected monthly throughout the intervention or until a participant withdrew from the study.

TEST PROCEDURES

Outcome measures were assessed at baseline, at 3 and 6 months, and 3 months after completion of the intervention. Participants were instructed to follow their normal schedules for physical activity and medication during the 6-month intervention period. Assessments were conducted during times when participants were in "on" periods (i.e., when medication was working and symptoms were controlled). The participants' antiparkinsonian medications were monitored by means of a self-reported measure.[29]

STATISTICAL ANALYSIS

All primary and secondary analyses were conducted on an intention-to-treat basis. Between-group differences in demographic and baseline variables were tested with a chi-square test for categorical variables and a one-way analysis of variance for continuous variables.

Intervention effects on primary and secondary continuous outcome measures were compared by means of mixed repeated-measures analysis of variance, with and without adjustment for baseline and time-varying covariates (e.g., age, sex, disease stage, health status, medication use and change, and level of physical activity). Pairwise comparisons between the tai chi group and the two other groups were conducted only if the omnibus F-test statistics indicated that the null hypothesis should be rejected. Independent-sample t-tests (with 95% confidence intervals) were used to compare group means. Paired t-tests were used to examine within-group changes from baseline to 6 months. Negative binomial regression was used to model data on falls and to derive incidence-rate ratios (with 95% confidence intervals). The same analytic procedures were used to examine the sustainability of the intervention effects.

We calculated that a sample of 45 participants per group would provide at least 80% power to detect a between-group difference of 6 percentage points in maximum excursion and 10 percentage points in directional control from baseline to 6 months, assuming a 15% attrition rate, at a two-tailed alpha level of 0.05. These predicted percentage-point differences equate to a medium effect size of 0.30 or greater (the difference between two means divided by the pooled standard deviation for the data). For the primary outcomes, a two-tailed alpha level of 0.01 (for four corrected comparisons by the Bonferroni method) was considered to indicate statistical significance. Statistical analyses were performed with the use of SPSS software, version 17 (IBM), and Stata software, version 11 (StataCorp).

RESULTS

BASELINE CHARACTERISTICS OF THE PARTICIPANTS

From May 2008 through November 2010, a total of 309 persons were screened for eligibility; 195 qualified and underwent randomization (Fig. 1 in the Supplementary Appendix). Table 1 shows the baseline characteristics of the study population. A total of 164 persons (84%) were at stage 2 or higher on the Hoehn and Yahr staging system (range, 1 to 4; median, 2.5). The groups were well matched with regard to baseline characteristics, including age, sex, duration of Parkinson's disease, Hoehn and Yahr stages, and baseline study outcomes of interest.

A total of 176 participants completed their assigned interventions, and 185 provided complete data on the outcome measures at follow-up. There were no significant differences in the baseline demographic variables or primary outcomes between participants who completed the trial and those who did not. The average attendance across the 24-week period was 37 sessions (77%; 37 of 48 in tai chi; 37 of 48 in resistance training; and 38 of 48 in stretching; median, 39; range, 3 to 48). A total of 137 participants (70%) attended 36 or more sessions (≥75%). Attendance did not differ significantly among the groups (P=0.67). There were no significant within-group changes in participants' outside physical activity (P=0.23) or use of antiparkinsonian medication (P=0.16).

PRIMARY OUTCOMES

Mean (±SD) between-group differences in outcomes at 6 months are shown in Table 2. The participants in the tai chi group performed significantly better than those in the resistance-training and stretching groups on the primary outcomes. The tai chi group had better performance than the resistance-training group in maximum excursion, with a between-group difference of 5.55 percentage points (95% confidence interval [CI], 1.12 to 9.97; P=0.01), and in directional control, with a between-group difference of 10.45 percentage points (95% CI, 3.89 to 17.00; P=0.002). The tai chi group also had significantly better performance than the stretching group in both maximum excursion and directional control, with between-group differenc-

Table 1. Demographic and Clinical Characteristics of the Study Participants at Baseline.*

Characteristic	Tai Chi (N=65)	Resistance (N=65)	Stretching (N=65)
Age — yr	68±9	69±8	69±9
Female sex — no. (%)	20 (30.8)	27 (41.5)	26 (40.0)
Body-mass index†	28±5	27±5	27±5
Hoehn and Yahr stage — no. (%)			
1–1.5	9 (13.8)	14 (21.5)	8 (12.3)
2–2.5	34 (52.3)	27 (41.5)	28 (43.1)
≥3	22 (33.8)	24 (36.9)	29 (44.6)
Age at initial diagnosis — yr	61±12	65±9	65±11
Duration of disease — yr	8±9	8±9	6±5
Antiparkinsonian medications taken — no.			
Levodopa or carbidopa	43	50	50
Pramipexole or ropinirole	20	21	12
Other	10	16	20
Self-reported health status — no. (%)			
Poor or fair	35 (53.8)	31 (47.7)	28 (43.1)
Good	23 (35.4)	28 (43.1)	29 (44.6)
Very good or excellent	7 (10.8)	6 (9.2)	8 (12.3)
Score for self-reported habitual physical activity‡	123±67	107±54	116±62
Self-reported coexisting chronic conditions — no. (%)§			
0	12 (18.5)	9 (13.8)	12 (18.5)
1	24 (36.9)	17 (26.2)	16 (24.6)
≥2	29 (44.6)	39 (60.0)	37 (56.9)

* Plus–minus values are means ±SD. The chi-square test was used for categorical variables, and one-way analysis of variance for continuous variables. There were no significant between-group differences in any baseline characteristics. A more detailed listing of baseline characteristics is available in the Supplementary Appendix.
† The body-mass index is the weight in kilograms divided by the square of the height in meters.
‡ Activity was measured by means of the Physical Activity Scale for the Elderly,[30] with scores ranging from 7 to 313 (derived by multiplying activity participation by established item weights). Higher scores indicate higher levels of habitual physical activity.
§ Conditions included arthritis, heart disease, high blood pressure, lung disease, diabetes, osteoporosis, depression, chronic back pain, and cancer; the number of conditions per participant ranged from 0 to 9.

es of 11.98 percentage points (95% CI, 7.21 to 16.74) and 11.38 percentage points (95% CI, 5.50 to 17.27), respectively (P<0.001 for both comparisons). The significant effect of tai chi remained after adjustment for covariates.

From baseline to 24 weeks, the participants in the tai chi group had a mean increase of 9.56 percentage points in maximum excursion and 8.02 percentage points in directional control (P<0.001 for both outcomes). Participants in the resistance-training group had a mean increase of 4.02 percentage points in maximum excursion (P=0.02) but did not have a significant change in directional control (−2.43 percentage points, P=0.35). No significant change from baseline was observed in the stretching group.

SECONDARY OUTCOMES

Significant between-group differences were observed after 24 weeks (Table 2). The tai chi group had significantly better performance on the measures of gait and strength, better scores on the functional-reach and timed up-and-go tests, and better UPDRS III scores, as compared with the stretching group (P<0.001 for all comparisons). The tai chi group also outperformed the resistance-training group on stride length and functional reach (P=0.01 for both comparisons).

From baseline to 24 weeks, participants in the tai chi group had mean increases of 10.3 cm in stride length (P<0.001), 10.4 cm per second in walking velocity (P<0.001), 13.9 Nm in knee extension (P=0.001), 5.1 Nm in knee flexion (P=0.01), and 5.0 cm in functional reach, (P<0.001), with decreases of 1.05 seconds on the up-and-go test and 6.42 points in the UPDRS III score (with lower scores indicating improvement). Similar improvements were observed in the resistance-training group: mean increases of 4.3 cm in stride length (P=0.01), 10.0 cm per second in walking velocity (P=0.001), 14.6 Nm in knee extension (P<0.001), 8.9 Nm in knee flexion (P=0.001), and 2.2 cm in functional reach (P=0.007), as well as decreases of 1.00 second on the up-and-go test and 5.07 points in the UPDRS III score (P<0.001 for both comparisons). No significant change from baseline was observed in the stretching group, except for deterioration in walking velocity (a decrease of 4.50 cm per second, P=0.01) and improvement in the UPDRS III scores (a decrease of 1.40 points, P=0.05).

A total of 381 falls in 76 of the 195 participants (39%) were documented during the 6-month study period (Table 3). The incidence rate of falls was lower in the tai chi group (0.22 per participant-month) than in the other two groups. Participants in the tai chi group had 67% fewer falls than those in the stretching group (incidence-rate ratio, 0.33; 95% CI, 0.16 to 0.71). They had marginally fewer falls than the participants in the resistance-train-

Table 2. Study Measures at Baseline and 6 Months and Between-Group Differences in the Change from Baseline.*

Measure	Tai Chi (N=65)	Resistance (N=65)	Stretching (N=65)	Between-Group Difference in Mean Change from Baseline†			
				Tai Chi vs. Resistance (95% CI)	P Value	Tai Chi vs. Stretching (95% CI)	P Value
Maximum excursion (%)‡							
Baseline	64.05±16.60	64.02±18.53	64.35±17.22				
6 mo	73.62±13.44	68.03±18.48	61.94±16.39	5.55 (1.12 to 9.97)	0.01	11.98 (7.21 to 16.74)	<0.001
Directional control (%)§							
Baseline	65.75±20.16	65.12±21.60	65.93±17.23				
6 mo	73.77±11.49	62.69±22.82	62.56±21.62	10.45 (3.89 to 17.00)	0.002	11.38 (5.50 to 17.27)	<0.001
Stride length (cm)¶							
Baseline	115.6±19.7	114.5±21.1	115.7±18.6				
6 mo	125.9±20.3	118.8±20.7	113.6±18.5	5.9 (1.5 to 10.4)	0.01	12.3 (8.3 to 16.4)	<0.001
Gait velocity (cm/sec)‖							
Baseline	110.1±21.0	109.2±25.4	110.9±21.7				
6 mo	120.6±21.5	119.1±24.0	106.4±20.2	0.5 (−6.2 to 7.1)	NS	14.9 (9.8 to 20.1)	<0.001
Peak torque knee extension (Nm)**							
Baseline	61.8±31.5	59.2±37.0	61.6±37.4				
6 mo	75.7±38.7	73.8±40.5	62.1±30.8	−0.6 (−10.8 to 9.5)	NS	13.5 (3.4 to 23.6)	0.01
Peak torque knee flexion (Nm)**							
Baseline	32.6±19.1	29.1±17.0	32.6±18.4				
6 mo	37.7±19.3	38.0±18.2	30.0±17.9	−3.8 (−10.2 to 2.7)	NS	7.7 (1.9 to 13.6)	0.01
Functional reach (cm)††							
Baseline	24.4±6.9	24.4±6.5	25.0±7.3				
6 mo	29.4±5.5	26.6±6.5	25.0±7.3	2.8 (0.6 to 5.0)	0.01	4.9 (3.0 to 6.9)	<0.001

Table 2. (Continued.)

Measure	Tai Chi (N=65)	Resistance (N=65)	Stretching (N=65)	Between-Group Difference in Mean Change from Baseline†			
				Tai Chi vs. Resistance (95% CI)	P Value	Tai Chi vs. Stretching (95% CI)	P Value
Timed up and go (sec)‡‡							
Baseline	8.60±2.90	8.95±2.72	8.69±3.18				
6 mo	7.55±2.69	7.95±2.60	8.67±3.45	−0.05 (−0.55 to 0.46)	NS	−1.03 (−1.58 to −0.47)	<0.001
UPDRS III score§§							
Baseline	15.28±5.59	15.32±6.04	15.06±6.17				
6 mo	8.86±4.12	10.25±4.83	13.66±7.54	−1.34 (−3.28 to 0.59)	NS	−5.02 (−6.90 to −3.13)	<0.001

* Plus–minus values are means ±SD. NS denotes not significant. A more detailed version of the table, including results from the 3-month postintervention follow-up, is available in the Supplementary Appendix.

† Mixed repeated-measures analysis of variance (group by time) with baseline, 3-month, and 6-month values indicated a significant between-group difference across all outcome measures (range, P=0.006 to P<0.001). Analyses were performed on an intention-to-treat basis. Point estimates and estimates falling within the 95% confidence interval were generated from independent t-tests for group differences. (See also Fig. 1 in the Supplementary Appendix.)

‡ Maximum excursion was assessed as the farthest distance displaced by the participant's center of gravity during performance of leaning and reaching tasks. Scores range from 0 to 100%, with higher percentages indicating better balance.

§ Directional control was assessed as the amount of movement toward a target, as compared with extraneous movement (away from the target), defined as the ratio of the amount of intended movement minus the amount of extraneous movement, divided by the amount of intended movement. The composite score of eight directions was used for analyses. Scores range from 0 to 100%, with higher percentages indicating better movement control.

¶ Stride length was measured as the distance between the heel points of two consecutive footprints of the same foot. Higher scores indicate greater stride length.

‖ Gait velocity was measured by dividing the distance traveled by the ambulation time. Higher scores indicate greater gait velocity.

** Peak torque was measured at an angular velocity of 60 degrees per second. Values are given in Newton meters (Nm). Results were the average of five repetitions of measurements at both limbs, with higher values indicating greater strength.

†† Functional reach was assessed as the maximal distance a participant could reach forward beyond arm's length while maintaining a fixed base of support in a standing position. Higher scores indicate better balance.

‡‡ Timed up and go was measured as the time taken to rise from a chair, walk 3.1 m (10 ft), return, and sit down. Higher scores indicate better mobility.

§§ The 14-item motor section of the Unified Parkinson's Disease Rating Scale (UPDRS) III was scored on a 5-point Likert scale from 0 to 4, with 0 representing no impairment and 4 representing marked impairment. Lower values indicate less motor disability. A change of 5 points or more in the score is considered clinically meaningful.[31]

ing group (incidence-rate ratio, 0.47; 95% CI, 0.21 to 1.00). All intervention effects remained significant after adjustment for baseline and time-varying covariates.

MAINTENANCE OF INTERVENTION GAINS

Analyses at the 3-month postintervention follow-up indicated that gains in primary and secondary outcomes in the tai chi group were maintained (Table 2 in the Supplementary Appendix) and that, in this postintervention period, participants in the tai chi group had fewer falls than those in the stretching group (incidence-rate ratio, 0.31; 95% CI, 0.14 to 0.67; P=0.003) and those in the resistance-training group (incidence-rate ratio, 0.40; 95% CI, 0.18 to 0.88; P=0.02)

ADVERSE EVENTS

No major adverse events were noted (Table 4).

DISCUSSION

We found that a program of twice-weekly tai chi for 24 weeks, as compared with a resistance-training program or a stretching program, was effective in improving postural stability and other functional outcomes in patients with mild-to-moderate Parkinson's disease. Tai chi training also significantly reduced the incidence of falls, as compared with the stretching program. Improvements in primary and secondary outcomes were maintained 3 months after the intervention, a finding that is consistent with prior research involving adults 70 years of age or older.[13] No serious adverse events were observed during tai chi training, indicating the safety and usefulness of this intervention for persons with Parkinson's disease.

The improvement in maximum excursion with reduced deviation in movement, as shown on the

Table 3. Self-Reported Falls during the 6-Month Intervention, According to Group.*

Falls	Tai Chi (N=65)	Resistance (N=65)	Stretching (N=65)
Total falls†	62	133	186
No. of falls — no. of participants (%)			
Any	19 (29)	31 (48)	26 (40)
1	3 (5)	8 (12)	4 (6)
2	4 (6)	7 (11)	2 (3)
≥3	12 (18)	16 (25)	20 (31)
Rate — no./participant-month	0.22	0.51	0.62

* Falls were defined as unintentionally coming to rest on the floor or the ground or falling and hitting objects such as stairs or pieces of furniture.
† A significant difference was found in the incidence-rate ratio between the tai chi and stretching groups (P=0.005); a nonsignificant difference was found between the tai chi and resistance-training groups (P=0.05).

Table 4. Adverse Events.

Event	Tai Chi	Resistance	Stretching
		number of events	
In class*			
Fall†	2	4	5
Muscle soreness or pain	1	4	1
Dizziness or faintness	0	3	2
Symptoms of hypotension	0	3	1
Out of class‡			
Fall†	19	31	26
Symptoms of chest pain or discomfort	0	3	2
Symptoms of hypotension	0	1	2
Low back pain	4	4	5
Ankle sprain	1	2	1

* Values are the number of events that occurred during in-class sessions.
† Data on falls are based on the total falls reported by participants in their "falls calendars."
‡ Values are the number of events that occurred outside class settings (i.e., in the home or during an assessment). Participants did not engage in home practice; events presented are those that occurred in a home environment while participants engaged in a habitual activity (self-reported) or that were observed during a laboratory assessment (assessor-reported).

posturographic limits-of-stability tests, suggests that tai chi training reduced dyskinesia by increasing the ability of the participants to adopt effective sway strategies (at the ankle or hip), engage in controlled movements with improved balance control near the limit of stability, or both. Clinically, these changes indicate increased potential for effectively performing daily life functions, such as reaching forward to take objects from a cabinet, transitioning from a seated to a standing position (and from standing to seated), and walking, while reducing the probability of falls. Similarly, the marked increase in gait velocity in participants in the tai chi group was associated with significant increases in stride length. These improvements in gait characteristics support the efficacy of tai chi in alleviating the bradykinetic movements associated with Parkinson's disease.

The tai chi protocol stresses weight shifting and ankle sway to effectively move the person's center of gravity toward the limits of stability, alternating between a narrow stance and a wide stance to continually change the base of support, increasing support-leg standing time and trailing-leg swing time, engaging rotational trunk movements with upright posture, and performing heel-to-toe (forward) and toe-to-heel (backward) stepping movements to strengthen dorsiflexion and plantar flexion. These inherent training features may have led to improved postural control and walking ability. Although these improvements indicate that tai chi would be effective in enhancing neuromuscular rehabilitation, the mechanisms behind the therapeutic change in participants' motor control and mobility remain less understood and warrant future exploration.

Falls are a common and sometimes life-threatening event in patients with Parkinson's disease.[32,33] However, to our knowledge, no clinical trial has shown the efficacy of exercise in reducing falls in this population. Thus, this study adds to the behavior-based treatment literature by showing that tai chi can effectively reduce the incidence of falls in patients with Parkinson's disease.

This study has some limitations. First, given the behavior-based treatments, participants were aware of their intervention assignments. This awareness may have introduced biases in the results, since persons interested in participating may have had positive expectations about the benefits of exercise. Second, we did not include a nonexercise control group, so the net gain of tai chi training cannot be gauged. However, the results of this trial show that tai chi is more effective than low-intensity, low-impact exercise programs in alleviating the symptoms of Parkinson's disease and improving functional ability. Finally, all participants were tested during "on" periods, which may have masked underlying changes induced by the training interventions.

In conclusion, tai chi appears to be effective as a stand-alone behavioral intervention designed to improve postural stability and functional ability in people with Parkinson's disease.

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Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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