The Effects of Aerobic Exercise and T'ai Chi on Blood Pressure in Older People: Results of a Randomized Trial

Deborah Rohm Young, PhD, Lawrence J. Appel, MD, MPH,* SunHa Jee, PhD,† and Edgar R. Miller III, MD, PhD**

OBJECTIVE: To compare the effects on blood pressure of a 12-week moderate-intensity aerobic exercise program and a T'ai Chi program of light activity.

DESIGN: A randomized clinical trial.

SETTING: A suburban clinic in the Baltimore, MD, area.

PARTICIPANTS: Sixty-two sedentary older adults (45% black, 79% women, aged ≥ 60 years) with systolic blood pressure 130–159 mm Hg and diastolic blood pressure < 95 mm Hg (not on antihypertensive medication).

INTERVENTION: Participants were randomized to a 12-week aerobic exercise program or a light intensity T'ai Chi program. The goal of each condition was to exercise 4 days per week, 30 minutes per day.

MEASUREMENTS: Blood pressure was measured during three screening visits and every 2 weeks during the intervention. Estimated maximal oxygen uptake and measures of physical activity level were determined at baseline and at the end of the intervention period.

RESULTS: Mean (SD) baseline systolic and diastolic blood pressures were 139.9 (9.3) mm Hg and 76.0 (7.3) mm Hg, respectively. For systolic blood pressure, adjusted mean (SE) changes during the 12-week intervention period were −8.4 (1.6) mm Hg and −7.0 (1.6) mm Hg in the aerobic exercise and T'ai Chi groups, respectively (each within-group $P <$ .001; between-group $P = .56$). For diastolic blood pressure, corresponding changes were −3.2 (1.0) mm Hg in the aerobic exercise group and −2.4 (1.0) mm Hg in the T'ai Chi group (each within-group $P <$ .001; between-group $P = .54$). Body weight did not change in either group. Estimated maximal aerobic capacity tended to increase in aerobic exercise ($P =$ .06) but not in T'ai Chi ($P = .24$).

CONCLUSIONS: Programs of moderate intensity aerobic exercise and light exercise may have similar effects on blood pressure in previously sedentary older individuals. If additional trials confirm these results, promoting light intensity activity could have substantial public health benefits as a means to reduce blood pressure in older aged persons. J Am Geriatr Soc 47:277–284, 1999.

Key words: **blood pressure; exercise; elderly; clinical trial**

Regular physical activity is associated with multiple health benefits, including a reduced incidence of cardiovascular diseases such as coronary heart disease[1,2] and stroke.[3,4] It is also generally accepted that regular physical activity reduces blood pressure and prevents hypertension,[5–6] although existing studies documenting these effects have been inconsistent. In cross-sectional studies, physically fit or physically active individuals tend to have lower blood pressure than their unfit or sedentary counterparts,[7–9] but this association is not always observed.[10–12] Population-based cohort studies suggest that being physically fit or active is associated with a reduced incidence of developing hypertension.[1,2,13] Likewise, clinical trials tend to demonstrate a significant blood pressure-lowering effect of exercise. However, it is well recognized that many of the trials had major design limitations (e.g., no control group, small sample size, inadequate blood pressure measurement procedures[14–16]). Despite the limitations of available data, several national organizations have recommended regular physical activity as a nonpharmacologic strategy to reduce blood pressure.[17–19]

The intensity of physical activity necessary to reduce blood pressure remains uncertain.[20] The instruments that assessed physical activity in the population-based studies are sufficient to rank groups of individuals according to physical activity status but are inadequate to characterize the actual intensity of habitual physical activity. Most intervention trials have tested the effects of vigorous exercise on blood pressure.[21,22] In the trials that compared vigorous and moderate-intensity exercise, moderate-intensity activity seems to lower blood pressure as much as higher-intensity exercise training in middle-aged and older adults.[23–25] The effects of light intensity activity have not been evaluated, nor have alternative physical activity formats such as T'ai Chi.

The purpose of this randomized trial was to compare the effects over 12 weeks of a moderate-intensity aerobic training program with a T'ai Chi program of light activity as a means to reduce blood pressure in previously sedentary, older-aged

From the *Welch Center for Prevention, Epidemiology, and Clinical Research, Johns Hopkins Medical Institutions, Baltimore, Maryland; and †Yonsei University, Seoul, Korea.

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Address correspondence to Deborah Rohm Young, PhD, Welch Center for Prevention, Epidemiology, and Clinical Research, 2024 E. Monument St., No. 2–600, Baltimore, MD 21205.

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men and women with high-normal blood pressure or Stage I hypertension. Cardiorespiratory responses associated with T'ai Chi,[26–29] as well as the effects of T'ai Chi for improving balance[30,31] and reducing risk of falls[32] in older adults, have been studied previously. However, investigations have not evaluated the effects of T'ai Chi for reducing blood pressure or other cardiovascular risk factors.

MATERIALS AND METHODS

This clinical trial was approved by an institutional review board of the Johns Hopkins Medical Institutions. All participants provided written informed consent.

Study Participants

Persons were eligible for the trial if they were between the ages of 60 and 80 years; had an average systolic blood pressure between 130 and 159 mm Hg and diastolic blood pressure less than or equal to 95 mm Hg (average across screening visits); participated in less than 10 minutes of vigorous exercise per week; and had approval from their personal physician. Exclusion criteria included: current use of antihypertensive medication or insulin; myocardial infarction or stroke within the previous 6 months; current symptoms of angina, congestive heart failure, or exercise-induced asthma; inability to perform moderate-intensity activity; or inability to participate in follow-up evaluations. Recruitment strategies included mass mailings to registered voters, targeted mailings to previous study participants, advertisements in local newspapers, and presentations at local senior centers.

Trial Conduct

After an initial pre-screen telephone contact that determined basic eligibility (age, medication use, and current exercise status), participants underwent three in-person screening visits. At these visits, eligibility and continued interest in the trial were ascertained, and baseline data were collected. At the third visit, participants were randomly assigned to either the aerobic exercise or T'ai Chi exercise condition. Intervention groups of 10 to 12 participants were assembled at times that participants identified as convenient. Follow-up visits were scheduled 2, 4, 6, 8, 10, and 12 weeks after the intervention start date and were conducted independently of intervention classes. Blood pressure and weight were measured at all follow-up data collection visits. Physical activity, medical history, and psychosocial questionnaires were administered at either the 10- or 12-week visit; cardiorespiratory fitness was also assessed at this time. All outcome measures were obtained by staff who were masked to intervention assignment.

Measurements

At each screening and follow-up visit, two blood pressure measurements were recorded in the seated position after the participant had rested 5 minutes. All technicians were trained and certified to measure blood pressure using a random zero syphgmomanometer according to criteria implemented in other trials.[33,34] Technicians were masked to intervention status and did not provide participants with blood pressure information during follow-up. Systolic blood pressure was measured as the point of appearance (phase I) of the Korotkoff sounds and diastolic blood pressure as the point of disappearance (phase V). Pulse rate was counted by palpitation for 30 seconds and multiplied by 2 to determine resting pulse rate. Height and weight were measured without shoes, using a calibrated scale from which body mass index (BMI) was calculated (kg/m^2). Participants completed questionnaires that collected demographic, medical history, and psychosocial information. A baseline history, physical examination, and resting electrocardiogram were obtained by a physician to rule out the possibility of occult cardiovascular disease, particularly angina and congestive heart failure. Individuals with non-insulin-dependent diabetes or equivocal symptoms suggestive of ischemic heart disease underwent exercise stress tests. Follow-up blood pressure measurements were usually conducted on days in which the exercise class did not meet. If blood pressure was measured on exercise class days, its measurements were obtained before class at a separate location.

Cardiorespiratory fitness was assessed by estimating maximal oxygen uptake from a cycle ergometer test using the YMCA submaximal cycle ergometer protocol.[35] The workload was increased progressively until the participant's heart rate exceeded 110 beats/minute at two consecutive workloads, at which time the test was terminated. Estimated maximal workload was determined from plotting heart rate and workload and estimating the workload at which predicted maximal heart rate (i.e., 220 − age = predicted maximal heart rate) would have been achieved. Maximal oxygen uptake was estimated from predicted maximal workload using published equations.[36]

Habitual physical activity was assessed from two interviewer-administered instruments, the Stanford 7-Day Physical Activity Recall (PAR)[37] and the Yale Physical Activity Survey (YPAS).[38] The PAR estimates total daily energy expenditure by asking subjects to estimate the number of hours spent over the previous 7 days in sleep and in activities classified into moderate, hard, and very hard categories. Light activity is calculated as the remaining time. The PAR has acceptable reliability and validity[37,39] and has been used in observational[40] and intervention studies.[41,42]

The YPAS was developed specifically to capture physical activities relevant to older adults and includes queries about activities across household, caretaking, exercise, and recreational domains. Weekly hours spent in the activities are determined, multiplied by their energy cost, and summed to estimate weekly energy expenditure in physical activity. The YPAS also assesses indices of vigorous activity, leisurely walking, moving, sitting, and standing, from which a summary variable can be calculated. Two-week test-retest reliabilities range between .42 to .65 across indices.[38] YPAS indices correlate significantly with maximal oxygen uptake, percent body fat, and BMI.[38]

Interventions

Participants were randomly assigned to either a moderate-intensity aerobic exercise condition or a light intensity T'ai Chi exercise condition. Randomization was determined by a fixed randomization scheme generated by the Moses-Oakford algorithm,[43] with a block size of 4 and an allocation ratio of 1:1. Both conditions consisted of 1-hour group exercise conducted twice weekly, supplemented by home-based exercise, with the goal of exercising 4 to 5 days per week, 30 to 45 minutes per day. Participants were asked to complete and return weekly exercise logs and were taught behavioral skills and strategies relevant to each exercise condition.

The goal of the aerobic exercise condition was for participants to exercise at 40 to 60% of their heart rate reserve, defined as the difference between estimated maximal heart rate and resting pulse rate. This intensity of exercise corresponds to moderate-intensity physical activity as defined in the Surgeon General's Report on Physical Activity and Health.[20] Participants met with an interventionist for one individual counseling session during the first 3 weeks of the intervention and were provided an exercise prescription that included weekly heart rate goals at progressive intensities. Examples of activities in the 3–4 MET, 4–5 MET, and 5–6 MET range were identified to provide a range of physical activities that would meet intensity requirements. (1 MET = metabolic equivalent, or resting energy expenditure. A 4-MET activity requires energy expenditure 4 times that of rest.) In addition, each subject's previous experience with exercise, expectations from the intervention, and ways to increase exercise outside of class were discussed at this time. Group exercise classes were conducted twice a week and consisted of warm-up exercise, aerobic exercise in the form of walking and low-impact aerobic dance, and cool-down. The aerobic exercise portion increased progressively from 20 minutes to 40 minutes by the ninth intervention week. Class attendance was recorded for each session.

In addition to the exercise, classes provided exercise-related practical knowledge and fostered behavioral skills for adopting and maintaining a physically active lifestyle. For example, information about exercising in hot weather, proper shoes for exercise, and self-treatment of minor injuries was provided. Behavioral strategies such as setting weekly exercise goals, identifying short-term benefits, determining personal barriers to regular exercise, and identifying a person who can provide social support were discussed.

T'ai Chi is an ancient Chinese exercise that is performed in slow, relaxed, continuous movements. The T'ai Chi intervention used in this trial emphasized its physical movements rather than its meditational aspects or its underpinnings in traditional Chinese philosophy. One-hour group classes, led by a certified T'ai Chi instructor, were held twice per week. The form of T'ai Chi taught, the Yang style, is its most popular form and consists of 13 movements practiced in sequence in a slow, fluid, and continuous manner. Low impact and low velocity movements were performed in a steady rhythm consistent with breathing frequency, with change in direction, plane, and center of balance occurring with the movements. The instructor emphasized slow, relaxed movements to minimize heart rate increase resulting from the activity. Flexibility and stretching exercises were performed at the beginning of each class to complement the T'ai Chi movements. In addition, general principles related to balance and flexibility exercises and behavioral strategies to optimize adherence (e.g., goal-setting, self-monitoring, social support) were discussed.

Measures of adherence to the interventions included class attendance and frequency of exercise. Participants were instructed to record their weekly exercise goals as well as specific information about each exercise session (i.e., the type of activity, total exercise time, heart rate achieved, and ratings of perceived exertion[44]). Distinct logs were developed for the aerobic exercise and T'ai Chi interventions. Those in the T'ai Chi condition only recorded their frequency, duration, and heart rate achieved during T'ai Chi, whereas participants in the aerobic exercise condition recorded all physical activity in which they achieved their target heart rate (e.g., housework, gardening).

Analysis

The study was a standard comparative trial testing the effects on blood pressure of the two interventions. The sample size of 31 participants in each group was estimated to provide 80% power to detect a mean between-intervention difference of 5 mm Hg in systolic blood pressure.

Change in resting systolic blood pressure was the primary outcome variable; change in diastolic blood pressure, cardiorespiratory fitness, and physical activity level were secondary outcomes. Change in blood pressure was the difference between blood pressure at follow-up (the average of the follow-up measures during weeks 2 through 12 of the intervention phase) and baseline (the average of three pairs during screening). In addition to evaluating change in blood pressure over the entire follow-up period, we also examined blood pressure change during the early intervention follow-up (average change during weeks 2 through 6) and late intervention follow-up periods (average change during weeks 8 through 12). If a follow-up blood pressure was not obtained, the average of the available follow-up blood pressures was used in the analysis.

All analyses were performed on an intent-to-treat basis. Within-group change for all outcome variables was determined from paired t tests, after adjustment for baseline levels. Between-group differences in blood pressure change were determined from analysis of covariance, in which change in blood pressure was the dependent variable and baseline level of blood pressure was entered as a covariate. Similar analyses were performed to determine between-group differences in cardiorespiratory fitness and physical activity level.

Subgroup analyses according to baseline blood pressure and physical activity status were determined using the same analysis plan. Participants were considered to be hypertensive if baseline systolic blood pressure was 140 mm Hg or higher or diastolic blood pressure was 90 mm Hg or higher. A median split was used to classify baseline physical activity level as low or high.

RESULTS

Of the 179 persons who expressed interest during the recruitment drive, 62 were randomized, 31 in each group. Of those who did not enroll, 60 were not interested in joining the study, 56 were ineligible because of blood pressure (primarily too low), and one refused to be randomized.

Baseline characteristics of study participants are displayed in Tables 1 and 2. Participants were primarily women. Approximately 45% were black. The mean BMI was high [mean (SD) = 30.6 (4.2) kg/m^2]; 93% of the sample had BMI values greater than 25.0 kg/m.^{2} Mean systolic blood pressure in the T'ai Chi group was slightly higher than that of the aerobic exercise group ($P = .14$)). Nearly half of the sample met systolic blood pressure criteria for hypertension ($\geq$ 140 mm Hg); diastolic blood pressure was elevated in only one subject. Estimated maximal aerobic capacity was low, and the mean estimated daily energy expenditure, as determined from the PAR, indicated that the participants were sedentary (Table 2). The aerobic exercise group had a higher level of estimated daily energy expenditure ($P < .05$) and spent more time in moderate intensity physical activity ($P < .06$) than the

Table 1. Baseline Measurements: Demographic, Physiologic, and Blood Pressure Characteristics*

	Aerobic Exercise (n = 31)	T'ai Chi Exercise (n = 31)	All (n = 62)
Age (years)	67.0 ± 7.9	66.4 ± 5.1	66.7 ± 5.2
Female (%)	80.7	77.4	79.0
Black (%)	48.4	41.9	45.2
Weight (kg)	83.1 ± 12.4	82.1 ± 13.9	82.6 ± 13.1
Body mass index (kg/m^2)	31.0 ± 4.3	30.2 ± 4.0	30.6 ± 4.2
Resting pulse (beats/min)	72.8 ± 7.3	73.2 ± 6.9	73.0 ± 7.0
Maximal aerobic capacity (mL O_2/kg/min)	19.2 ± 4.5	20.4 ± 3.9	19.9 ± 4.2
Systolic blood pressure (mm Hg)**	138.2 ± 8.1	141.7 ± 10.2	139.9 ± 9.3
≥140 (%)	38.7	54.8	46.8
Diastolic blood pressure (mm Hg)**	75.4 ± 7.5	76.6 ± 7.2	76.0 ± 7.3
≥90 (%)	3.2	0	1.6

*Continuous data presented as mean ± standard deviation.
**Mean blood pressure across three screening visits.
Sample size for maximal aerobic capacity: n = 57; 27 in aerobic exercise, 30 in T'ai Chi.

Table 2. Baseline Measurements: Physical Activity Characteristics*

	Aerobic Exercise	T'ai Chi Exercise	All
7-Day Physical Activity Recall (PAR)			
Daily energy expenditure (kcal/kg/day)	40.6 ± 10.0	36.2 ± 5.3†	38.4 ± 8.2
Moderate activity (hrs)	2.5 ± 2.9	1.3 ± 1.9‡	1.9 ± 2.5
Yale Physical Activity Survey (YPAS)			
Weekly energy expenditure (kcal/wk)	4585 ± 3201	4345 ± 2335	4463 ± 2773
Activity time (hrs/wk)	24.0 ± 15.6	22.0 ± 10.8	23.0 ± 13.3
Summary activity (total units)**	31.3 ± 16.4	29.3 ± 14.8	30.3 ± 15.5
Vigorous activity (units/mo)	8.1 ± 10.4	7.2 ± 10.2	7.6 ± 10.2
Leisurely walks (units/mo)	9.4 ± 10.7	7.7 ± 8.5	8.5 ± 9.6
Moving (units/day)	8.3 ± 2.7	8.5 ± 3.2	8.4 ± 2.9
Standing (units/day)	3.3 ± 1.8	3.3 ± 1.7	3.3 ± 1.7
Sitting (units/day)	2.3 ± 0.7	2.6 ± 1.2	2.4 ± 1.0

*Data presented as mean ± standard deviation.
**Total units = sum of unit score for vigorous activity, leisurely walks, moving, standing, and sitting.
†$P < .05$, comparison between aerobic exercise and T'ai Chi groups.
‡$P < .06$, comparison between aerobic exercise and T'ai Chi groups.
Sample sizes for PAR and YPAS: n = 59; 29 in aerobic exercise, 30 in T'ai Chi.

T'ai Chi group. Physical activity measures from the YPAS also suggested that the sample was, as a group, inactive.

Follow-up

Follow-up blood pressure data were available for 60 (97%) of the randomized participants. One person assigned to aerobic exercise developed an arrhythmia before the start of the intervention and was prescribed an antihypertensive agent. One person assigned to T'ai Chi dropped out of the intervention and did not attend follow-up sessions. Of the 260 follow-up blood pressure measurement visits, 90 (35%) were conducted on the same day in which a participant exercised. The remaining measurements were made either more than 1 day after exercise (40%) or at an unknown time interval from a participant's last exercise bout (25%).

Blood Pressure Change

In both the aerobic exercise and T'ai Chi groups, there were significant within-group reductions in systolic and diastolic blood pressure. Table 3 displays the average decline in blood pressure within each group over the first 6 weeks, second 6 weeks, and the total 12-week period after starting the intervention. Significant declines in systolic blood pressure were detected over the first 6 weeks of follow-up, and additional reduction was found during the next 6 weeks, although they were of lesser magnitude. A similar pattern was evident for diastolic blood pressure. Figures 1 and 2 display trends in blood pressure change across the intervention period. For both groups, the greatest reduction in systolic blood pressure occurred during the initial weeks of the intervention, with periods of lesser decline and stabilization thereafter. Similar results were found for diastolic blood pressure.

As shown in Table 3, there were no significant between-group differences in change in blood pressure. Subgroup analyses of participants considered to be hypertensive at baseline (n = 29, with follow-up data on 26 participants) revealed no between-group blood pressure change (adjusted mean systolic blood pressure change (SE) over 12 weeks: aerobic exercise, −8.1 (3.4) mm Hg; T'ai Chi, −7.7 (2.7) mm Hg). Also, there was no between-group difference in blood

Table 3. Change in Blood Pressure: Within-Group Mean Change (Baseline to Follow-Up) and Between-Group Differences, Adjusted for Baseline Levels

	Change in Aerobic Exercise Group		Change in T'ai Chi Exercise Group		Change in Aerobic Exercise Group Minus Change in T'ai Chi Exercise Group	
	Mean ± SE	Within-Group *P* Value	Mean ± SE	Within-Group *P* Value	Mean (95% CI*)	Between-Group *P* Value
Systolic blood pressure (mm Hg)						
Mean change over 1st 6 weeks	−7.6 ± 1.6	<.001	−7.2 ± 1.7	<.001	−0.4 (−4.9, 4.1)	.86
Mean change over 2nd 6 weeks	−10.4 ± 1.7	<.001	−7.4 ± 1.7	<.001	−3.0 (−7.7, 1.7)	.23
Mean change over all 12 weeks	−8.4 ± 1.6	<.001	−7.0 ± 1.6	<.001	−1.4 (−5.9, 3.1)	.56
Diastolic blood pressure (mm Hg)						
Mean change over 1st 6 weeks	−2.7 ± 1.0	.01	−2.1 ± 1.0	.04	−0.6 (−3.3, 2.1)	.69
Mean change over 2nd 6 weeks	−4.2 ± 1.1	<.001	−2.5 ± 1.1	.03	−1.7 (−4.8, 1.4)	.27
Mean change over all 12 weeks	−3.2 ± 1.0	.002	−2.4 ± 1.0	.02	−0.8 (−3.5, 1.9)	.54

*CI = Confidence Interval.
Sample size: 1st 6 weeks: n = 59; 30 in aerobic exercise, 29 in T'ai Chi; 2nd 6 weeks: n = 56; 28 in aerobic exercise, 28 in T'ai Chi; all 12 weeks: n = 60; 30 in aerobic exercise, 30 in T'ai Chi.

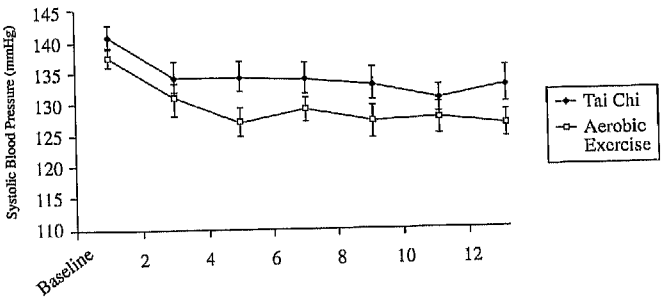

Figure 1. Systolic blood pressure (± SE) at baseline and during follow-up, according to intervention group (T'ai Chi and Aerobic Exercise).

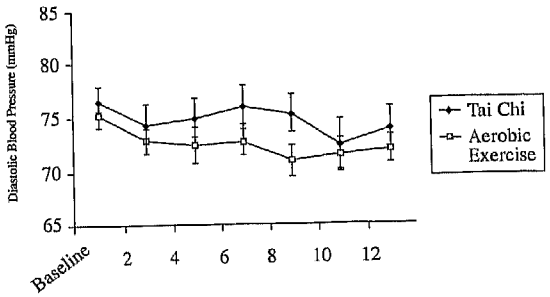

Figure 2. Diastolic blood pressure (± SE) at baseline and during follow-up, according to intervention group (T'ai Chi and Aerobic Exercise).

pressure change for those whose baseline daily or weekly energy expenditure was below the median value (data not shown).

Cardiorespiratory Fitness, Physical Activity, and Body Weight Change

A trend toward increased within-group cardiorespiratory fitness was found for the aerobic exercise group (P = .06) but not for the T'ai Chi group (Table 4). There were significant within-group increases in most physical activity dimensions for the aerobic exercise group and, in some instances, for the T'ai Chi group. The patterns of change were generally consistent with the intervention assignment. For example, there was a significant increase in time spent in moderate activity, weekly energy expenditure, and leisurely walking in the aerobic exercise group but not in the T'ai Chi group. In contrast, the T'ai Chi group had a significant increase in the moving index, whereas significant increases were not detected in the aerobic exercise group. Body weight increased to a small extent in both groups [mean (SD) change of .8 (1.5) kg in the aerobic exercise group and .5 (2.1) kg in the T'ai Chi group; between group P = .60].

Intervention Adherence

Initial weekly class attendance was 90% for the aerobic exercise group and 84% for the T'ai Chi group. During the last 3 weeks of the intervention period, approximately 50% of all participants attended class. Overall attendance is depicted in Table 5. Throughout the 12-week intervention, weekly exercise logs were returned by between 45 and 71% of those in the aerobic exercise group (overall mean return: 59%) and between 26 and 55% (overall mean return: 45%) of those in the T'ai Chi group. More than 75% of participants in aerobic exercise who returned exercise logs exercised three or more sessions per week, and 58% exercised at least four sessions per week (Table 5). Virtually all of those in T'ai Chi who returned logs exercised four or more sessions per week; they often exercised multiple sessions per day (median sessions per week = 10; range 1–25). Participants in the aerobic exercise group exercised 36.3 minutes per session, on average, and those in the T'ai Chi group exercised an average of 13.2 minutes per session. Average heart rate during aerobic exercise was approximately 112 beats per minute, whereas average heart rate during T'ai Chi was approximately 75 beats per minute.

DISCUSSION

In this randomized trial, a program of T'ai Chi reduced blood pressure to an extent similar to a program of moderate-intensity aerobic exercise. Changes in maximal aerobic ca-

Table 4. Changes in Estimated Maximal Aerobic Capacity and Physical Activity Level: Within-Group Mean Change (Baseline to Follow-Up) and Between-Group Differences, Adjusted for Baseline Levels

	Change in Aerobic Exercise Group		Change in T'ai Chi Exercise Group		Change in Aerobic Exercise Group Minus Change in T'ai Chi Exercise Group	
	Mean ± SE	Within-Group *P* Value	Mean ± SE	Within-Group *P* Value	Mean (95% CI*)	Between-Group *P* Value
Mean change in estimated maximal aerobic capacity (mL O_2/kg/day)	1.64 ± 0.86*	.06	0.97 ± 0.81	.24	0.67 (−1.7, 3.1)	.57
7-Day Physical Activity Recall (PAR)						
Mean change in daily energy expenditure (kcal/kg/day)	3.0 ± 2.0	.14	2.5 ± 2.1	.23	0.5 (−5.2, 6.2)	.89
Mean change in moderate activity (hrs)	1.7 ± 0.7	.02	0.6 ± 0.7	.4	1.1 (−0.9, 3.1)	.30
Yale Physical Activity Survey (YPAS)						
Mean change in weekly energy expenditure (kcal/wk)	2607 ± 850	.004	713 ± 906	.44	1894 (−540, 4328)	.13
Mean change in activity time (hrs/wk)	10.3 ± 4.1	.01	2.2 ± 4.3	.62	8.1 (−3.5, 19.7)	.18
Mean change in summary activity (total units)	20.6 ± 3.7	<.001	18.3 ± 4.0	<.001	2.3 (−8.5, 13.1)	.68
Mean change in vigorous activity (units/mo)	15.9 ± 3.5	<.001	13.1 ± 3.7	.001	2.8 (−7.2, 12.8)	.59
Mean change in leisurely walks (units/mo)	3.7 ± 1.8	.04	2.5 ± 1.9	.20	1.2 (−3.9, 6.3)	.65
Mean change in moving (units/day)	1.2 ± 0.70	.08	1.9 ± 0.7	.02	−0.7 (−2.7, 1.3)	.56
Mean change in standing (units/day)	0.12 ± 0.34	.72	0.50 ± 0.36	.17	−0.38 (−1.4, 0.6)	.45
Mean change in sitting (units/day)	−0.15 ± 0.16	.36	0.08 ± 0.17	.65	−0.23 (−0.6, 0.2)	.34

*CI = Confidence Interval.
Sample size for maximal aerobic capacity: n = 51; 24 in aerobic exercise, 27 in T'ai Chi. Sample size for PAR and YPAS: n = 47; 25 in aerobic exercise, 22 in T'ai Chi.

Table 5. Frequency of Class Attendance and Weekly Exercise Frequency, Based on Exercise Logs

	Aerobic Exercise	T'ai Chi
Class attendance		
% attending ≥ 1 session per week	66.7	64.8
Exercise frequency*		
% ≥ 1 session per week	100	100
% ≥ 2 sessions per week	93.4	99.5
% ≥ 3 sessions per week	77.3	98.5
% ≥ 4 sessions per week	58.0	95.7

*Determined from those returning exercise logs; percent of participants returning weekly logs ranged from 45 to 71% of aerobic exercise group (percent mean across 12 weeks = 59%), and from 26 to 55% of participants in the T'ai Chi group (percent mean across 12 weeks = 45%).

pacity and physical activity suggest that participants adhered to their assigned group. In the aerobic exercise group, there was a trend toward improved maximal aerobic capacity that approached statistical significance and an increase in hours spent in moderate activity, weekly energy expenditure, and other measures that are indicative of increases in aerobic physical activity. In the T'ai Chi group, there was no change in maximal aerobic capacity and fewer consistent changes in the physical activity measures. Body weight increased to a small but similar extent in both groups, precluding weight change as a possible explanation for observed changes in blood pressure.

Salient features of this trial that enhance its generalizability include the study population and the interventions. For instance, we successfully recruited subgroups of the population that are typically underrepresented in clinical trials of exercise, specifically, women and blacks. Given the high prevalence of hypertension among older people and blacks, studying the effects of exercise on blood pressure in these groups has clinical and public health relevance. The interventions were relevant to the population under study in that they incorporated light and moderate intensity activity, which is preferred to vigorous exercise by most adults.[4,5] For both conditions, the intervention was designed to be flexible so that individuals could exercise at convenient times outside the group setting, consistent with adult preferences.[4,5] Other strengths of the trial include blood pressure measurement procedures (i.e., multiple readings over multiple visits by trained, masked observers) and high follow-up rates.

Potential limitations of the study include a relatively small sample size, lack of a no-exercise group, and incomplete measures of adherence to the interventions. The trial's sample size may have reduced our ability to detect a between-group difference in blood pressure, which would increase our probability of a type II error. During the last 6 weeks of the intervention, there was a 3 mm Hg between-group difference in systolic blood pressure. Given a larger sample size, a significant difference in blood pressure between the aerobic exercise and T'ai Chi groups may have been detected.

Each randomized group received an exercise intervention. Accordingly, the within-group changes could potentially be interpreted as resulting from regression to the mean. However, the magnitude of blood pressure declines observed in both intervention groups in our study are consistent with those found by other exercise trials[14–16] and are likely greater than expected from regression to the mean, familiarity with clinic surroundings, or other unexplained factors. In other clinical trials of non-drug therapies to reduce blood pressure, decreases in systolic blood pressure within a control group are generally less than 4 mm Hg, at least in individuals with high normal systolic blood pressure.[34,46–48] Two studies that enrolled hypertensive participants with systolic blood pressures greater than 140 mm Hg documented control group declines in systolic blood pressure of greater than 5 mm Hg.[49] Blumenthal et al.[49] enrolled participants with systolic blood pressure between 140 and 180 mm Hg, which may account for the 9 mm Hg decline they observed in the wait-list controls. Nonetheless, future trials examining lifestyle changes for reducing blood pressure should include no-exercise, attention-only control groups.

Adherence to the intervention condition cannot be determined with certainty. Class attendance in both groups was approximately 65% throughout the intervention period, but this is not an ideal adherence measure because attendance was not an intervention requirement. Exercise logs, which document exercise sessions, were returned by approximately half of the participants. However, among those who returned exercise logs, the majority exercised at least four sessions per week, and, in general, heart rate goals were met (i.e., target heart rates were typically achieved in the aerobic exercise group and were well below 100 beats per minute in the T'ai Chi group). Our results indicate that the aerobic exercise group increased their maximal aerobic capacity and increased their physical activity, which is consistent with adhering to moderate-intensity aerobic exercise. In contrast, the T'ai Chi group did not improve their maximal aerobic capacity and had less consistent changes in physical activity. These data, along with information from the logs, suggest that participants adhered to their randomized condition.

Of considerable importance is understanding which dimensions of physical activity (i.e., frequency, duration, intensity, overall energy expenditure) reduce blood pressure. Our results, as well as those of others, suggest that intensity may be less important than other factors. Previous studies comparing the effects of moderate- versus high-intensity exercise found similar or greater blood pressure reductions for moderate-intensity exercise.[23–25] As in our trial, overall duration requirements were constant (i.e., minutes of exercise per week). However, similar to our trial, energy expenditure between conditions varied. The minimum weekly frequency, overall energy expenditure, and, based on our data, intensity required to reduce blood pressure have not been established. Future trials should examine not only dose-response issues within a given physical activity dimension but also the impact of modifying dimensions.

Promoting light intensity activity to older adults could have substantial public health benefits as a means to reduce blood pressure. Many older adults, particularly women, have had little or no experience with exercise[50] and may find even moderate-intensity activity undesirable. For those older individuals with sedentary lifestyles, engaging in light-intensity activity may be an effective and practical alternative to traditional aerobic exercise. T'ai Chi can be performed at any time or place and does not require change of shoes or clothing, which may be desirable to older adults who do not identify themselves as "exercisers."

Although the T'ai Chi practiced in our study was of light intensity, others have found that T'ai Chi can produce acute cardiorespiratory responses that meet criteria for moderate-intensity activity.[26,28,29] T'ai Chi style, speed of movement, and proficiency with postures may account for these differences. Future studies are required to evaluate additional health benefits of light and moderate-intensity T'ai Chi.

In summary, results from this trial suggest that light-intensity activity and moderate-intensity aerobic exercise have similar effects on blood pressure in sedentary older persons. The results are sufficiently provocative to warrant further investigation. A large-scale clinical trial should be conducted that includes a no-exercise control group and that is designed to evaluate the dimension and dose of physical activity necessary to reduce blood pressure.

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