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Effectiveness of Tai Chi on Cardiac Autonomic Function and Symptomatology in Women With Fibromyalgia: A Randomized Controlled Trial

Alexei Wong, Arturo Figueroa, Marcos A. Sanchez-Gonzalez, Won-Mok Son, Oksana Chernykh, and Song-Young Park

The present study examined the effects of a 12-week Tai Chi (TC) training regimen on heart rate variability (HRV), symptomatology, muscle fitness and body composition in women with fibromyalgia. Participants were randomly assigned to either a TC training group (n = 18) or a control group (n = 19). HRV, symptomatology, muscle fitness and body composition were measured before and after 12 weeks. There were significant decreases ($p < 0.05$) in sympathovagal balance (LnLF/LnHF), sympathetic tone (LnLF, nLF), pain, and fatigue, and significant increases ($p < 0.05$) in parasympathetic tone (LnHF, nHF), strength and flexibility following TC compared with no changes after control. The changes in LnLF and LnLF/LnHF were correlated with changes in pain. There were no significant changes in HR, sleep quality and body composition after TC or control. TC may be an effective therapeutic intervention for improving sympathovagal balance, pain, fatigue, strength and flexibility in women with fibromyalgia.

Keywords: sympathovagal balance, pain, fatigue, strength, flexibility

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Fibromyalgia (FM) is an idiopathic disease affecting approximately 3% of the world population, primarily diagnosed in middle- aged women (Queiroz, 2013). Although FM is mainly characterized by chronic pain and fatigue, reduced muscular strength and flexibility are common symptoms associated with the presentation of the disorder (Olsen & Park, 1998). Interestingly, the etiology and underlying mechanism of FM are not completely understood, but previous findings suggest that autonomic dysfunction may explain some of the FM symptoms (Furlan et al., 2005; Martinez-Lavin, 2004; Raj, Brouillard, Simpson, Hopman, & Abdollah, 2000).

Heart rate variability (HRV), the beat-to-beat variation in R-R intervals, is a non-invasive tool for the evaluation of cardiac autonomic function. Compared to age-matched healthy individuals, patients with FM have an attenuated HRV which is associated with low parasympathetic (vagal) and high sympathetic activity, leading to an increased sympathovagal balance (the relationship between sympathetic and vagal activity) (Cohen et al., 2000, 2001; Furlan et al., 2005; Martínez-Lavín, Hermosillo, Rosas, & Soto, 1998). HRV indexes in the frequency domain are the low-frequency (LF, sympathetic) power, high-frequency (HF, vagal) power, and the LF/HF ratio, which indicates the sympathovagal balance (Pagani et al., 1986). An increased sympathovagal balance reflects predominance of sympathetic activity.

Therefore, HRV is a worthwhile target intervention in individuals with FM. Although traditional exercise (both aerobic and resistance) has been shown to effectively improve HRV parameters and FM symptoms (Figueroa, Kingsley, McMillan, & Panton, 2008; Sañudo, Carrasco, de Hoyo, Figueroa, & Saxton, 2015), most FM patients display a decline in adherence to traditional exercise and continue to experience considerable pain and fatigue years after the original diagnosis ultimately requiring medication to control their symptoms (Dobkin, Abrahamowicz, Fitzcharles, Dritsa, & Da Costa, 2005; Jones & Liptan, 2009). A long-term adherence to moderate and high intensity exercise is low in individuals with FM (Busch et al., 2011). Thus, new approaches are needed to improve HRV and clinical symptoms in patients with FM, which will ultimately improve their physical and emotional functioning lead- ing to a better quality of life.

Tai Chi (TC) is a form of ancient Chinese martial art which integrates slow movements, controlled breathing, and mental concentration. TC training is safe for special populations (Busch et al., 2011; Chang et al., 2008; Sato, Makita, Uchida, Ishihara, & Masuda, 2010) and has been found to decrease pain and fatigue in addition to other FM related symptoms (Jones et al., 2012; Mist, Firestone, & Jones, 2013; Wang et al., 2011). However, the potential role of TC training on HRV variability is largely unexplored. Two previous studies reported no change in resting HRV parameters when TC training was added to a cardiac rehabilitation regimen (Chang et al., 2008; Sato et al., 2010). In contrast, Audette et al. (2006) showed that 12 weeks of TC training decreased resting sympathetic and increased vagal activity in elderly women without FM. Yet, the effects of TC training on HRV in individuals with FM remains unknown. Therefore, the purpose of this study was to evaluate the effects of TC training on cardiac autonomic function in women with FM. We hypothesized that TC training would improve our primary outcome of HRV through improvements in sympathovagal balance, and the secondary outcomes measures of FM symptoms, strength and flexibility.

Methods

Participant

Women with FM from the Busan, Korea area were recruited as potential participants. FM was defined according to the American College of Rheumatology guidelines (Wolfe et al., 1990). Participants were excluded if they had pulmonary, cardiovascular, renal, adrenal, pituitary, severe psychiatric, thyroid diseases and the use of hormone replacement therapy during the 6 months prior the study. Participants were also excluded if they had any medication changes in the previous year. In addition, those who attended to psychological or physical therapy, had a history of steady exercise or received exercise training in the last year, were excluded to avoid potential confounders with the present trial. All participants received complete information about the study design and provided written informed consent. All protocols were approved by the Institutional Review Board of the Public Institutional Review Board designated by Ministry of Health and Welfare (PNU IRB/2016-56-HR), registered in Clinicaltrials.gov (NCT03016585) and carried out in accordance with the Declaration of Helsinki.

Study Design

Before baseline measurements, participants were familiarized with the study tests and procedures. Using a two-armed, parallel-design, individually randomized trial participants were randomly assigned to one of the following groups: TC training or control. Participants were allocated using computer-generated blocks (10 randomized group assignments per block) and stratified by disease duration (≤5 or >5 years). Laboratory personnel were blind to the group assignment. Measurements were collected at baseline and after 12 weeks during the same time of day (±1 hour) in the morning following an overnight fast and abstinence from caffeinated drinks, alcohol, and between 48 and 72 hours after the last TC session. Participants on medication (Table 1) were asked to discontinue their medication the night and the morning before testing. All premenopausal women (n = 8) were examined during the early- to mid-follicular (days 1–10) and late-luteal phases (>day 19) of the menstrual cycle to avoid possible effects of endogenous estrogens on autonomic function (Saeki, Atogami, Takahashi, & Yoshizawa, 1997). Participants in both groups were instructed not to alter their regular lifestyle habits (e.g., dietary patterns, exercise, medications) during the study.

Cardiac Autonomic Modulation

Measurements were conducted in a noise-free and temperature controlled room (23 ± 1 °C) in the supine position after at least 10 min of rest. HRV was collected using the SA-2000E model (Medicore, Korea, SA-2000E) according to the guidelines of the task force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996). All R–R intervals were inspected for artifacts and premature beats. HRV was quantified from 5-min segments free from artifacts. The autoregressive model was used to estimate the power spectrum of HRV in the total power (TP, 0.00–0.40 Hz) and its main components: LF (0.04–0.15 Hz) and HF (0.15–0.40 Hz). TP of HRV is an estimation of the global activity of the autonomic nervous system. The HF power is a marker of cardiac parasympathetic activity (Pagani et al., 1986; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). The LF component of HRV in absolute units is mediated by both sympathetic and parasympathetic activities and may also reflect baroreflex function (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). The HF and LF were normalized (nHF and nLF) and expressed as a percentage of the TP (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). The ratio of LF to HF (LF/HF) has been suggested as a means to quantify the relationship between sympathetic and parasympathetic nerve activities (sympathovagal balance) (Pagani et al., 1986). We followed the standards for the measurement and interpretation of the HRV (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Participants' breathing rate was controlled throughout the measurements (12 breaths/min) using a metronome.

Table 1 Participant's Characteristics and Medication Use Before and After 12 Weeks of TC or Control

Variable	TC (n=17)		Control (n=14)	
	Before	After	Before	After
Age (years)	51 ± 2	–	51 ± 2	–
Disease duration (years)	8 ± 1	–	9 ± 1	–
Anthropometry				
Height (m)	1.53 ± 0.01	–	1.56 ± 0.02	–
Body weight (kg)	54.4 ± 1.7	53.8± 1.7	54.4 ± 1.9	53.9 ± 1.9
BMI (kg/m^2)	23.1 ± 0.5	22.9 ± 0.5	22.2 ± 0.6	22.0 ± 0.5
Fat Free Mass (kg)	37.1 ± 1.3	37.0 ± 1.3	37.2 ± 1.3	36.8 ± 1.3
Fat mass (kg)	17.3 ± 0.7	16.8 ± 0.6	17.2 ± 0.8	17.1 ± 0.8
Muscle fitness				
Leg strength (kg)	35.2 ± 1.5	39.7 ± 1.8$^{\#,\dagger}$	35.6 ± 1.7	35.7 ± 1.9
SRS (cm)	19 ± 0.6	23 ± 0.6$^{\#,\dagger}$	19 ± 1.2	19 ± 1.0
Symptomatology				
Pain	7.5 ± 0.4	5.3 ± 0.3$^{\#,\dagger}$	7.3 ± 0.4	7.0 ± 0.5
Fatigue	8.2 ± 0.3	5.8 ± 0.2$^{\#,\dagger}$	8.4 ± 0.2	8.5 ± 0.3
Sleep Quality	7.9 ± 0.3	7.8 ± 0.3	7.8 ± 0.6	7.6 ± 0.4
Medication Use				
Analgesics	12	–	11	–
Anticonvulsants	3	–	3	–
Antidepressants	7	–	5	–
Benzodiazepines	2	–	2	–
Diuretics	1	–	2	–
Gastric Antacid	2	–	3	–
Lipid Lowering	0	–	2	–
Muscle Relaxants	2	–	3	–

Abbreviations: BMI = body mass index; SRS = sit and reach score; TC = Tai Chi training.
Note. Data are mean ± standard error of the mean.
$^{\#}p < 0.01$ different than before; $^{\dagger}p < 0.05$ different than no treatment.

Fibromyalgia Symptomatology

FM patients filled visual analog scales (VAS) to evaluate symptom severity before and after 12 weeks. Pain, fatigue and sleep quality were evaluated using a 10-point graded scale; 0 indicated absence of symptoms and 10 indicated the worst symptoms (Carlsson, 1983; Salaffi, Sarzi-Puttini, Ciapetti, & Atzeni, 2009).

Flexibility

Flexibility was measured using the Sit and Reach Test (Thompson, Arena, Riebe, & Pescatello, 2013). Participants sat on the floor, with their back and head against a wall and with the legs being held straight by a researcher. They put both hands on the device, with arms held straight. In the position, zero point of the device was set. They were then asked to bend forward slowly and reach as far as possible. The best of two trials was recorded as the sit and reach score (SRS) at each time point (Thompson et al., 2013). All flexibility tests were conducted by the same researcher who was unaware of group assignment.

Muscle Strength

Muscle strength was assessed by the one repetition maximum (1RM) test using a leg extension machine (Cybex 6000; Lumex, Albertson, NY). Women were familiarized with the exercise and lifting technique before 1RM measurement, which was achieved within five attempts. The 1RM was considered the highest weight lifted using the proper form. Following a minimum of 72 hours, the 1RM was verified in all participants. The highest measurement from the two days of testing was considered the 1RM. After 12 weeks, the 1RM was performed 48–72 hours after the last exercise session following the same procedures. All 1RM tests were conducted by the same researcher who was unaware of group assignment.

Anthropometry and Body Composition

Body composition was assessed using an eight-polar tactile- electrode impedance meter (InBody 720; Biospace, Seoul, Korea), which simultaneously recorded bodyweight, fat mass and fat free mass (Bedogni et al., 2002). Height was measured with a stadiometer to the nearest 1 cm. Body mass index (BMI) was calculated as weight/height^2.

Tai Chi Exercise Regimen

Participants in the TC group participated in supervised sessions three times a week for 12 weeks. The TC training was led by an experienced instructor who was trained in TC. In the first session, the instructor explained the theory behind TC and its procedures providing participants with printed materials on its principles and techniques. In subsequent sessions, participants practiced, under supervised instruction, 10 forms from the classic Yang style of TC (Wolf, Coogler, & Xu, 1997). The TC sessions lasted approximately 55 minutes and included a 10-minute warm up, 40 minutes of practice and exercise finalizing with a 5-minute cool-down period. During TC practice, the participant's heart rate (HR) was 40-50% of the HR reserve as they imitated the instructor's motion at the same speed. HR during the TC training sessions was monitored using a polar device (Electro, Oy, Kempele, Finland). The TC training protocol was adapted from prior literature in special populations (Audette et al., 2006; Sato et al., 2010), including women with FM (Jones et al., 2012; Mist et al., 2013; Wang et al., 2011).

Control Group

Participants in the control group did not participate in any super- vised or unsupervised exercise protocol and were asked to maintain their regular lifestyle habits (dietary patterns, medications, etc) for the duration of the study. They did not receive any therapy or benefit.

Statistical Analysis

Data were examined for normality with the Shapiro–Wilk test. Since TP, LF, HF, LF/HF were not normally distributed, a logarithmic transformation (Ln) was performed for these variables.

Student's *t*-test was used to detect potential differences in parameters between groups at baseline. A two-way analysis of variance with repeated measures (group [control and TC] × time [before and after 12 weeks]) with Bonferroni correction was used to determine the effects of the TC intervention over time. When a significant interaction or main effect was noted, univariate analysis was used for post hoc comparisons. Statistical significance was defined a priori as $p < 0.05$. Pearson's correlation coefficients were used to examine associations between changes in variables with significant interactions. Statistical analyses were performed using SPSS version 21.0 (SPSS Inc., Chicago, IL). Power analysis calculation determined a minimum sample size of at least 24 to establish 80% sensitivity in detecting 3%–5% variability between the groups (TC vs control) on the primary study outcome of HRV, including its components of LF, HF, LF/HF (Audette et al., 2006; Figueroa et al., 2008).

Results

Between January and May of 2016, we screened 56 women with FM. Of these only 41 qualified for baseline evaluation. Four women in this group were excluded for various reasons, and the 37 eligible were randomized to either the TC or control groups. After randomization, five participants in the control group dropped out of the study, four for personal reasons and one due to an adverse event (shingles). In the TC group, one participant dropped out of the study for personal reasons. There were no adverse effects or injuries reported. Data are presented for the 31 participants that successfully completed our 12-week intervention; 17 and 14 participants in the TC and control groups, respectively. Figure 1 maps the subject flow through the trial. The attendance to the TC sessions was 97.3% ± 1.4%. Women taking prescribed medications had stable doses for at least one year (Table 1) and had no changes in their prescriptions during the study.

Participant's characteristics before and after 12 weeks for the control and TC groups are presented in Table 1 (Data are shown as means ± SE). Baseline parameters between the two groups were not significantly different ($p > 0.05$).

Table 2 shows changes from baseline to 12 weeks in the two treatment groups for the primary and secondary outcomes measures. At 12 weeks the TC group had a significantly greater decrease in pain than did the control group [−2.2 vs. −0.3 points (95% confidence interval {CI},−2.9 to −1.7 vs. −0.8 to 0.2); $p = 0.006$]. Similarly, at 12 weeks the TC group had a significant reduction in fatigue than the control group [−2.4 vs. 0.1 points (95% CI, −2.7 to −2.0 vs. −0.6 to 0.9); $p = 0.001$]. Sleep quality did not change significantly in either group [−0.2 vs. −0.2 points (95% CI, −1.2 to 0.8 vs −1.3 to 0.9); $p > 0.05$].

Muscle strength and flexibility improved. Muscle strength improved significantly in the TC group compared to the control group [4.5 vs. 0.1 kg (95% CI, 2.7 to 6.3 vs. −0.7 to 0.9); $p = 0.001$]. SRS improved significantly in the TC group compared to the control group [3.8 vs. −0.1 cm (95% CI, 3.0 to 4.6 vs. −1.2 to 1.0); $p = 0.001$].

At 12 weeks, the TC group had greater decreases in LnLF than the control group [−0.8 vs. 0.3 ms^2 (95% CI, −1.0 to −0.6 vs. 0.1 to 0.5); $p = 0.016$]. In addition, the TC group had greater improvement in parasympathetic activity as measured by the change in LnHF [0.7 vs 0.1 ms^2 (95% CI, 0.5 to 0.8 vs −0.1 to 0.3); $p = 0.039$]. The change from baseline to 12 weeks in LnLF/LnHF also differed significantly between the two groups [−0.3 vs 0.1 (95% CI, −0.4 to −0.2 vs. −0.1 to 0.3); $p = 0.028$].

Other autonomic variables at baseline and after 12 weeks for the control and TC groups are presented in Table 3. There was a significant group × time interaction ($p < 0.05$) for nLF such that it significantly decreased ($p < 0.01$); and nHF which significantly increased ($p < 0.01$) following TC compared to no changes after control. There were no significant changes in heart rate and TP after TC or control. Additionally, there were no significant changes in weight, BMI, fat free mass, fat mass in the TC or control groups during the 12 week study period (Table 1). Correlation analysis revealed a significant positive relationship between the changes in LnLF and LnLF/LnHF with pain ($r = 0.68$, $p < 0.05$) in the TC group. No other significant correlation was observed between changes in any other HRV variables and FM symptoms.

Table 2 Change Between Groups on Primary and Secondary Outcome Measures After 12 Weeks of TC or Control

Outcome	**TC (*n*= 17)**	**Control (*n*=14)**	***p*-value**
	Mean (95% CI)	**Mean (95% CI)**	
LnLF (ms^2)	-0.8 (-1.0 to -0.6)	0.3 (0.1 tp 0.5)	0.016
LnHF (ms^2)	0.7 (0.5 to 0.8)	0.1 (-0.1 to 0.3)	0.039
LnLF/LnHF	-0.3 (-0.4 to -0.2)	0.1 (-0.1 to 0.3)	0.028
VAS Pain	-2.2 (-2.8 to -1.7)	-0.2 (-0.8 to 0.2)	0.006
VAS Fatigue	-2.4 (-2.7 to -2.0)	0.1 (-0.6 to 0.9)	0.01
VAS Sleep	-0.2 (-1.1 to 0.8)	-0.2 (-1.3 to 0.9)	NS
Strength (kg)	4.5 (2.7 to 6.3)	0.1 (-0.7 to 0.9)	0.001
SRS (cm)	3.8 (3.0 to 4.6)	-0.1 (-1.2 to 1.0)	0.001

Abbreviations: HF = high frequency; LF = low frequency; LF/HF = LF to HF ratio; Ln = natural logarithm; NS = non-significant; SRS = sit and reach score; TC = Tai Chi training; VAS = visual analog scale.

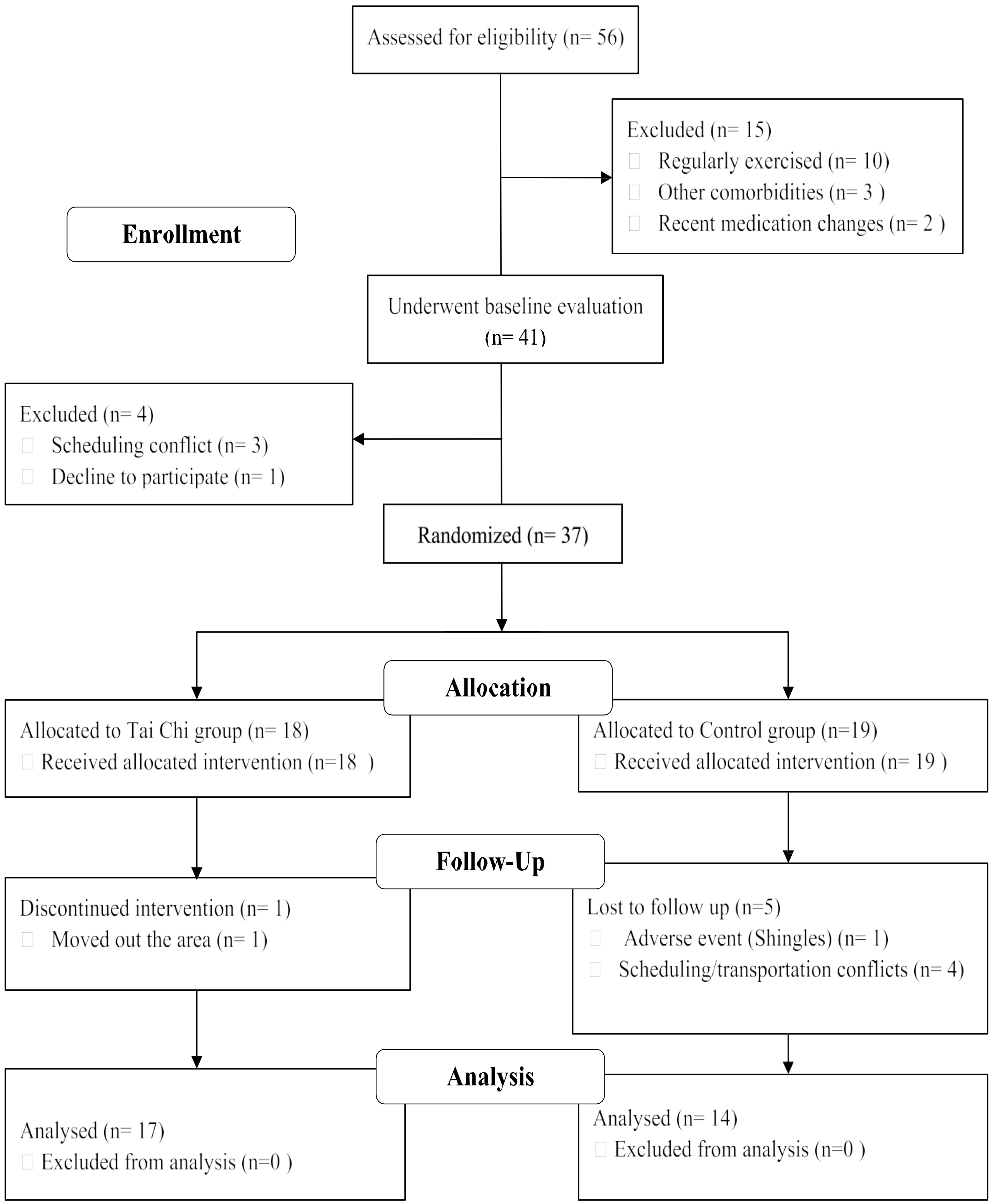

Figure 1 — Participants flow diagram.

Table 3 Heart Rate and Heart Rate Variability Measurements Before and After 12 Weeks of TC Training or Control

	TC (n=17)		Control (n=14)	
Variable	Before	After	Before	After
Heart Rate (bpm)	73 ± 2	72 ± 2	72 ± 2	72 ± 2
LnTP (ms^2)	6.2 ± 0.3	6.1 ± 0.2	6.3 ± 0.3	6.2 ± 0.3
nLF (%)	64.9 ± 5.0	55.1 ± 5.2$^{†,\#}$	63.1 ± 5.0	63.6 ± 5.0
nHF (%)	35.1 ± 5.1	44.8 ± 5.1$^{†,\#}$	36.9 ± 5.1	36.3 ± 5.1
LnLF (ms^2)	4.8 ± 0.2	4.0 ± 0.3†,*	4.7 ± 0.2	4.9 ± 0.3
LnHF (ms^2)	3.8 ± 0.2	4.5 ± 0.3†,*	4.1 ± 0.2	4.2 ± 0.2
LnLF/LnHF	1.3 ± 0.1	0.9 ± 0.1†,*	1.1 ± 0.1	1.2 ± 0.1

Abbreviations: HF = high frequency; LF = low frequency; LF/HF = LF to HF ratio; Ln = natural logarithm; *n* = normalized to TP; TC = Tai Chi; TP = total power.
Note. Data are mean ± standard error of the mean.
$^*p < 0.05$; $^\#p < 0.01$ different than before; $^†p < 0.05$ different than no treatment.

Discussion

The aim of this study was to evaluate the effect of a 12-week TC training on HRV parameters, fitness, and symptom severity in women with FM. The results of this study indicated that TC training improves HRV, primarily by decreasing sympathovagal balance. Additionally, pain and fatigue were significant improved after the TC intervention. The present findings suggest that addition of TC as part of an integrated program for treating FM could potentially alleviate FM symptomatology, decrease cardiac risk, and improve quality of life in patients with FM.

Women in the TC group showed evidence of beneficial changes in HRV, with a concurrent increase in parasympathetic and decrease in sympathetic indices after the intervention. These findings suggest that the intensity, frequency and duration of the TC training were effective for improving sympathovagal balance due to a shift towards cardiovagal predominance. Only a few studies have addressed the effects of TC on HRV. Chang et al. (2008) found increases in HF and decreases in LF and LF/HF 30 minute after recovery from acute single TC session in patients with coronary artery disease following the addition of a TC regime to their standard care for a period of 9 months. Moreover, Lu et al. showed a decrease in LF/HF at 30 and 60 minutes following acute TC session in subjects with 1.9 years of TC experience when compared to subjects without TC experience (Lu & Kuo, 2003). Consistent with our findings, a previous study has documented an increase in nHF power concurrently with decreases in nLF and LF/HF after a TC training regimen in elderly women without FM (Audette et al., 2006). However, the present study is the first to report such changes in women with

FM after a TC intervention, in conjunction with improvements in FM symptoms (pain and fatigue). The current results have important clinical implications because a reduced sympathovagal balance decreases myocardial workload through reductions in chronotropy, inotropy and after- load, leading to a decrease in cardiac risk (Thayer, Yamamoto, & Brosschot, 2010).

In the present study we found that TC did not change HR. This finding is in agreement with a previous study that found no change in resting HR after 12 weeks of TC training in elderly women (Audette et al., 2006). In contrast, Hong, Xian, and Robinson (2000) reported lower resting HR in a group of men with 13.2 years of TC experience, as compared to age matched men. These findings were corroborated by another cross-sectional study by Lu et al. which showed a significantly longer resting R-R intervals in 20 subjects with two years of TC experience, when compared to 20 control subjects of similar age and cardiopulmonary function (Lu & Kuo, 2003). Thus, it appears that longer training periods are required for TC training induced resting HR or R-R interval alterations.

Improvements in pain and fatigue were observed in the TC training group. Our results are consistent with those of previous randomized and non-randomized TC trials in FM (Romero-Zurita et al., 2012; Taggart, Arslanian, Bae, & Singh, 2003; Wang et al., 2011). Our findings are also consistent with other different exercise interventional studies which support the beneficial effects of physical exercise training and mind-body practice for symptom management in FM (Astin et al., 2003; Creamer, Singh, Hochberg, & Berman, 2000; Figueroa et al., 2008; Kingsley, McMillan, & Figueroa, 2010; Ramel, Bannuru, Griffith, & Wang, 2009; San˜udo et al., 2015). It appears that exercise interventions, such as TC, evoke improvements in pain and fatigue by increasing blood flow to the skeletal muscle, the production of endorphins and activation of the descending inhibitory pathways that are impaired in FM (Jones & Liptan, 2009). The changes in sleep quality were not statistically significant in the present study. In contrast to our results, Wang et al. previously reported improvements in sleep quality after a 12-week TC regime in a group of 33 individuals with FM (Wang et al., 2011). It is likely that the present study was insufficiently powered to detect statistically significant changes in sleep quality. Nonetheless, our findings suggest that TC training could be used for the management of cardiac autonomic dysfunction, pain and fatigue in women with FM.

One of the aims of this study was to evaluate whether the improvement in symptoms of FM is related to the changes in HRV. Indeed, the results revealed an interesting correlation between the improvement in LnLF and LnLF/LnHF and the improvement in pain. These findings indicate that the participants who showed higher decrease in pain were the ones who showed higher decrease in the cardiac sympathetic activity and sympathovagal balance. Although it is not possible to infer causality from correlation, i.e., whether the decrease in sympathetic activity at rest leads to the improvement of pain or vice versa, the present findings are consistent with the model proposed by Martínez-Lavín et al. (1998) in which the alterations in HRV due to predominance of the LF band oscillations may explain many common symptoms in patients with FM. The authors proposed that exaggerated sympathetic modulation of the sinus node can lead to chronic pain and fatigue.

Impaired microvascular function in individuals with FM leads to a reduction in muscle oxygen delivery causing sensitization of pain receptors, alterations in muscle metabolism, a decoupling of the excitation–contraction process and hence increased fatigue as well as decreased muscle strength and flexibility (Jones & Liptan, 2009; Williams & Clauw, 2009). The TC training program was effective for improving flexibility and lower-body strength. Similarly, Carbonell-Baeza et al. (2011) found improvements in the SRS in men with FM after 16 weeks of TC training. Li and Manor (2010) observed improvements in lower-body strength in patients with peripheral neuropathy after 24 weeks (3 times/week) of TC training. Likewise, concurrent improvements in both lower body strength and flexibility have been reported in middle-age women with FM by Romero-Zurita et al. (2012). In that study, positive changes in the SRS score and the chair stand test (a measure of lower body strength) were reported after a 28-week TC regime (3 times/week). The need for strategies that favor the simultaneous development of strength and flexibility in women with FM , such as TC, has been previously highlighted by Jones et al. since strength training produces high attrition rates and there is not yet enough evidence that supports the use of flexibility training as a single modality in FM (Jones & Liptan, 2009). Additionally, decreased muscular strength and flexibility may contribute to reduced functional capacity in women with FM (Okumus, Gokoglu, Kocaoglu, Ceceli, & Yorgancioglu, 2006; Soriano-Maldonado et al., 2015); therefore, our study could have important consequences for the performance of activities of the daily living in this population.

The mechanisms by which TC might affect HRV in women with FM remain unknown. However, increases in baroreflex sensitivity and nitric oxide (NO) levels could be related to the improvements of HRV in our study. A previous study by Sato et al. (2010) found that spontaneous baroreflex sensitivity improves when TC is added to a cardiac rehabilitation regimen in patients with coronary heart disease. Additionally, several lines of evidence point out that NO may play a role in cardiac autonomic function by increasing vagal and decreasing sympathetic activity (Conlon, Collins, & Kidd, 1996; Hare et al., 1995; Zanzinger, Czachurski, & Seller, 1995). In fact, a 12 weeks TC training has been shown to increase circulating NO in patients with essential hypertension (Pan, Zhang, & Tao, 2015). Hence, increases in NO via TC training may, to some extent, improve cardiac autonomic activity. The interesting findings of the present study should be interpreted in the context of the following limitations. We did not measure baroreflex sensitivity, plasma catecholamines and blood pressure, which would have aid to explain our results. Also, the number of participants in both groups was relatively small. We evaluated cardiac autonomic function in middle-age women with FM and, hence, we cannot generalize our results to other populations. The matched parallel control group in the present study was used to control different effects that could have influenced our results. However, it could be argued that the interpretation of our findings may not completely account for some unspecific effects of observation (i.e., the Hawthorne effect), which is also the case of the vast majority of studies in the medical field.

In summary, the results of this study demonstrated that 12 weeks of TC training improved sympathovagal balance through increases in parasympathetic tone and a decreased sympathetic activity in middle-age women with fibromyalgia. Additionally, there were improvements in strength, flexibility, pain and fatigue after the TC training intervention. The improvement in pain perception may be with a decrease in sympathetic activity and sympathovagal balance after TC exercise training. Further research, aimed at investigating HRV indices with a larger number of participants, longer training periods of TC training and associations with FM symptom severity, are clearly warranted.

Acknowledgments

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