**Community Based Mind-body Meditative Tai Chi Program and Its Effects
on Improvement of Blood Pressure, Weight, Renal function, Serum
Lipoprotein, and Quality of Life in Chinese Adults with Hypertension**

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Running head: hypertension

Abstract

Obesity, metabolic syndrome, dyslipidemia, and poor quality of life are common conditions associated with hypertension, and incidence of hypertension is age dependent. However, an effective program to prevent hypertension and to improve biomedical factors and quality of life has not been adequately examined or evaluated in Chinese older adults. This study aims to examine the effectiveness of a Tai Chi program to improve health status in participants with hypertension and its related risk factors such as dyslipidemia, hyperglycemia, and quality of life in older adults in China. A randomised study design was used. At the conclusion of the intervention 266 patients remained in the study. Blood pressure and biomedical factors were measured according to the World Diabetes Association standard 2002. A standardised quality of life measure was used to measure health related quality of life. It was found that a Tai Chi program to improve hypertension in older adults is effective in reducing blood pressure, body mass index, maintaining normal renal function and improving physical health of health related quality of life. It did not improve existing metabolic syndrome levels lipid level (dyslipidemia) or fasting glucose level (hyperglycemia) to prevent further deterioration of the biomedical risk factors. In conclusion, Tai Chi is effective in managing a number of risk factors associated with hypertension in Chinese older adults. Future research should examine a combination of Tai Chi and nutritional intervention to further reduce the level of biomedical risks.

Keywords: Chinese adults, hypertension, blood pressure, weight, serum lipoproteins, health related quality of life

Despite the potential of Tai Chi to manage conditions such as heart failure (1), there have been few studies examining its potential to improve health and manage patients with hypertension in China. Most studies that have been conducted had short term interventions, ranging from 8 to 16 weeks (2-4) and there are no studies that have examined the longer term effects (e.g. > 12 months) of Tai Chi to improve health in hypertension patients. The purpose of this study was to examine the effectiveness of a 12 month mind-body meditation intervention program on improvement of blood pressure, body mass index, dyslipidemia, and quality of life in Chinese adults with hypertension. It was hypothesised that hypertension participants participating in Tai Chi would have:

- 1) Significant reduction in blood pressure and body mass index (BMI) levels;
- 2) Significant improvement in biochemical markers including total cholesterol, LDL, HDL, triglycerides, and eGFR; and
- 3) Improved psychosocial outcomes including quality of life.

METHODS

This study used a randomized study design to investigate the effectiveness of mind-body meditation approach on improvements blood pressure, BMI, lipid profiles, and quality of life factors associated with hypertension, and age-related chronic disease. The study population consisted of a sample of Chinese adults aged 45–80 years in Changshu in Jinagsu Province, and Fang Shan District in Beijing, China. Both Changshu and Fangshan were selected as the study site because of its well developed economic status in China, which has resulted in dramatic changes in the lifestyle, dietary and disease patterns of its residents in recent years. The trial was registred in International Standard Randomized Controlled Trial with Number ISRCTN 87289137 (Web address: <http://www.controlled-trials.com/ISRCTN87289137>). Ethical approval was obtained from the Jiangsu Province Changshu Center for Disease

Control and Prevention (CDC) and Fang Shan CDC Research Review Committee in China and the Griffith University Research Ethics Committee in Australia.

To be included in the study participants had to be aged 45 or older and diagnosed with hypertension. This age group was chosen because they have an increased prevalence of hypertension (5, 6), providing a unique opportunity to observe risk factors associated with this condition. Participants also had to be resident in Changshu city of Jiangsu Province or in the Fangshan District of Beijing, within 20 kilometers of the metropolitan area. Participants who met these criteria were randomly selected from medical records located in the Changshu CDC and Fang Shan CDC. They then participated in a clinical interview conducted by trained physicians at the CDC or the Bureaus of Health in Changshu City and Fangshan District in Beijing. At the same time a medical examination was conducted and a medical history taken regarding experience of chronic diseases. Participants were also asked to provide a biomedical blood sample and complete a survey measuring HRQoL and demographic factors. People were excluded from the study if they had a neurological impairment or could not provide consent to participate.

Of the 350 people who met the inclusion criteria, 300 participated in the clinical interview, blood sample test and survey, representing a high response rate of 86%. All participants presented with hypertension at the time of data collection or were on hypertensive medication. Equal numbers of participants were randomly assigned to the Tai Chi intervention group (n=150) and control group (n=150) by the three physicians using a simple randomization method (See Figure 1). Researchers who conducted the statistical analysis and who conducted the laboratory tests were not aware of the allocation status of the participants. The sample met the statistical power requirement for a moderate effect size on systolic blood pressure of 0.47 (1).

Participants in the intervention group attended Tai Chi training for 12 months between April 2012 – April 2014, while control group participants were active controls who attended non-exercise related activities such as reading and learning computer software applications for the same period. In the Tai Chi group, participants were taught a variety of meditation techniques by an experienced trainer including breathing, balance, flexibility, concentration, calming and stress reduction techniques. Both Tai Chi and control group participants participated in group activities three hours per week, and two hours practice by themselves at home.

Following the completion of interview, data were collected using a combination of biomedical assessments and standardized questionnaires as part of a free physical examination. Participants were required to fast overnight. Fasting venous blood samples were then collected and analyzed for biomedical indicators, including total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), triglycerides (TG), fasting glucose, and serum creatinine (Scr). Participants, wearing light indoor clothing without shoes, were then weighed to the nearest 0.1 kg and measured to the nearest 0.1cm in height. BMI was calculated as $\text{weight (kg)/height (m)}^2$. The China CDC and Ministry of Health adopted the World Diabetes Federation criteria (7), which is based on the BMI, and defines overweight as 25.0–29.9 kg/m² and obesity as ≥ 30.0 kg/m². Waist (cm) girth was measured at the minimum circumference between the iliac crest and the rib cage using an anthropometric tape over light clothing. Abdominal obesity was defined as waist circumference (WC) ≥ 90 cm for men and ≥ 80 cm for women, based on the World Federation Diabetes standard (8). Systolic and diastolic BP (SBP and DBP) were measured using an inflatable cuff wrapped around the upper arm (not the forearm or wrist) and attached to an electronic monitor that gave a digital readout of the BP (mmHg) and pulse. The criteria for hypertension are SBP > 140 mmHg and

DBP >90 mmHg, based on the International Diabetes Federation (IDF) (7) and China CDC criteria (8).

Metabolic syndrome was based on the updated IDF criteria (8). Metabolic syndrome was diagnosed by the presence of central obesity assessed as above (using cutoff values from Chinese people), plus on at least two other components including high TG (> 1.69 mmol/L), low HDL (HDL <1.03 mmol/L for men, and <1.29 mmol/L for women), elevated BP (SBP $\geq$ 130mmHg or DBP $\geq$ 85 mmHg), and hyperglycemia (fasting glucose $\geq$ 5.6 mmol/L). Dyslipidemia was defined as total cholesterol $\geq$ 5.17 mmol/L and/ LDL $\geq$ 4.1 mmol/L or HDL-C) <1.03 (for men), <1.29 (for women) and/or TG >1.69 mmol/L, according to the IDF definition (8). Estimated Glomerular Filtration Rate (eGFR) was used to measure renal functions by using the following equation of the Modification of Diet in Renal Disease Study for Chinese eGFR (mL/min/1.73m²) = $186 \times [\text{Scr}]^{-1.154} \times [\text{age}]^{-0.20} \times [0.74 \text{ (if female)}] \times [1.23 \text{ (Chinese coefficient)}]$ (9).

HRQoL were measured using the Short-Form 12 Health Survey (SF-12), which has 12 items and is a reliable and valid means of measuring quality of life in people with chronic conditions(10). Two aggregate physical and mental component summary scores were also calculated based on Chinese population norms (11).The physical health components of the SF-12 encompass: (1) physical functioning; (2) role limitations due to physical health problems; (3) bodily pain; and (4) general health perception. The mental health component includes: (1) vitality/fatigue; (2) social functioning; (3) role limitation due to emotional problems; and (4) mental health status.

The chief investigators were blind to the allocation of the participants. The percentage of normal and abnormal biomedical levels in a number of biomedical factors in both Tai Chi intervention group and control group at the baseline phase was compared using the Chi-square test. All continuous variables were checked for normal distribution before Multivariate

General Linear Model (GLM) was used to compare differences pre and post intervention in both the Tai Chi group and control group on biomedical factors and HRQoL measures as continuous variables. Any differences between the Tai Chi and control group on demographic factors including age, gender, education, income, and marital status were controlled in the GLM when the intervention effect was analysed. The statistical significance level was at a P value < 0.05 for Chi-square and GLM tests. All statistics were conducted on the remaining participants at post intervention. To examine sample biases participants in both the intervention and control groups were compared pre and post-intervention on age, gender, education, income, employment and marital status .

RESULTS

The recruitment and study procedure is illustrated in Figure 1. At baseline 300 patients were assessed in the pre-intervention phase of the study. During the intervention period 14 patients in the Tai Chi group were excluded in the final data analysis due to illness ($n=9$), discontinuation from the activity ($n=1$), and/or failure to attend the post intervention assessment ($n=4$). Of those who were excluded from the final analysis, the attrition rate was 9%. In the control group a total 20 participants (13% attrition rate) were excluded from the final analysis due to discontinuation ($n=13$) and failure to attend the post intervention assessment ($n=7$). The total number of participants included in the final analysis was 136 in the intervention group and 130 in the control group.

Table 1 summarizes the differences between Tai Chi intervention participants on demographic characteristics. All participants in the Tai Chi intervention group were of Han ethnic origin, the main ethnic group in China. The results indicate there were no significant differences between the Tai Chi group and control group on age, gender, employment, marital status and income. Baseline characteristics related to cardiovascular risk factors and quality of life indicate no statistical differences between the intervention and control groups

on cardiovascular risk factors including SBP, DBP, total cholesterol, LDL, HDL, TG, glucose, eGFR, waist, BMI, and quality of life factors. There were significant differences between the intervention and control groups on physical functioning and general health. There was no difference between the participants in the pre-intervention period and those who remained to the post-intervention period on age, gender, education, income, marital status in both intervention and control groups.

As indicated in Table 2, significant interactions between group and time were obtained from the repeated measures GLM analysis in SBP, DBP, BMI and eGFR (Table 2). These findings indicated that the changes over time on these variables were significantly different between the Tai Chi and control groups. Specifically, intervention group participants at the post intervention had much lower SBP, DBP, and BMI than pre intervention, with a 10 point difference for SBP, 7 points for DBP and 1 point for BMI. All Tai Chi participants at post intervention had a BMI at the normal level (22.3 ± 2.9), while at pre intervention they had a mean BMI of 23.4 (standard deviation is 3.1). All participants in both the Tai Chi and control groups had a normal eGFR score (90.77 versus 92.42) at pre intervention. At post intervention the Tai Chi group the eGFR score (91.01) remained at normal levels. However, the control group had a significant decrease in eGFR score (82.06) from a normal to a marginal level.

There was also a significant interaction between group and time in eGFR, in that the change over time in kidney functioning was significantly different between Tai Chi and control groups, suggesting the Tai Chi group had maintained or significantly improved kidney functioning compared to the control group. There were no statistical significant interactions between group and time on lipid components and glucose factors. There was also no significant interaction between group and time on waist circumference, suggesting the changes over time in lipid components, glucose factors and waist circumference were not

significantly different between the Tai Chi and control groups. The relationship between eGFR and SBP, DBP, and BMI in Tai Chi group was further analysed through a multiple linear regression analysis. This found that the improvement of eGFR was significantly related to the improvement of SBP, DBP and BMI (Table 3).

Table 4 demonstrates that there were improvements on quality of life measures for Tai Chi group participants post-intervention compared to pre intervention in physical role, bodily pain, vitality, and total physical health. These findings were significantly different between the Tai Chi and control groups. There were also significant differences between group and pre and post intervention time on the mental health subscale and overall mental health score, but there were no significant interactions between group and time on these factors, suggesting both groups improved their mental health at a similar magnitude.

DISCUSSION

To our knowledge, this is the first randomised control trial and community based program study to explore the long-term effects of habitual Tai Chi exercise on blood pressure and quality of life using a large sample of patients with hypertension in China. These findings indicate a greater improvement over time in SBP, DBP, BMI, eGFR, physical health scales (including role physical health plays, bodily pain, and total physical health score on the HRQoL), and vitality scale of mental health HRQoL in the Tai Chi group compared to the control group.

Clinically significant improvement in blood pressure and BMI were found between pre and post intervention time in Tai Chi participants compared to the control group. In this context, these are the first Chinese findings to demonstrate that Tai Chi may be an effective adjunct at a community level to primary prevention in improving blood pressure of patients with hypertension. Lower blood pressure in the Tai Chi group post intervention indicates that this activity is effective in reducing blood pressure in hypertension patients. This supports

previous results reported for people with mild hypertension, in which a significant reduction of high-level SBP was found after 12 weeks of Tai Chi exercise (12) and 24 months of Tai Chi exercise (13). Previous studies have reported inconsistent results regarding the effects of Tai Chi on BMI and waist circumference improvement. The significant improvement of BMI found in the present study may be because Tai Chi is an activity that requires routine and regular exercise and long-term training for the effects on BMI to be significant. The significant reduction of blood pressure and BMI in hypertension patients may be present because Tai Chi training can improve metabolic functioning by influencing insulin sensitivity, the partitioning of fuels towards oxidation rather than storage (14).

Our study did not find that Tai Chi was effective in preventing deterioration in biomedical factors including total cholesterol, LDL, HDL, TG, and glucose. As hypertension and dyslipidemia frequently coexist (15, 16), people with these conditions have an increased risk of cardiovascular disease compared to people with individual risk factors (17, 18). The relationship between glucose abnormalities and hypertension may exist because hyperinsulinemia directly contributes to elevated BP. The non-significant change in these biomedical factors including total cholesterol, LDL, HDL, TG and glucose in the Tai Chi group may be due to the fact that patients were not advised to reduce the dietary fat intake level. It has been suggested that lipid profiles such as total cholesterol and HDL cannot be modified by Tai Chi unless dietary fat intake is reduced (13).

Tai Chi exercise was significantly related to prevention of deterioration on eGFR measuring renal function in the Tai Chi group compared with the control group, which had a significantly decreased eGFR. With the reduction of blood pressure and weight, the renal functioning in the Tai Chi group has remained at a normal level. This may be because eGFR was significantly related to the improvement of SBP, DBP and BM. Our results on eGFR suggest that renal function may depend on the level of blood pressure and weight. This result

is consistent with Shi and colleagues (9) who have found a significant positive effect of a 12-week Tai Chi exercise program on renal function.

Participants in the Tai Chi group reported significantly higher scores in HRQoL post intervention versus pre-intervention compared to control group participants, although the degree of difference varied across the components of HRQoL. Intervention participants post-intervention versus pre-intervention had higher scores in areas such as role physical health, reduced bodily pain, and total physical health scores, compared to control group participants. These results are consistent with the findings of previous studies using Tai Chi treatment on people with elevated blood glucose or diabetes (19) that demonstrated a significant improvement in physical health component of the quality of life. These findings suggest that Tai Chi may have had a role in helping people to become more physically healthy.

Tai Chi exercise was significantly related to high scores only on vitality scales measuring mental health in the intervention group. This is consistent with previous research that found that Tai Chi improved vitality and mental health and better social functioning, mood, and psychological functioning than did control groups (20). Tai Chi has no significant effect on other mental health scales and total mental health score. One explanation for our result is that most patients had normal or above average mental health status, as measured by the HRQoL, due to their supportive communities and family environments. Another explanation is that the control group was an 'active' control group, with people also participating in social interaction with other participants during the intervention, and that these social activities may have the same effect as the Tai Chi exercise, sustaining mental health and preventing deterioration.

A possible limitation of the study is that the sample was restricted to only two regions in China which may limit the generalization of the results to other areas and regions in the

country. Furthermore, the study only focused on older adults, a group which may have poor physical health related to age rather than hypertension per se. Further studies are required to extend the study to more areas and regions and include other age groups. Despite these limitations, the use of a randomized controlled trial in this study provides empirical support for the casual link between Tai Chi exercise and improvement of blood pressure, BMI, quality of life and maintaining renal function in patients with hypertension.

Acknowledgement:

The first author had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. We would like to acknowledge the support of the data collection work by Changshu Center for Disease Control and Prevention, Jiangsu Province and Fangshan Center for Disease Control and Prevention, Fangshan District, Beijing, China. The authors wish to acknowledge the following people's data collection work: Dr Zhenyuan Zhou, Dr Ning Zhan, and Dr Minhao Xu from Changshu Center for Disease Control and Prevention.

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Figure legend

Figure 1: Consort chart of recruitment of participants

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Table 1. Characteristics of participants in Tai Chi intervention group (n=136) and control group (N=130)

Characteristics	Intervention group (n=136)	Control group (n= 130)	χ^2	<i>p</i>
Age (Years)				
45–64	87(64%)	90(70%)	1.18	0.28
≥ 65	49(36%)	40(30%)		
Gender				
Female	117(86%)	101(78%)	2.84	0.09
Male	19(14%)	29(22%)		
Education (Years)				
<10	61(45%)	50(39%)	5.19	0.06
10–12	43(31%)	60(46%)		
Bachelor and above	32(24%)	20(15%)		
Employment				
Retired	132(97%)	126(98%)	3.86	0.10
Others	4(3%)	4(2%)		
Marital status				
Married	128(94%)	112(86%)	4.44	0.11
Widowed	4(3%)	12(9%)		
Never married	4(3%)	6 (5%)		
Income				
<20,000 RMB	57(42%)	51(39%)	0.43	0.81
20000-39999 RMB	58(43%)	55(42%)		
≥40,000 RMB	21(15%)	24(19%)		

Notes. Chi-square test was used to compare the difference between normal and hypertension group participants. P value in bold indicates statistical significant difference between normal and hypertension group participants. Statistical significance: $P < 0.05$

Table 2. Differences between pre intervention and post intervention in blood pressure, biomedical factors in both Tai Chi and control group participants

Variables	Group	N	Baseline Mean(SD)	12 month Mean (SD)	P value		
					Group	Time	Interaction
1. Systolic blood pressure (mm Hg)	Taichi	136	130.71 ± 16.65	120.28 ± 14.63	0.04	<0.001	0.02
	Control	130	130.46 ± 15.97	128.13 ± 14.55			
2. Diastolic blood Pressure (mm Hg)	Taichi	136	82.21 ± 7.94	75.31 ± 14.53	0.008	<0.001	0.007
	Control	130	81.92 ± (8.25)	79.58 ± 12.44			
3. Serum total cholesterol (mmol / L)	Taichi	136	4.75 ± 1.15	4.81 ± 0.95	0.54	0.11	0.71
	Control	130	4.65 ± 3.16	5.49 ± 0.97			
4. High-density lipoprotein cholesterol (mmol / L)	Taichi	136	1.57 ± 0.55	1.59 ± 0.34	0.91	0.18	0.15
	Control	130	1.49 (0.62)	1.63 (0.37)			
5. Triglycerides (mmol / L)	Taichi	136	1.66 ± 1.03	1.92 ± 0.98	0.58	0.22	0.84
	Control	130	1.58 ± 1.37	1.96 ± 1.03			
6. Low-density lipoprotein (mmol / L)	Taichi	136	2.72 ± 0.87	2.73 ± 0.79	0.24	0.30	0.30
	Control	130	2.59 ± 1.11	5.41 ± 2.82			
7. Fasting glucose (mmol / L)	Taichi	136	5.65 ± 1.22	5.88 ± 0.63	0.64	0.005	0.94
	Control	130	5.50 ± 2.17	6.07 ± 0.95			
8. Estimated Glomerular Filtration Rate (mL/min/1.73m ²)	Taichi	136	90.77 ± 10.28	91.00 ± 10.68	0.85	<0.001	0.002
	Control	130	92.42 ± 9.70	82.86 ± 11.96			
9. Waist (cm)	Taichi	136	76.06 ± 6.86	75.73 ± 7.56	0.84	0.27	0.99
	Control	130	79.82 ± 4.80	79.49 ± 8.27			
10. Body Mass Index (kg/m ²)	Taichi	136	23.38 ± 3.05	22.25 ± 2.91	0.03	<0.001	0.04
	Control	130	23.50 ± 2.99	23.16 ± 2.94			

Notes. p-values were calculated using two-way repeated-measures general linear model. Statistical significant difference between pre and post intervention time: $p < 0.05$. Figure in bold indicates statistical significance.

Table 3. Relationship between eGFR and systolic blood pressure, diastolic blood pressure and body mass index

Variables	Regression Coefficient (95% CI)	Beta	P
Systolic blood pressure	-0.15 (-0.25 to -0.04)	-0.19	0.005
Diastolic blood pressure	0.24 (0.06-0.42)	0.17	0.01
Body mass index	-0.40 (-0.81 to 0.01)	-0.10	0.05

Multiple linear regression was used to analyse the relationship between between eGFR and systolic blood pressure, diastolic blood pressure and body mass index; Statistical significance $P < 0.05$

Table 4. Differences between pre intervention and post intervention time in intervention and control group participants in quality of life

Variables	Group	N	Baseline	12 month	P value		
					Group	Time	Interaction
			Mean (SD)	Mean (SD)			
1. Physical functioning	Taichi	136	55.13 ± 14.91	54.44 ± 15.74	0.02	0.95	0.65
	Control	130	50.16 ± 17.11	51.08 ± 17.22			
2. Role Physical	Taichi	136	83.27 ± 20.03	94.58 ± 10.72	<0.001	0.003	0.01
	Control	130	81.27 ± 18.90	82.06 ± 20.11			
1) Bodily pain	Taichi	136	79.48 ± 22.30	90.83 ± 16.72	<0.001	0.008	0.05
	Control	130	75.00 ± 23.74	76.79 ± 22.89			
4. General health	Taichi	136	44.32 ± 25.20	48.33 ± 24.51	0.002	0.14	0.95
	Control	130	52.51 ± 23.89	56.17 ± 23.10			
5. Vitality	Taichi	136	74.40 ± 22.01	84.17 ± 17.96	0.005	0.003	0.05
	Control	130	68.62 ± 27.23	74.84 ± 22.78			
6. Social functioning	Taichi	136	68.13 ± 17.37	70.67 ± 17.21	0.03	0.35	0.73
	Control	130	64.40 ± 19.18	65.58 ± 17.64			
7. Role emotional	Taichi	136	85.21 ± 17.35	88.75 ± 17.48	0.02	0.15	0.73
	Control	130	81.42 ± 19.21	83.60 ± 18.55			
8. Mental Health	Taichi	136	81.13 ± 16.41	85.00 ± 17.80	0.02	0.12	0.71
	Control	130	77.09 ± 19.79	79.46 ± 19.68			
Physical total score	Taichi	136	73.16 ± 15.59	81.05 ± 9.64	0.006	0.004	0.05
	Control	130	71.45 ± 16.32	73.41 ± 14.92			
Mental total score	Taichi	136	83.42 ± 12.99	87.69 ± 11.71	0.002	0.03	0.60
	Control	130	79.34 ± 15.50	81.99 ± 14.22			

Notes. p-values were calculated using two-way repeated-measures general linear model. Statistical significant difference between pre and post intervention time: $p < 0.05$. Figure in bold indicates statistical significance.

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PII: S0002-9149(15)01617-3

DOI: [10.1016/j.amjcard.2015.07.012](https://doi.org/10.1016/j.amjcard.2015.07.012)

Reference: AJC 21276

To appear in: *The American Journal of Cardiology*

Received Date: 11 May 2015

Revised Date: 23 June 2015

Accepted Date: 3 July 2015

Please cite this article as: Sun J, Buys N, Community Based Mind-body Meditative Tai Chi Program and Its Effects on Improvement of Blood Pressure, Weight, Renal function, Serum Lipoprotein, and Quality of Life in Chinese Adults with Hypertension, *The American Journal of Cardiology* (2015), doi: 10.1016/j.amjcard.2015.07.012.

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