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ADDITIVE EFFECT OF TAI CHI DURING DIETARY WEIGHT LOSS ON PHYSICAL FUNCTION AND BODY COMPOSITION IN OBESE OLDER WOMEN

L.A. Katkowski[1], M.C. Benson[1], S. Magnanti[2], I.E. Lofgren[2], F. Xu[1], M.J. Delmonico[1]

Abstract: *Background:* While exercise during dietary weight loss has been shown to improve physical function and body composition, Tai Chi during weight loss has not been studied in obese older women. *Objective:* To investigate the effects of Tai Chi during dietary weight loss on measures of body composition and physical function. *Design:* Randomized controlled trial. *Setting:* Laboratory setting at a university. *Participants:* Twenty seven obese older women randomized to a weight loss only group (WL, n=13; aged 62.7±6.0 years) or a Tai Chi plus weight loss group (TCWL, n=14; aged 60.4±5.9 years). *Intervention:* Both groups participated in behaviorally-based, 16-week, dietary program (modified Dietary Approaches to Stop Hypertension) for weight loss. In addition, the TCWL group completed three sessions per week of a modified 24 form Yang style Tai Chi. *Measurements:* Body fat mass and the 400 meter walk. *Results:* Both groups significantly lost body mass (TCWL, -2.2±0.9 kg; WL, -3.7±0.9 kg; $p<0.05$) with no between-group differences. Body fat mass change did not differ between the groups ($p=0.727$). There was a borderline attenuation of fat-free mass (FFM) between the TCWL group and the WL group ($p=0.056$). A tendency for significance was observed between the TCWL and WL groups for leg strength ($p=0.062$), grip strength ($p=0.070$), timed up and go test ($p=0.069$), and FFM ($p=0.056$). *Conclusion:* Tai Chi during dietary weight loss does not appear to have a significant additive effect on global measures of physical function and most measures of body composition but may help increase muscle strength.

Key words: Tai Chi, dietary weight loss, obesity, postmenopausal women.

Introduction

Obesity is associated with an increased risk of cardiovascular disease, diabetes, physical disability including frailty and low physical functioning, and mortality (1, 2). Postmenopausal women are at particularly high risk for obesity-related consequences, including lower physical and muscle functioning, due to lower initial values of muscle mass and physical function compared to men, a longer life expectancy, declines in hormonal levels after menopause, and declines in physical activity (3, 4).

Treatments for obesity exist such as surgery and medications, but these are associated with negative side effects, particularly in older adults (5, 6). Weight loss via dietary changes is another viable treatment for obesity (7), but weight loss by diet alone may result in loss of lean mass (8), leading to declined physical function (9). Positive effects of resistance training concomitantly with weight loss on measures of physical function and body composition in older adults have been previously reported (10, 11) but other exercise modalities have not been thoroughly studied. The efficacy of alternative exercise methods needs to be explored to understand the full complement of exercise modalities, especially in a weight loss setting in obese postmenopausal women.

Tai Chi is a low impact, Chinese martial art involving slow and continuous movements (12), and is safe for older adults (13). Previous studies have shown Tai Chi to be a moderate-intensity exercise not exceeding more than 60% of an individual's maximum heart rate (14). It is effective at increasing leg strength, improving gait and balance, as well as reducing the risk of falls in older adults (15). However, no studies to date have investigated the effects of Tai Chi during dietary weight loss on physical function in obese, older women. A recent study in obese women reported that Tai Chi reduced body fat during weight loss (16). However, older women were not included in that study, physical function was not measured, and a weight loss-only group was not included to determine the additive effect of Tai

1. University of Rhode Island Department of Kinesiology; 2. University of Rhode Island Department of Nutrition and Food Sciences

Corresponding Author: Matthew J. Delmonico, Ph.D., M.P.H. Department of Kinesiology, University of Rhode Island, Kingston RI 02881, 401-874-5440, delmonico@uri.edu

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Chi. Thus, the purpose of this study was to determine the additive effect of Tai Chi during dietary weight loss on body composition and physical function in obese older women. It was hypothesized that Tai Chi during dietary weight loss would result in a significantly greater body fat mass loss and improved physical function (as measured by the 400 meter walk test (400 MW) compared to dietary weight loss-only. Secondary outcomes included the retention of lean mass, mid-thigh tissue composition, and additional measures of physical and muscle function.

Methods

Study Design

This was a 16-week, randomized pre-post measures experimental design. Baseline testing occurred during the two weeks prior to the intervention. Following baseline testing, participants were randomized into Tai Chi plus weight loss (TCWL) or weight loss-only (WL) groups to determine the change over time between the two groups. This study was approved by the Institutional Review Board of the University of Rhode Island.

Participants

Participants were recruited through newspaper advertisements, flyers, and word of mouth and qualified participants signed an informed consent. Inclusion criteria were 1) females, 2) aged 55-79 years, 3) a body mass index (BMI) of 30.0-49.9 kg/m^2, 4) postmenopausal by self-report, 5) not engaged in a regular physical activity program within the last six months, 6) weight stable within 5% over the previous three months, 7) medication stable within the previous three weeks (six months for lipid lowering medications), 8) able to provide physician clearance, and 9) the ability to safely engage in mild to moderate exercise with muscular exertion. One participant withdrew prior to randomization due to an illness unrelated to the study, which resulted in a cohort of 32 women.

Outcome Measures

Primary Aims

Body Fat Mass: Body fat mass (kg) was assessed by dual-energy x-ray absorptiometry (DXA, GE Lunar iDXA, Waukesha, WI). Participants were fasted for 12 hours, wore medical scrubs, and standard procedures for patient positioning were used (17). Body composition measures of fat-free mass and percent body fat were also obtained from DXA.

Physical Function: The primary outcome for physical function was the 400 MW, a valid and reproducible measure of physical functioning that has been shown to predict mortality, mobility limitation, and disability in older adults (18, 19). The 400 MW was performed on an indoor corridor with two cones located 20 meters away from each other. Participants were instructed to complete a full 10 laps. Participants were required to walk at a pace as fast as possible that is maintainable through the duration of the walk (20). After each lap was completed encouragement was provided and a lap count was given to each participant. Time was recorded to the nearest 0.1 second.

Secondary Aims

Physical Function: Other global measures of physical function included the short physical performance battery (SPPB) and the timed up and go test (TUG). The SPPB is composed of a series of three tests including a balance assessment, 4-meter gait speed assessment, and timed 5-chair stands, which measures lower extremity physical function in older adults (21). Each of the three assessments is scored from 0 to 4. A summary score is then calculated out of 12. The TUG test is a test of physical function that requires the participant to stand up from a chair, walk 10 feet forward, turn around a cone, walk back and sit down (22). This was performed at a participant's usual pace, repeated twice. Time was recorded in seconds, and the better of the times was used.

Flexibility: The chair-sit and reach is a measure of flexibility in older adults (23). This test required the participant to sit on the edge of a chair with one knee bent and the other knee extended straight in front with the heel on the floor and foot bent at 90°. While keeping the leg straight, the participant reached down their leg attempting to touch their toes. A practice trial was done followed by two trials. The score was the number of centimeters short of reaching the toes (negative number) or beyond the toes (positive number) and the best score was used.

Muscle Strength: The leg strength one repetition maximum (1-RM) test was assessed using previously published techniques (24) using a pneumatic leg press machine (A420, Keiser Corp., Fresno, CA). Grip strength was assessed using a handgrip dynamometer (Jaymar Hydraulic Dynamometer, J.A. Preston, Corp., Jackson, MS). Each participant was seated in a chair and the dominant hand was used. Two trials of the grip strength test were performed with the best score (kg) taken.

Mid-Thigh Tissue Composition: Cross-sectional computed tomography (CT) scans (GE CT Lightspeed, Milwaukee, WI) were performed centered at the mid-thigh. Axial sections (100 mAs, 1 cm thickness) of both thighs were obtained using previously used methods (10).

Areas (cm^2) of total adipose tissue, intermuscular adipose tissue, normal density muscle (NDM), and low density muscle (LDM) were calculated using Medical Image Processing, Analysis, and Visualization Software (NIH, Bethesda, MD, version 5.2.1) by a single trained technician blinded to participant and group assignment. Skeletal muscle mass is expressed in Hounsfield units (HU) with normal density muscle area between +31 and +100 HU, low density muscle area between 0 and +30 HU, and adipose tissue between -190 and -30 HU (25).

Muscle Quality: Total mid-thigh skeletal muscle area was measured and recorded in cm^2. Muscle quality was calculated using leg strength divided by thigh muscle area (N/cm^2) (26).

Anthropometrics: Body weight was measured to the nearest 0.25 pound using a balance beam scale (Detecto 3P704, Web City, MO, USA), converted to kilograms. Height was measured to the nearest 0.25 inch using a wall mounted stadiometer (Seca Stadio Model 216), converted to centimeters. Waist circumference was measured to the nearest 0.25 centimeter at the point of the iliac crest and hip circumference was measured to the nearest 0.25 centimeter at the broadest circumference of the hips above the gluteal fold (11) using a standard Gulick non-stretch tape measure (Creative Health Products, Ann Arbor, MI).

Other Measures

Physical Activity: Average energy expenditure from physical activity was assessed using the Yale Physical Activity Survey (YPAS), which has been shown to be valid and reliable for assessing physical activity levels in older adults (27). Data are expressed as total kilocalories (kcal) per week.

Dietary Compliance: Dietary compliance was assessed using the Fred Hutchinson Food Frequency Questionnaire (FFQ) (28), and data are expressed as total caloric intake (kcals/day).

Randomization

A total of 32 participants were randomized into two groups (WL or TCWL), with 16 participants per group using Random Allocation Software (Isfahan University of Medical Sciences, Isfahan, Iran).

Intervention

Dietary Weight Loss Intervention: Both the WL and TCWL groups attended 45-minute behaviorally-based dietary education classes once a week for 16 weeks. Program development was supervised by a registered dietitian and dietary education classes were led by trained study staff. A modified Dietary Approaches to Stop Hypertension (DASH) diet (7) was used with diet goals including: low intake of saturated fat (<7% of caloric intake), moderate intake of total fat (<35% of caloric intake), high intake of fruits, vegetables, and whole grains, consumption of low-fat dairy products and meats, and a moderate intake of sodium (less than 3,000 mg/day). Individualized diets based on DASH servings were given to each participant using the Mifflin St. Jeor equation (29), multiplied by 1.2 for activity because of sedentary lifestyles with a 500 kcal/day reduction to promote 5-10% weight loss (10). In the dietary education session, nutrition staff worked with participants to improve their behaviors on how to estimate portion sizes, accurately interpret food labels, decrease caloric intake, and decrease saturated and trans fat intake. Participants were asked to complete food logs three days per week that the nutrition staff used to assess compliance and to provide constructive feedback to participants.

Tai Chi: In addition to dietary weight loss sessions, participants in the TCWL group participated in three non-consecutive, 45 minute Tai Chi sessions per week. Participants were taught a 24-form Yang style Tai Chi, modified to be appropriate for an older population and for improving health-related fitness (30). Additionally, movements involving ankle rotation and hip turns were eliminated and high kicks were replaced with step aside and long steps shortened. An experienced Tai Chi instructor with over 18 years of practical and more than 8 years of teaching experience and trained study staff led and supervised Tai Chi sessions. Classes consisted of a 5-minute warm up (Appendix), 35 minutes of learning and practicing Tai Chi movements, and a 5-minute cool down (Appendix) (30). Movements were taught progressively and participants received a DVD of the movements to review.

Statistical Analysis

A Shapiro-Wilk test was used to test for normal distribution of the changes in the outcome measures. Outliers, identified as any result greater than three standard deviations above or below the mean, were excluded for the primary outcome analysis. Within-group comparisons were determined using paired samples t-tests or Wilcoxon signed-rank tests. Between-group analyses were performed using analysis of covariance (ANCOVA), adjusted for baseline values. Since there were no significant differences between the groups at baseline, no additional adjustments were made. Significance was set at $p < 0.05$. All analyses were performed using SAS version 9.2 (Cary, NC).

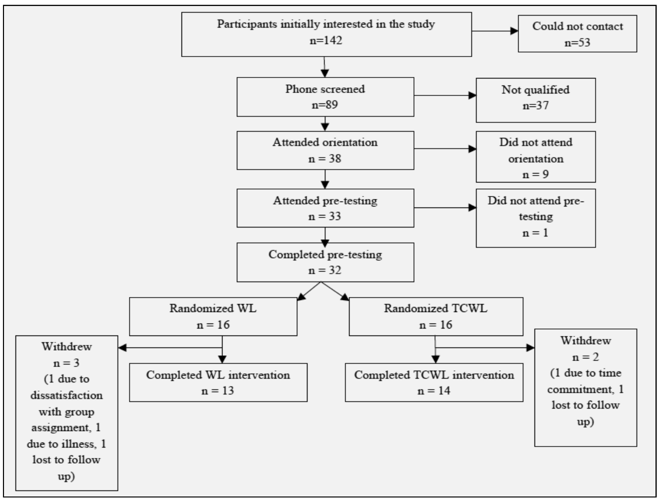
Sample Size Calculation

Sample size to detect differences in body fat mass changes between groups was based on a 4 kg difference in fat mass change between the intervention groups with a standard deviation of 3.4 kg (31). A change of -5 seconds in the 400 MW test for the WL group and a change of -52 seconds in the TCWL (32) and based upon these criteria, sample size was calculated as 13 participants. Statistical power was set at 0.80 and alpha was set at 0.05. Planning for a 20% attrition rate, the final sample for the study was 16 participants per group. The sample size calculation was performed using SAS Analyst version 9.2 (Cary, NC).

Results

Twenty-seven participants (WL, n=13; TCWL, n=14) completed the study. The participant flow chart is presented in Figure 1. Baseline participant characteristics for the two groups are presented in Table 1. There were no significant between-group differences for any characteristics at baseline. Attendance to the dietary weight loss session was 86.5% for the WL group and 78.1% for the TCWL group. Attendance to TC sessions was 73.1%. Additionally, there was a significant within-group decrease in caloric intake in the TCWL group ($p<0.05$) but not a between-group difference at baseline or post-intervention (data not shown).

Figure 1
Participant Flow Chart



Anthropometric and body composition changes are presented in Table 2. There was a significant within-group reduction in body weight in both groups "(WL, $p<0.001$; TCWL, $p=0.017$). Within-group differences were also observed in BMI (WL, $p<0.001$; TCWL, $p=0.018$), waist circumference (WL, $p<0.001$; TCWL, $p=0.006$), body fat mass (WL, $p=0.004$; TCWL, $p=0.011$), and percent body fat (WL, $p=0.005$; TCWL, $p=0.010$). There was a significant within-group reduction in FFM in the WL group ($p=0.002$) that was not observed in the TCWL group. The between-group difference in FFM was borderline significant ($p=0.056$).

Table 1
Baseline Subject Characteristics for the weight loss (WL) and Tai Chi plus weight loss (TCWL) groups

Characteristic	WL (n = 13)	TCWL (n = 14)	P value
Age (years)	62.7 ± 6.0	60.4 ± 5.9	0.334
Weight (kg)	90.3 ± 9.0	90 ± 14.4	0.956
BMI (kg/m²)	34.8 ± 2.9	34.3 ± 5.1	0.725
% Body Fat	50.7 ± 3.2	49.2 ± 4.1	0.318
Physical Activity (kcals/week)	10,295 ± 1,980	8,661 ± 1,908	0.558
Caloric Intake (kcals/day)	1,882.7 ± 611.3	2,113.1 ± 1,609.9	0.633

* Values are least square means ± SD.

Table 2 shows the changes in the physical and muscle function measures between groups. While there were no statistically significant differences between groups for any other measures, there was a tendency for a between-group difference in changes in leg strength ($p=0.062$), grip strength ($p=0.070$), TUG ($p=0.069$), and FFM ($p=0.056$). From these measures, leg strength, grip strength, and FFM improved in the TCWL group. Time to complete the TUG test increased for both the WL and TCWL group with a significant within group difference ($p<0.001$) for the WL group. Another significant within group change for the WL group included a significant decrease ($p=0.038$) in their grip strength. Conversely, the TCWL group saw several changes at post intervention including a significant increases in flexibility ($p=0.022$), leg strength ($p=0.003$) and TUG time ($p=0.031$), and muscle quality ($p<0.01$).

Changes in mid-thigh tissue composition are presented in Table 2. There was a significant between-group change in mid-thigh NDM ($p=0.031$). There were no significant changes in mid-thigh adipose tissue area or intermuscular fat area. The WL group had significant within-group changes in mid-thigh muscle area ($p=0.001$) and low density muscle area ($p=0.007$).

Because of the high level of variability in weight loss, data were further analyzed to explore the effects of weight loss within each intervention group on the major outcomes. Table 3 shows changes in non-weight losers, defined as individuals who did not lose 3% or more of their total body weight vs. those who did (weight losers). Significant between-group changes were observed between non-weight losers and weight losers in the WL group in body weight ($p=0.026$) and BMI ($p=0.026$) with weight losers losing more weight and BMI changes compared to non-weight losers. In the TCWL group,

Table 2
Changes in Anthropometrics, Mid-thigh and Body Composition, Physical and Muscle Function With the 16 Week Intervention for the weight loss (WL) and Tai Chi plus weight loss (TCWL) Groups

Outcomes	WL (n = 13)			TCWL (n = 14)			P value
	Pre	Post	Change	Pre	Post	Change	
Weight (kg)	90.3 ± 2.5	86.6 ± 2.7	-3.7 ± 0.9*	90.0 ± 3.9	87.7 ± 4.0	-2.2 ± 0.9*	0.266
% Body Fat	33.5 ± 1.8	28.1 ± 1.1	-5.5 ± 1.8*	34.9 ± 1.2	30.9 ± 1.4	-4.8 ± 1.7*	0.780
Waist Circumference (cm)	107.1± 2.5	102.0 ± 2.9	-5.2 ± 1.2*	106.8 ± 2.6	103.6 ± 3.0	-3.4 ± 1.1*	0.257
Fat Mass (kg)	44.2 ± 1.9	41.8 ± 2.3	-2.3 ± 0.7*	43.0 ± 2.5	41.0 ± 2.6	-2.0 ± 0.7*	0.727
Fat-Free Mass (kg)	44.9 ± 8.6	43.8 ± 7.9	-1.2 ± 0.3*	46.1 ± 1.6	45.8 ± 1.4	-0.2 ± 0.3	0.056
400m Walk (sec)	316.5 ± 13.3	330.8 ± 15.1	14.9 ± 9.1	310.3 ± 8.9	307.7 ± 10.1	-3.2 ± 8.8	0.169
SPPB	10.3 ± 0.2	10.3 ± 0.2	-0.2 ± 0.3	10.8 ± 0.3	10.5 ± 0.4	-0.2 ± 0.3	0.995
Gait Speed (sec)	3.5 ± 0.2	3.5 ± 0.1	-0.1 ± 0.1	3.6 ± 0.1	3.4 ± 0.2	-0.2 ± 0.1	0.492
Chair Stand (sec)	13.8 ± 0.8	14.3 ± 0.8	0.6 ±0.6	12.5 ± 0.6	13.4 ± 0.8	0.7 ± 0.5	0.885
Sit and Reach (cm)	0.3 ± 3.7	2.8 ± 4.5	2.6 ± 2.2	-3.4 ± 1.8	1.9 ± 2.1	5.3 ± 2.2*	0.393
Grip Strength (kg)	26.1 ± 1.2	24.5±1.2	-1.7 ± 0.8*	26.6 ± 1.3	26.9 ± 1.2	0.3 ± 0.8	0.070
Leg Strength (N)	313.5 ± 25.6	324.0 ± 24.3	6.5 ± 13.5	336.3 ± 23.0	375.9 ± 18.0	43.3 ± 13.0*	0.062
Muscle Quality (N/cm²)	1.5 ± 0.1	1.7 ± 0.1	0.1 ± 0.1	1.6 ± 0.1°	1.9 ± 0.1°	0.2 ± 0.1*°	0.150
TUG (sec)	7.8 ± 0.3	8.8 ± 0.3	1.0 ± 0.2*	7.7 ± 0.4	8.2 ± 0.3	0.5 ± 0.2	0.069
Mid-Thigh Muscle Area (cm²)	203.6 ± 3.8	194.5 ± 3.8	-9.3 ± 2.2*	209.8 ± 5.4	205.4 ± 6.1	-4.4 ± 2.2°	0.138
Mid-Thigh NDM Area (cm²)	170.2 ± 5.3	157.0 ± 6.0	-13.2 ± 2.4*	174.0 ± 5.3	169.6 ± 5.9	-5.4 ± 2.4°*	0.031
Mid-Thigh LDM Area (cm²)	32.6 ± 3.8	36.6 ± 3.4	3.9 ± 1.3*	34.9 ± 3.5	35.0 ± 3.5	1.0 ± 1.3°	0.131
Mid-Thigh Intermuscular Fat Area (cm²)	11.8 ± 2.2	12.5 ± 3.6	0.8 ± 1.4	13.9 ± 3.1	14.3 ± 2.9	-0.02 ± 1.4°	0.668

†SPPB = Short Physical Performance Battery; TUG= timed up and go; NDM= normal density muscle (+31 to +100 Hounsfield units); LDM= low density muscle (0 to +30 Hounsfield units). ‡Values are least square means ± SE. °n=13, *p<0.05 within group.

Table 3
Changes in Anthropometric, Body and Mid-thigh Composition, Physical and Muscle Function With the 16-week Intervention: Non-weight Losers vs. Weight Losers by Intervention Group

Outcomes	WL (n = 13) Non Weight Losers (n = 5)	WL (n = 13) Weight Losers (n = 8)	P value	TCWL (n = 14) Non Weight Losers (n = 9)	TCWL (n = 14) Weight Losers (n = 5)	P value
Weight (kg)	-1.5 ± 1.0	-5.0 ± 0.8*	0.026	-0.2 ±0.8	-5.8 ±1.0*	0.001
% Body Fat	-2.5 ± 3.1	-7.4 ± 2.4*	0.246	-1.3 ± 1.2	-11.1 ± 1.7*	0.001
Waist Circumference (cm)	-3.2 ± 1.9	-6.4 ±1.5*	0.226	-1.2 ± 1.0	-7.4 ± 1.3*	0.003
Body Fat Mass (kg)	-1.2 ± 1.3	-3.0 ± 1.0*	0.298	-0.6 ± 0.5	-4.5 ± 0.7*	0.001
Fat-Free Mass (kg)	-0.8 ± 0.6	-1.3 ± 0.5*	0.541	0.2 ± 0.3	-1.2 ± 0.4*	0.017
400m Walk (sec)	13.4 ± 20.6	14.8 ± 16.3	0.958	0.4 ± 6.3	-8.1 ± 8.5	0.442
SPPB	0.2 ± 0.4	-0.1 ± 0.3	0.589	-0.2 ± 0.5	-0.5 ± 0.7	0.655
Gait Speed (sec)	-0.3 ± 0.2	0.2 ± 0.1	0.051	-0.2 ± 0.2	-0.2 ± 0.3	0.870
Chair Stand (sec)	0.2 ± 0.5	0.6 ± 0.4	0.581	0.9 ± 0.9	0.6 ± 1.2	0.846
Sit and Reach (cm)	3.5 ± 3.1	1.9 ± 2.5	0.695	2.7 ± 2.5	10.1 ± 3.4*	0.116
Grip Strength (kg)	02. ± 1.4	-2.8 ± 1.1*	0.150	0.9 ± 0.8	-0.8 ± 1.2	0.293
Leg Strength (N)	1.2 ± 18.1	16.3 ± 14.2	0.529	56.9 ± 16.6*	8.6 ± 22.3	0.111
Muscle Quality (N/cm²)	0.1 ± 0.1	0.2 ± 0.1*	0.330	0.3 ± 0.1°*	0.1 ± 0.1	0.256
Timed up	0.9 ± 0.4*	1.1 ± 0.3*	0.749	0.5 ± 0.3	0.5± 0.3	0.991
Mid-Thigh NDM Area (cm²)	-8.0 ± 3.2*	-16.5 ± 2.5*	0.075	-2.7 ± 3.4°	-9.7 ± 4.3*	0.228
Mid-Thigh LDM Area (cm²)	4.8 ± 2.3	3.5 ± 1.8	0.676	0.3 ± 1.9°	1.8 ± 2.4	0.623
Mid-Thigh Intermuscular Fat Area (cm²)	-1.1 ± 2.4	1.9 ± 1.8	0.362	0.7 ± 1.0°	-1.1 ± 1.2	0.263

†Non weight loser defined as weight loss < 3% of baseline weight; Weight loser defined as weight loss ≥ 3% of baseline weight; NDM = normal density muscle (+31 to +100 Hounsfield units); LDM = low density muscle (0 to +30 Hounsfield units); ‡ Values are least squared means ± SE; * n = 8, * p < 0.05 within group.

weight losers lost significantly more waist circumference (p=0.003), body fat mass (p=0.001), FFM (p=0.017), and percent body fat (p=0.001) compared to non-weight losers. There were no significant between-group changes in any of the mid-thigh tissue measurements between non-weight losers and weight losers in either group. A comparison of TCWL weight losers to WL weight losers yielded no significant differences. In addition, a comparison of TCWL non-weight losers to WL non-weight losers yielded no significant differences. The non-weight losers in this group only had a significant within-group difference in TUG time change, with an increase of 0.92±0.41 seconds (p<0.05). Weight losers, however, experienced significant changes in several measures including a decrease in grip strength ($p<0.05$), and an increase in muscle quality ($p<0.05$). Other significant within group differences include increases in TUG time ($p<0.001$).

Discussion

The main finding of this trial is that Tai Chi does not appear to significantly decrease body fat mass greater than dietary weight loss alone despite significant within-group reductions in body weight. While Tai Chi is considered to be moderate intensity physical activity (12), the intervention only consisted of 135 minutes of Tai Chi per week, which may not have been enough physical activity to promote an additional loss of fat mass.

Another major finding was that there was no additive effect of Tai Chi on the 400 MW time, which is a well-validated assessment of global physical functioning (33). This was unexpected as previous research showed a positive effect of Tai Chi on muscular endurance and aerobic fitness (15, 34). One reason for a lack of significance may have been because this cohort of women was relatively high functioning based on baseline SPPB scores. Previous research has indicated there is a moderate correlation between SPPB scores and time to complete 400 MW in older adults (33). As a result, this could have resulted in a ceiling effect, making significant changes in the 400 MW time difficult to induce. In a 2010 study by Chalé-Rush et al., (35) moderate to vigorous physical activity was positively associated with performance on the SPPB and 400 MW test. Performing greater than 150 minutes of moderate to vigorous physical activity per week was associated with higher scores on both tests while less than 150 minutes of moderate to vigorous physical activity was associated with lower scores. Participants in our study, although sedentary at baseline, did not complete the recommended 150 minutes per week of moderate to vigorous physical activity through the supervised Tai Chi intervention but were encouraged to practice Tai Chi on their own to add minutes to physical activity each week. However, because these minutes were not supervised and due to the very low participation at-home practice as determined by the poor response to recording logs, we did not include them in our minutes per week calculation. Moreover, the modified Yang style Tai Chi may not have been vigorous enough to exhibit the benefits on the SPPB and 400 MW with a metabolic equivalent (MET) level of up to 4 (12). Finally, although speculative, the loss of lean mass in the WL group may have contributed to the apparent (but not significant) worsening in 400 MW performance.

However, the intervention did result in a significant difference in mid-thigh NDM area, with TCWL participants losing less mid-thigh NDM area compared to participants in the WL only group, suggesting a greater retention of "leaner" muscle containing lower lipid concentrations (25) during dietary weight loss. Another study performed by Chomentowski and colleagues (36) observed a significant between-group difference in NDM area in the weight loss group compared to the weight loss plus aerobic exercise group in a population of older, obese men and women. In the present study there was also a tendency towards the preservation of fat-free mass between-groups, suggesting that Tai Chi aids in the preservation of fat-free mass during weight loss. Chomentowski and colleagues (36) also observed a significant between-group difference in fat-free mass, with the weight loss only group losing significantly more fat-free mass than the weight loss plus aerobic exercise group. This type of retention of fat-free mass during weight loss has also been observed in resistance training investigations (10, 37). Preservation of leaner muscle may lead to reductions in disability risk and mobility impairments associated with aging (38).

This is the first study to show evidence of an additive effect of Tai Chi when combined with a behaviorally-based dietary weight loss on leg strength and grip strength. These results suggest that Tai Chi may aid in the preservation of muscle strength during dietary weight loss, an important finding because of the already occurring loss of muscle strength with aging in this population (39). Muscle strength, as measured by leg and grip strength, has been shown to help predict future disability in older adults (39, 40).

To the authors' knowledge, this was also the first study to investigate the effects of Tai Chi on muscle quality calculated using leg strength and thigh muscle area, which allows for an examination of the relationship between muscle mass and function. From this, a positive within-group change was observed in the TCWL group when compared to no change in the WL group. While significant between-group differences were not seen, the results may indicate that Tai Chi helps to preserve muscle function during dietary weight loss. This finding supports previous research (10) on dietary weight loss and resistance training. In that study, muscle quality was preserved after 10-week resistance training plus DASH-induced dietary weight loss intervention older adults (10).

Significant within-group differences were observed in TUG time with both groups demonstrating a surprising worsening of TUG time. While it can be hypothesized that increases in leg strength may have decreased TUG time overall, the reason for the increase in TUG time is unclear. In a study performed by Buchner et al., researchers investigated the relationship between strength and gait speed in older adults and found a nonlinear relationship between strength and gait speed (41). Thus, small changes in physiological capacity, or leg strength, can produce large effects on frail older adults. However, large changes in physiological capacity may have little to no effect on function in higher functioning older adults (41). The population in our study was a relatively healthy and higher functioning, cohort of older women. Therefore even with changes in leg strength, these may have not been large enough to produce significant positive changes on TUG time.

This study had many strengths including a randomized design, a relatively homogenous sample, and objective measures of function and body composition. Despite these strengths, there are some limitations that need to be addressed. First, the length of the intervention was relatively short, but in some cases longer than other interventions in older adults that showed significant changes in body composition with exercise and dietary weight loss (10, 16). Additionally, there was no true control group or a Tai Chi only group, making it difficult to determine the individual effects of Tai Chi. Future studies should include a Tai Chi-only and control groups in order to test the efficacy of the individual and additive effects of Tai Chi. Finally, except for the CT scan assessor, the assessors for the study outcomes were not blinded as to study group, which presents a potential limitation in our study design. However, randomization occurred after baseline testing and most of our outcomes measures were objective in nature, which reduced the chance for human error or bias.

In conclusion, Tai Chi may have the ability to increase leg and grip strength while preserving muscle quality during dietary weight loss, but global physical functioning does not seem to be improved. The addition of Tai Chi also results in a loss of NDM that is less than the loss in the diet-only group with a trend towards the preservation of fat-free mass. Moreover, based on the results of this study, the addition of Tai Chi does not seem to aid in the loss of overall fat mass in obese older women in a weight loss setting. Future studies should examine these intervention strategies in a lower functioning, obese female population as well as when combined with other exercise intervention modalities.

Appendix
Warm-up and Cool-down Protocol

Warm up

Warm up incorporated six simple Qigong movements with four repetitions per movement. All movements were conducted in standing posture with emphasis on continuity, accuracy, and slowness of the motion.

1. With legs slightly apart, arms flexed at the elbows, palms facing upward, and straight back raise up both arms in front of the body to shoulder height, bend knees while bringing arms back to resting position.
2. Raise and open both arms in front of the body while straightening knees, and close arms at the same level while bending knees; after the last repetition lower arms to resting position.
3. Lift arms up sideways and then overhead, flex wrists so palms face upward, while bending knees, lower arms to abdomen with palms facing upward; this is the resting position.
4. Raise arms over the head, palms facing upward, rotate upper body to the left and lean forward, straighten up and rotate back to original position; repeat to the other side.
5. With arms overhead but with palms touching in praying position lower hands down in front of the chest while bending knees, raise hands up back to the overhead position while straightening knees; after the last repetition lower arms to resting position.
6. Bring hands up to the face with elbows pointing downward, rotate wrists so palms are facing outward, fully extend arms to the sides at the shoulder level, rotate wrists so palms are facing up and bring hands back in front of the face.

Stenlund T., Lindstrom B, Granlund M, Burell G. Cardiac rehabilitation for the elderly: Qigong and group discussions. Eur J Cardiovasc Prev Rehabil 2005;12: 5- 11.

Cool down

At the end of each Tai Chi session, there was a 5-minute cool down. Six stretches were selected following American College of Sport Medicine (ACSM) guidelines for physical exercise in older adults with consideration for individual differences.

1. Neck stretch,
2. Upper-back stretch
3. Side stretch
4. Sit and reach
5. Quadriceps stretch
6. Ankle circles

Jones, C.J. & Rose, D.J. Physical activity instruction of older adults. 2005. Champaign, IL: Human Kinetics.

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References

1. Adams KF, Schatzkin A, Harris TB, Kipnis V, Mouw T, Ballard-Barbash R. Overweight, obesity, and mortality in a large prospective cohort of persons 50 to 71 years old. New Eng J Med 2006; 355: 763-778.
2. Sturm R, Ringel JS, Andreyeva T. Increasing Obesity Rates and Disability Trends. Health Affairs 2004; 23(2): 199-205.
3. Cagnacci A, Zanin R, Cannoletta M, Generali M, Caretto S, Volpe A. Menopause, estrogens, progestin, or their combination on body weight and anthropometric measurements. Fertil Steril 2007; 88(6): 1603-1608.
4. Campbell WW, Crim MC, Young VR, Evans WJ. Increased energy requirements and changes in body composition with resistance training in older adults. Am J Clin Nut 1994;60(2): 167-175.
5. Blanck HM, Khan LK, Serdula MK. Use of Nonprescription Weight Loss Products: results from a multistate survey. JAMA 2001;286(8): 930-935
6. St Peter SD, Craft RO, Tiede JL, Swain JM. Impact of Advanced Age on Weight Loss and Health Benefits after Laparoscopic Gastric Bypass. Arch Surg 2005;140(2): 165-168.
7. Appel LJ, Moore TJ, Obarzanek E et al. A clinical trial of the effects of dietary patterns on blood pressure. DASH Collaborative Research Group. N Engl J Med 1997;336:1117-1124.
8. Villareal DT, Apovian CM, Kushner RF, Klein S. Obesity in older adults: technical review and position statement of the American Society for Nutrition and NAASO, The Obesity Society. Obes Res 2005;13(11): 1849-1863.
9. Weinheimer EM, Sands LP, Campbell WW. A systematic review of the separate and combined effects of energy restriction and exercise on fat-free mass in middle-aged and older adults: implications for sarcopenic obesity. Nutrition Reviews 2010;68(7): 375-388.
10. Avila JJ, Gutierres JA , Sheehy ME, Lofgren IE, Delmonico MJ. Effect of moderate intensity resistance training during weight loss on body composition and physical performance in overweight older adults. Eur J Appl Physiol 2010;109(3): 517-525.
11. Straight CR, Dorfman LR, Cottell KE, Krol JM, Lofgren IE, Delmonico MJ. Effects of Resistance Training and Dietary Changes on Physical Function and Body Composition in Overweight and Obese Older Adults. J Phys Act Health 2012;9(6): 875-83.
12. Yeh GY, Wood MJ, Lorell BH et al. Effects of Tai Chi Mind-Body Movement Therapy on Functional Status and Exercise Capacity in Patients with Chronic Heart Failure: A Randomized Controlled Trial. Am J Med 2004;117:541-548.

13. Lan C, Chen SY, Lai JS. Relative exercise intensity of Tai Chi Chaun is similar in different ages and gender. Am J Chin Med 2004;32(1): 151-160.
14. Li JX, Hong Y, Chan KM. Tai Chi: physiological characteristics and beneficial effects on health. Br J Sports Med 2001;35(3): 148-156.
15. Rogers CE, Larkey LK, Keller C. A review of clinical trials of tai chi and qigong in older adults. West J Nurs Res 2009;31(2): 245-279.
16. Dechamps A, Gatta B, Bourdel-Marchasson I, Tabarin A, Roger P. Pilot study of a 10 week multidisciplinary Tai Chi intervention in sedentary obese women. Clin J Sport Med 2008;19(1): 49-53.
17. Delmonico MJ, Kostek MC, Johns J, Hurley BF, Conway JM. Can dual energy X-ray absorptiometry provide a valid assessment of changes in thigh muscle mass with strength training in older adults? Eur J Clin Nutr 2008;62(12): 1372-1378.
18. Newman AB, Simonsick EM, Naydeck BL et al. Association of long-distance corridor walk performance with mortality, cardiovascular disease, mobility limitation, and disability. JAMA 2006;295(17): 2018-2026.
19. Simonsick EM, Montgomery PS, Newman AB, Bauer DC, Harris T. Measuring fitness in healthy older adults: the Health ABC Long Distance Corridor Walk. J Am Geriatr Soc 2011;49(11): 1544-1548.
20. Vasunilashorn S, Coppin AK, Patel KV, et al. Use of the Short Physical Performance Battery Score to Predict Loss of Ability to Walk 400 Meter: Analysis From the InCHIANTI Study. J Gerontol A Biol Sci Med Sci 2009;64(2): 223-229.
21. Guralnik JM, Simonsick EM, Ferrucci L et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994;49(2): M85-M94.
22. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991;39(2): 142-148.
23. Takeshima N, Rogers NL, Rogers ME, Islam MM, Koizumi D, Lee S. Functional fitness gain varies in older adults depending on exercise mode. Med Sci Sports Exerc 2007;39(11): 2036-2043.
24. Delmonico MJ, Ferrell RE, Meerasahib A et al. Blood pressure response to strength training may be influenced by angiotensinogen A-20C and angiotensin II type I receptor A1166C genotypes in older men and women. J Am Geriatr Soc 2005;53(2):204-210.
25. Goodpaster BH, Thaete FL, Kelley DE. Thigh adipose tissue distribution is associated with insulin resistance in obesity and in type 2 diabetes mellitus. Am J Clin Nutr 2000;71(4): 885-892.
26. Goodpaster BH, Carlson CL, Visser M et al. Attenuation of skeletal muscle and strength in the elderly: The Health ABC Study. J Appl Physiol 2001;90(6):2157-2165.
27. Dipietro L, Caspersen CJ, Ostfield AM, Nadel ER. A survey for assessing physical activity among older adults. Med Sci Sports Exer 1993; 25:628-642.
28. Patterson RE, Kristal AR, Tinker LF, Carter RA, Bolton MP, Agurs-Collins T. Measurement Characteristics of the Women's Health Initiative Food Frequency Questionnaire. Ann Epidemiol 1999; 9(3):178-187.
29. Mifflin MD, St Jeor ST, Hill LA, et al. A new predictive equation for resting energy expenditure in healthy individuals. Am J Clin Nutr 1990;51(2):241-247.
30. Thomas GN, Hong AWL, Tomlinson B et al. Effects of Tai Chi and resistance training on cardiovascular risk factors in elderly Chinese participants: a 12-month longitudinal randomized, controlled intervention study. Clin Endocrinol 2005;63:663-669.
31. Villareal DT, Banks M, Sinacore DR, Siener C, Klein S. Effects of weight loss and exercise on frailty in obese older adults. Arch Intern Med 2006;166: 860-866.
32. Kwon S, Perera S, Pahor M et al. What is a meaningful change in physical performance? Findings from a clinical trial in older adults (the LIFE-P study). J Nutr Health Aging 2009;13(6): 538-544.
33. Sayers SP, Guralnik JM, Newman AB, Brach JS, Fielding RA. Concordance and discordance between two measures of lower extremity function: 400 meter self-paced walk and SPPB. Aging Clin Exp Res 2006;18(2):100-106.
34. Audette JF, Jin YS, Newcomer R, Stein L, Duncan G, Frontera WR. Tai Chi versus brisk walking in elderly women. Age Aging 2006; 35: 388-93. Arch Intern Med 2001; 161:1581-1586.
35. Chalé-Rush A, Guralnik JM, Walkup MP, et al. Relationship between physical functioning and physical activity in the lifestyle interventions and independence for elders pilot. J Am Geriatr Soc 2010;58:1918-1924.
36. Chomentowski P, Dube JJ, Amati F et al. Moderate Exercise Attenuates the Loss of Skeletal Muscle Mass That Occurs With Intentional Caloric Restriction-Induced Weight Loss in Older, Overweight to Obese Adults. J Gerontol A Biol Sci Med Sci 2009;64(5): 575-80.
37. Frimel TN, Sinacore DR, Villareal DT. Exercise attenuates the weight-loss-induced reduction in muscle mass in frail obese older adults. Med Sci Sports Exerc 2008;40(7): 1213-9.
38. Koster A, Ding J, Stenholm S et al. Does the Amount of Fat Mass Predict Age-Related Loss of Lean Mass, Muscle Strength, and Muscle Quality in Older Adults? J Gerontol A Biol Sci Med Sci 2011;66(8): 888-95.
39. Rantanen T, Guralnik JM, Foley D, Masaki K, Leveille S, Curb JD, White L. Midlife hand grip strength as a predictor of old age disability. JAMA 1999;281(6):558-560.
40. Bouchard DR, Héroux M, Janssen I. Association between muscle mass, leg strength, and fat mass with physical function in older adults: influence of age and sex. J Aging Health 2011;23(313):314-328.
41. Buchner DM, Larson EB, Wagner EH, Koepsel TD, de Lateur BJ. Evidence for a non-linear relationship between leg strength and gait speed. Age Ageing 1996;25(5):386-391.