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Tai Chi in Chinese adults with metabolic syndrome: A pilot randomized controlled trial

Leona Yuen-ling Leung[a], Aileen Wai-kiu Chan[b,*], Janet Wing-hung Sit[b], Ting Liu[c], Ruth E. Taylor-Piliae[d]

[a] Kiang Wu Nursing College of Macau, Est. Repouso No. 35, R/C, Macau
[b] The Nethersole School of Nursing, 7th Floor, Esther Lee Building, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong Special Administrative Region
[c] The Nethersole School of Nursing, 6th Floor, Esther Lee Building, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong Special Administrative Region
[d] College of Nursing, The University of Arizona, 1305 N. Martin, PO Box 210203, Tucson, AZ 85721-0203, USA

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ABSTRACT

Objective: To determine the feasibility, acceptability and effects of a 12-week Tai Chi exercise program on cardiometabolic risk factors and quality of life in community-dwelling Chinese adults with metabolic syndrome.
Design: A single blind, pilot randomized controlled trial.
Setting/location: A general outpatient clinic of a community-based hospital in Hong Kong.
Subjects: Ethnic Chinese, 18 years and older, who had at least three of the five criteria of metabolic syndrome defined by the National Cholesterol Education– Adult Treatment Panel III.
Intervention: The Tai Chi group attended a 1 -h Tai Chi class, twice a week for 12 weeks, plus 30-minutes home practice three-times per week. The control group maintained their usual daily activities.
Outcome measures: Primary outcomes were feasibility and acceptability of the Tai Chi intervention. Secondary outcome measures were cardiometabolic risk factors, quality of life, stress and Tai Chi exercise self-efficacy.
Results: Study retention rate was 65% (n = 35). Overall satisfaction of completers with the Tai Chi intervention was 4.5 ± 0.63 (possible range = 1–5). When compared to controls, the Tai Chi group had significantly lower systolic blood pressure ($p = 0.037$) at 12-weeks. Significant within group changes for the Tai Chi group included lower diastolic blood pressure ($p = 0.015$), higher fasting blood glucose ($p = 0.009$), higher waist circumference (females only, $p = 0.007$), and better perceived mental health ($p = 0.046$); while controls had significantly higher fasting blood glucose ($p = 0.031$), and higher waist circumference (females only, $p = 0.003$).
Conclusion: The study intervention was feasible and acceptable for Chinese adults with metabolic syndrome. While not powered to find statistically significant differences, positive and negative changes were observed in some cardiometabolic risk factors and quality of life. Further investigation with a larger sample size and longer study period is needed to explore potential environmental factors that may have influenced the study results.

1. Introduction

Metabolic syndrome is a global health issue,[1] and is a cluster of biochemical and clinical alterations characterized by hypertension, impaired glucose tolerance, dyslipidemia, and obesity[2,3] This syndrome includes cardiometabolic disturbances that not only increase one's chances to develop a fatal disease, such as cardiovascular disease, type 2 diabetes mellitus, or stroke, but also imposes a huge economic burden on healthcare systems worldwide.[4] Different therapeutic interventions have been proposed to manage metabolic syndrome, including both pharmacological and non-pharmacological therapies. However, the high costs of medications along with their potential side effects may reduce the willingness of individuals afflicted with metabolic syndrome to adhere to pharmacological treatment.[5] More attention to non-pharmacological therapy, such as lifestyle modifications for promoting physical activity and reducing obesity, is thereby suggested.

Physical activity may be considered as one of the most effective non-pharmacological therapies for metabolic syndrome.[6] Research evidence has indicated that regular physical activity is beneficial in preventing and managing metabolic syndrome and its components.,[78] A recent

* Corresponding author at: The Nethersole School of Nursing, Rm727, Esther Lee Building, The Chinese University of Hong Kong, Shatin, N.T., Hong Kong Special Administrative Region.
E-mail addresses: leonaleung@kwnc.edu.mo (L.Y.-l. Leung), aileenchan@cuhk.edu.hk (A.W.-k. Chan), janet.sit@cuhk.edu.hk (J.W.-h. Sit), liuting@link.cuhk.edu.hk (T. Liu), rtaylor@nursing.arizona.edu (R.E. Taylor-Piliae).

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study found that a 12-week aerobic exercise training program had significant effects on weight loss and decreased glucose, cholesterol, and triglyceride levels in people with metabolic syndrome.[9] Regular physical activity at a moderate intensity can prevent or delay the onset of type 2 diabetes, lower blood lipid or reduce the risk for heart attack and stroke.[10]

Tai Chi, a type of Chinese ancient martial arts, is a therapeutic exercise based on traditional Chinese medicine. Despite different Tai Chi Schools and Styles, such as Chen, Yang, Sun, and Wu developed over the centuries for health maintenance or self-defense, a simplified 24-form Tai Chi was developed and commonly adopted as a form of exercise for health maintenance purpose. Exercise intensity, metabolic and cardiovascular responses during the performance of Tai Chi were examined in prior research, with Tai Chi classified as a moderate-intensity exercise across different age and gender groups, based on various cardiopulmonary fitness indicators.[11,12] Tai Chi exercise combines meditation, body awareness, controlled breathing, and continuous flowing movements of the head, torso, arms, and legs in a coordinated manner,[13,14] and its impacts on improving physical and mental health have gradually been recognized worldwide. Several research studies and systematic reviews have documented health benefits associated with regular Tai Chi practice among older adults.[14–18]

To date, only a few studies have examined the potential benefits of Tai Chi among adults with metabolic syndrome.[2,19,20] These studies did not use rigorous study designs, had statistical analysis concerns,[21] or combined Tai Chi with Qi Gong. Thus, we conducted a pilot randomized controlled study among community-dwelling Chinese adults with metabolic syndrome to determine the feasibility and acceptability of the Tai Chi intervention, and explore the effects of Tai Chi on cardiometabolic risk factors, quality of life, stress, and Tai Chi exercise Self-efficacy.

2. Materials and methods

2.1. Study design

This study was a single-blind, pilot randomized controlled trial among community-dwelling Chinese adults with metabolic syndrome.

2.2. Participants and setting

Participants were recruited from the general outpatient clinic of a community-based hospital in Hong Kong. Eligible participants were ethnic Chinese with metabolic syndrome, 18 years and older, living in the community and able to perform their activities of daily living. Potential participants were screened to ensure they had at least three of the five criteria defined by the National Cholesterol Education–Adult Treatment Panel III[22] as follows:

- Systolic blood pressure ≥130 mmHg or diastolic blood pressure ≥85 mmHg
- Fasting blood glucose ≥5.6 mmol/L
- Fasting blood triglyceride ≥1.7 mmol/L
- Fasting blood high-density lipoprotein cholesterol < 1.03 mmol/L for men and < 1.29 mmol/L for women
- Waist circumference > 102 cm for men and > 88 cm for women

Participants were excluded if they had prior Tai Chi experience within the past six months, were living in a nursing care home, had a diagnosis of coronary artery disease or stroke, had cognitive impairment (Abbreviated Mental Test < 7),[23] met the DSM-V criteria for major depressive disorder, or were on antidepressants.[24] The Joint Chinese University of Hong Kong-New Territory East Cluster Clinical Research Ethics Committee approved this study.

2.3. Recruitment strategies

All participants who visited the general outpatient clinic were screened for eligibility using a standardized checklist. Patients who met the inclusion criteria were invited to enroll in this study. Detailed explanations including the study aim, intervention strategies, rights of patients, benefits and possible risks was provided. Informed consent was obtained from every eligible participant who agreed to participate.

2.4. Randomization

The random allocation of participants was performed using computer-generated numbers, which were put in opaque envelopes and were drawn by participants. They were randomly allocated into either the Tai Chi group or the control group in a 1:1 ratio via block randomization. A block size of 6 was adopted. The randomization status was undisclosed to the principal investigator and outcome assessors.

2.5. Intervention protocol

2.5.1. Tai Chi group

The 24-form Yang-style Tai Chi is the most frequently used type of Tai Chi for healthcare in both Eastern and Western countries. It was modified from traditional Yang-style Tai Chi to make Tai Chi standardized and easier to learn, practice, remember, and available for public use.[25,26] This Tai Chi intervention has been demonstrated to be effective on improving cardiometabolic risk factors and psychosocial well-being.[27] Hence, it was adopted in current study. Participants in the intervention group attended an exercise-based Tai Chi class, teaching 24-form Yang-style Tai Chi which included evenly paced, flowing movements with the trunk erect, adding deep breathing and mental concentration with body movements, thus integrating the mind, body and breathing while practicing Tai Chi. Each Tai Chi class lasted for one hour including 10 min warm up exercise and 5 min cool down exercise, twice per week for 12 weeks. In addition, participants were encouraged to perform 30-min of self-practice at home three times per week for 12 weeks. To ensure intervention fidelity, all Tai Chi classes were conducted by a qualified Tai Chi master with 20 years of teaching experience, according to a standardized 24-form Yang-style Tai Chi protocol that met a moderate level of exercise intensity and duration (Appendix). To ensure skill mastery of the participants, the Tai Chi Master assessed their skills using return demonstrations during the class. Any incorrect postures or movements were identified and rectified. All Tai Chi classes were conducted in an indoor activity room. Fall precaution and safety were monitored by the Tai Chi master and a research assistant throughout all Tai Chi classes.

The research assistant made phone calls to participants every week to remind them to attend the classes. To monitor intervention adherence, Tai Chi class attendance was tracked by a research assistant using an attendance record. As for home practice, each participant was given a Tai Chi exercise logbook for recording home-based practice. The logbooks were collected weekly by the research assistant.

2.5.2. Control group

Participants in the control group continued their usual daily activities and attended weekly 1 -h non-exercise recreational class, conducted by another research assistant, in order to balance the psychological effects of contact by study staff. Recreational activities consisted of making handcraft and Chinese calligraphy to provide similar attention and social interaction as the Tai Chi group. Same as the intervention group, the research assistant made phone calls weekly to the control group reminding participants to attend the classes. Medical treatments of all participants in both intervention and control groups were uninterrupted throughout the study.

2.6. Primary outcomes

2.6.1. Feasibility

Feasibility was tested in terms of the participant recruitment process, data collection methods, study instruments, the study intervention and retention rates. The reasons that participants dropped out of the study or failed to attend the interventions were recorded. Adequate recruitment was defined as 54 participants enrolled in the study over a 3-month time period, with less than a 30% dropout rate. Acceptable intervention adherence was defined as attendance of > 70% of the scheduled Tai Chi classes.

2.6.2. Acceptability

Overall satisfaction assessed intervention acceptability. Following the 12-week intervention, participants' satisfaction with the Tai Chi exercise intervention was assessed, using the Tai Chi Exercise Satisfaction Questionnaire. An investigator developed (AWKC) 12-item, two-part questionnaire used a five-point Likert scale (1 = strongly disagree, 5 = strongly agree), to ascertain participants perceived benefits of Tai Chi and satisfaction with the Tai Chi classes. In addition, a yes/no question asked participants if they intended to continue practicing Tai Chi exercise in the future.

2.7. Secondary outcomes

2.7.1. Cardiometabolic risk factors

1 Blood pressure: Participants were asked to sit for at least 15 min in a quiet location. Blood pressure was then measured twice at five-minute intervals using a digital blood pressure monitor (CARESCAPE V100, GE Healthcare). The average of the two blood pressure readings was used for analysis.
2 Blood samples for fasting blood glucose, triglycerides, and high-density lipoprotein cholesterol: Prior to collecting blood samples using point of care testing, participants fasted for eight hours. Blood samples involved finger pricks to collect fasting blood glucose, triglycerides, and high-density lipoprotein cholesterol. A blood glucose analyzer (ACCU-CHEK Performa, model NC, Roche) was used to measure fasting blood glucose. A blood lipid analyzer (CardioChek PA, PTS Diagnostics) was used to measure triglycerides and high-density lipoprotein cholesterol. All equipment was calibrated before data collection.
3 Waist circumference: Participants' waist circumference was measured to the nearest 0.1 cm at the mid-point between the lower margin of the last palpable rib and the top of the iliac crest using a stretch-resistant measuring tape.[28]

2.7.2. Quality of life

The Hong Kong version of the 12-item Short-Form Health Survey version 2 (SF-12v2) was used to assess participants' perceived quality of life. The SF-12v2 contains 12 self-report items, evaluates eight health domains, along with a physical component summary (PCS) and a mental component summary (MCS). The PCS assessed physical functioning, bodily pain, general health, and physical role. The MCS assessed social functioning, vitality, mental health, and emotional role.[29] Possible SF-12v2 scores range from 0 to 100, with higher scores indicating greater perceived quality of life. The Hong Kong version of SF-12v2 has favorable internal consistency and test–retest reliability (from 0.67 to 0.82).[30]

2.7.3. Stress

The Chinese version of the 10-item Perceived Stress Scale (PSS-10) was used to assess participants' perceived stress. The PSS-10 is a self-reported scale comprises four positive items and six negative items.[31] Each item is on a Likert scale ranging from 0 ("never") to 4 ("very often"), with a higher score indicating a higher stress level. Prior research using the PSS-10 among Chinese populations reported good internal consistency (Cronbach's $\alpha = 0.83$).[32]

2.7.4. Tai Chi exercise self-efficacy

The Chinese version of Tai Chi Exercise Self-Efficacy (TCSE) was used to Tai Chi exercise self-efficacy, only among those assigned to the Tai Chi group. The TCSE measures the capability of an individual to overcome barriers and perform Tai Chi. This self-report scale ranges between 0 ("not at all confident") and 100 ("very confident"), with a higher score indicating higher self-efficacy. The Chinese version of TCSE Barriers and Performance scales had Cronbach's α of 0.95 and 0.97, respectively.[33]

2.8. Data collection and statistical analyses

Data collection was done at the general outpatient clinic of a community-based hospital by independently trained research assistants. They were blinded to the group assignment and study aims. Data were collected at baseline and post-intervention at 12-weeks. IBM SPSS version 22 (IBM Corporation, Armonk, New York) was used for the statistical analyses. Per protocol analysis was adopted for participants that completed the pre- and post-intervention assessments. The distribution frequency and percentage of the ordinal and categorical variables identified from the socio-demographic data were calculated along with the mean and standard deviation of the continuous variables. While this pilot study was not adequately powered to detect significant group differences, nevertheless we used Fisher's exact test, Pearson's chi-square test, and independent sample *t*-test to explore between group differences. A within-group paired *t*-test was performed to explore changes between baseline and post-intervention. Independent *t*-test was performed to test between group differences at baseline and at 12-week. Statistical significance was set at $p < 0.05$.

3. Results

A total of 54 adults agreed to participate. Fig. 1 describes the flow of participants in the study including enrollment, group allocation, follow up and analysis. Majority of participants were married (65%, n = 35), males (52%, n = 28) and retired (52%, n = 28). The average age was 64 years old (range from 49 to 88 years). The majority of participants had a history of hypertension (100%, n = 54), Type 2 diabetes mellitus (96%, n = 52), dyslipidemia (70%, n = 38), and were overweight (Body Mass Index = 27.3 kg/m^2) (Table 1). At baseline, participants' cardiometabolic risk factors were elevated with the following average values: Systolic blood pressure (SBP) = 148 mmHg, diastolic blood pressure (DBP) = 86 mmHg, fasting blood glucose (FBG) = 7.2 mmol/L, triglyceride (TG) = 1.5 mmol/L, high-density lipoprotein (HDL) cholesterol level in males = 1.1 mmol/L and in females = 1.2 mmol/L, waist circumference in males = 95.7 cm and in females = 90.6 cm (Table 1). There were no statistically significant differences observed between intervention and control groups at baseline.

3.1. Primary outcomes

3.1.1. Study feasibility

An adequate number of participants were identified during study recruitment (Fig. 1). After informed consent was obtained, demographic data and baseline data were collected following the described procedure. The pilot study took six months to complete, with 3 months for participant recruitment and 3 months for data collection at baseline and 12-weeks post-intervention. The average time needed to collect baseline data was 45 min, while an average of 30 min was needed for post-intervention assessments. Participant responses toward the data collection instruments generally indicated that the questionnaires were understandable and that the physiological tests were easy to perform.

Participants in the Tai Chi group did not experience any discomfort

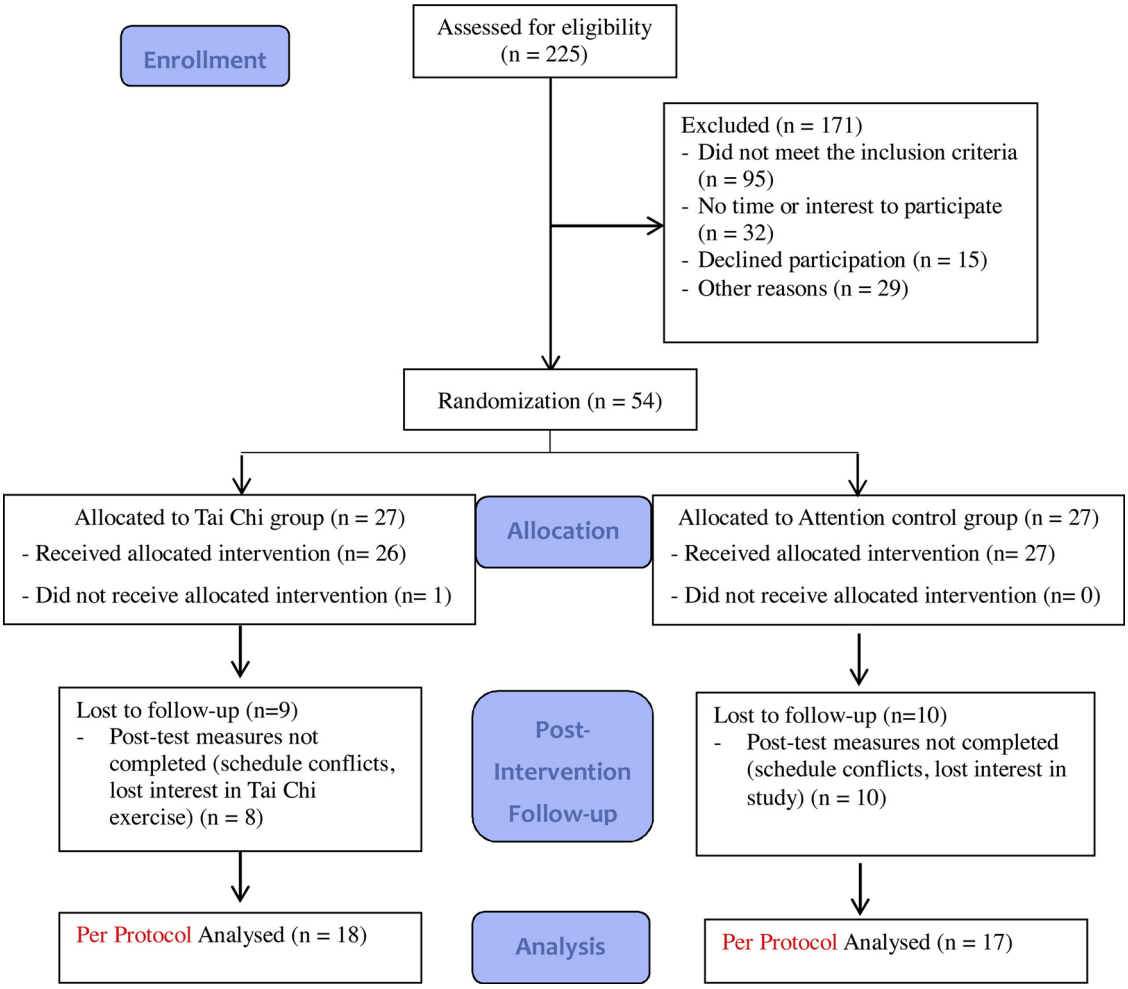

Fig. 1. Flow of Participants in the Study.

and difficulty during the Tai Chi practice. The Tai Chi instructor repeated the Tai Chi forms learned in prior sessions, to ensure the participants' mastery of skills before introducing new forms. Participants were able to master the Tai Chi skills within the 3-month training period.

Nineteen participants (35%) dropped out of the study (Tai Chi, n = 9, Control, n = 10). The baseline characteristics of those participants who completed and dropped out of the study were not significantly different. The main reasons for study attrition for both groups were due to scheduling conflicts or lack of interest in participating in the study (Fig. 1).

3.1.2. Intervention adherence

Of the 18 participants in the Tai Chi group, they attended on average 81% of the scheduled Tai Chi classes. Reasons for missed class (es) included scheduling conflicts, poor weather conditions, or lack of interest. Regarding home-based Tai Chi exercise, the majority of these participants failed to return their logbooks (n = 13, 72%), thus the research team was unable to monitor adherence rate correctly.

In the Control group, attendance of the non-exercise recreational classes was poor, with only 11% attendance rate. The reasons for not attending the classes were not interested in the activities and schedule time conflicts.

3.1.3. Study acceptability

A total of 16 Tai Chi participants (89%) who attended the Tai Chi classes, completed the Tai Chi exercise satisfaction questionnaire. Overall, the completers perceived benefits of Tai Chi, especially in lowering stress (average score = 3.88 ± 1.09). The completers were very satisfied with the Tai Chi exercise classes in terms of the days, time, venue and duration of the classes. They were most satisfied with the Tai Chi Master's instruction. Overall satisfaction was very high (average score = 4.50 ± 0.63), with the majority of completers (n = 15) indicating they would continue practicing Tai Chi exercise in the future (Table 2). However, since the satisfaction of the dropout subjects was unknown, the reports of overall satisfaction from the completers might be overestimated, as their satisfaction would be expected to be higher than those who dropped out of the study.

3.2. Secondary outcomes

3.2.1. Exploring between-group differences

We examined the group differences of outcomes for study completers (per protocol analysis). Compared to controls, the Tai Chi group had significantly lower systolic blood pressure (p = 0.037) after the intervention at 12-weeks. There were no other significant between group differences (Table 3).

3.2.2. Exploring within-group changes

Significant within group changes in the Tai Chi group included lower diastolic blood pressure (p = 0.015), higher fasting blood glucose (p = 0.009), higher waist circumference (women only, p = 0.007), and better perceived mental health (p = 0.046); while the control group had significant within group increases in fasting blood glucose (p = 0.031) and higher waist circumference (women only, p = 0.003) (Table 3).

Table 1
Baseline Characteristics of Study Participants (N = 54).

Characteristics	Tai Chi Group [n = 27, *f* (%)]	Control Group [n = 27, *f* (%)]	*p*-value
Age, years (mean, SD)	62.19 (5.93)	65.52 (9.34)	0.123#
Males	16 (59.3)	12 (44.4)	0.276
Married/Partner	19 (70.4)	16 (59.3)	0.285
Currently Employed	12 (44.5)	16 (59.3)	0.857
Body mass index, kg/m^2 (mean, SD)	27.40 (4.82)	27.25 (4.34)	0.908#
Body fat, % (mean, SD)	33.23 (5.47)	33.29 (6.04)	0.970#
History of Hypertension	27 (100.00)	27 (100.00)	0.999
History of Type 2 diabetes mellitus	25 (92.60)	27 (100.00)	0.491
History of Hyperlipidemia	18 (66.70)	20 (74.10)	0.766^
On anti-hypertensive medication	21 (77.80)	24 (88.90)	0.543
On anti-diabetic medication	22 (81.50)	27 (100.00)	0.128
On lipid-lowering agent	6 (22.20)	3 (11.10)	0.543
Cardiometabolic Risk Factors			
SBP (mmHg) (mean, SD)	144.78 (18.02)	150.33 (20.82)	0.299#
DBP (mmHg) (mean, SD)	84.67 (8.69)	86.44 (9.25)	0.470#
FBG (mmol/L) (mean, SD)	7.50 (2.56)	6.84 (1.98)	0.300#
HbA1c (%) (mean, SD)	7.63 (1.34)	7.70 (1.16)	0.829#
TG (mmol/L) (mean, SD)	1.35 (0.70)	1.65 (1.47)	0.354#
TC (mmol/L) (mean, SD)	3.68 (0.91)	3.92 (1.65)	0.515#
HDL-C (mmol/L)			
[male, n = 28] (mean, SD)	1.01 (0.31)	1.18 (0.61)	0.342#
[female, n = 26] (mean, SD)	1.19 (0.34)	1.25 (0.38)	0.699#
WC (cm)			
[male, n = 28] (mean, SD)	96.19 (9.35)	95.17 (14.39)	0.822#
[female, n = 26] (mean, SD)	90.27 (11.97)	90.87 (8.14)	0.881#
Quality of Life (SF-12v2)			
Physical Functioning (mean, SD)	49.48 (8.86)	48.32 (9.60)	0.645#
Role-Physical (mean, SD)	46.81 (9.56)	45.08 (10.88)	0.645#
Bodily Pain (mean, SD)	47.04 (11.20)	50.05 (8.18)	0.539#
General Health (mean, SD)	38.33 (9.46)	36.19 (8.05)	0.265#
Vitality (mean, SD)	50.89 (10.58)	51.25 (9.96)	0.376#
Social Functioning (mean, SD)	50.97 (8.89)	47.68 (11.70)	0.897#
Role-Emotional (mean, SD)	46.08 (11.12)	48.39 (10.53)	0.249#
Mental Health (mean, SD)	49.55 (8.76)	50.82 (12.32)	0.437#
PCS (mean, SD)	45.68 (8.87)	44.31 (8.49)	0.663#
MCS (mean, SD)	49.53 (8.53)	50.58 (11.94)	0.565#
Stress (PSS)			
Perceived stress (mean, SD)	12.96 (5.55)	13.63(7.30)	0.707#
Tai Chi Exercise Self-efficacy (TCSE) (n = 27)			
TCSE barriers (mean, SD)	57.61 (13.98)	—	
TCSE performance (mean, SD)	64.96 (22.21)	—	

Note. #independent *t*-test; ^Pearson chi-square test; Fisher's exact test used for other variables. DBP = diastolic blood pressure; *f* = frequency; FBG = fasting blood sugar; TC = total cholesterol; HDL-C = high-density lipoprotein; MCS = Mental component score; PCS = Physical component score; PSS = 10-item Perceived Stress Scale (Chinese); SBP = systolic blood pressure; SF-12v2 = 12-item Short-Form Health Survey version 2 (Hong Kong); TC = total cholesterol; TCSE = Tai Chi exercise self-efficacy Scale; TG = triglycerides; WC = waist circumference.

4. Discussion

Tai Chi among Chinese adults with metabolic syndrome was feasible and acceptable, though an exploration of the intervention effects on cardiometabolic risk factors, quality of life and perceived stress were mixed with positive and negative changes observed in both groups. Our results are likely due to the small study sample combined with the attrition rate. However, among the study participants completing the intervention, a statistically significant difference in systolic blood pressure was observed in Tai Chi group when compared to the control group, with the former having on average a 9 mmHg reduction in systolic blood pressure (p = 0.037) at 12-weeks. Our finding of lower systolic blood pressure is similar to prior research examining the effects of Tai Chi among Chinese adults with hypertension,[34,35] as well as a systematic review examining the effect of Tai Chi on blood pressure.[36]

When examining within group changes comparing pre- and post-intervention study assessments, those in the Tai Chi group had on average a 6 mmHg reduction in diastolic blood pressure after completion of the Tai Chi intervention; while the controls had no change in diastolic blood pressure. This finding is consistent with a recent systematic review[37] and other Tai Chi intervention studies reporting that Tai Chi exercise reduced blood pressure in diabetics or those with cardiovascular disease. Prior studies suggest that the influence of Tai Chi on systolic blood pressure and diastolic blood pressure greatly depends on the intervention protocol.[38,39] For example, Frye et al. reported that the failure to control for confounding variables such as usage of antihypertensive medications, could hinder significant reductions in systolic blood pressure, and that diastolic blood pressure at baseline was close to the normal range, resulting in non-significant changes post-intervention.[40]

Participants in both Tai Chi and control groups had statistically significant within-group increases in fasting blood glucose and waist circumference (females only). The increased fasting blood glucose is not consistent with recent systematic reviews,[37,41] and other studies.[34,35] A prior study reported that Tai Chi could not significantly improve fasting blood glucose due to glucose abnormalities that increase blood pressure.[34] Although we detected unexpected increases in FBG in both groups, there was no impact on HbA1c. Findings on waist circumference are in contrast to other studies as well as a systematic review.[20,37,42] Liu et al. attributed the lack of significant effects of Tai Chi on waist circumference may be due to performing the exercise at an insufficient intensity for metabolism control.[20] An observational study revealed that the mean waist circumference increased in midlife women who have regular physical activity. The reasons might be due to older age and post-menopausal status, as these women tend to have larger in waist circumferences than women who are pre-menopausal or early peri-menopausal.[43] In our study, the mean age of participants was 64, and all females were post-menopausal. The increased waist circumference of females might be due to the same reasons as stated by Sternfeld and colleagues.[43]

In our study, the intervention period was during the Chinese autumn festival. The Chinese traditional celebrations of this festival include family banquets and eating highly sweetened mooncakes. This may partly explain the increases in fasting blood glucose, and suggests that a change in diet played a role in the post-intervention study assessments.

Tai Chi participants in our study had a significant improvement in their perceived mental health following the intervention. This finding is consistent with previously reported research.[20,34] Tai Chi tends to offer greater benefits for perceived mental health than for other components. Our post-intervention findings for quality of life among the Tai Chi participants (average physical component summary = 48.33 ± 96.39, average mental component summary = 50.66 ± 8.7) were comparable with normative data for the general population of Hong Kong adults aged 41–64 years old (n = 1,073, average physical component summary = 49.8 ± 9.2, average mental component summary = 50.7 ± 9.2), though higher than reported quality of life among adults with a chronic illness (n = 433, average physical component summary = 45.2 ± 11.0, average mental component summary = 49.3 ± 10.5).[30]

We found no statistically significant changes in perceived stress or Tai Chi exercise self-efficacy after 12-weeks of Tai Chi training within the Tai Chi group. Given that the Tai Chi participants were generally beginners, they might have experienced some stress when learning the movements and philosophy of this exercise, leading to the findings obtained.[44] In terms of Tai Chi exercise self-efficacy, one participant reported that he had difficulty in recalling the Tai Chi movements, while other participants failed to attend some of the Tai Chi classes, thereby leaving them behind in learning the movements, leading to

Table 2
Tai Chi Exercise Satisfaction Questionnaire (N = 16).

Item	Question	Mean	SD
Part One: Perceived Benefits of Tai Chi Exercise			
Do you think the Tai Chi exercise class achieved the following…			
A	Improved your overall health status	3.69	0.87
B	Improved your physical strength	3.81	0.83
C	Improved your quality of life	3.63	0.81
D	Relieved your stress	3.88	1.09
Part Two: Satisfaction with the Tai Chi Exercise Classes			
A	Are you satisfied with the days of the Tai Chi exercise class?	4.25	0.68
B	Are you satisfied with the times of the Tai Chi exercise class?	4.06	0.77
C	Are you satisfied with the venue of the Tai Chi exercise class?	4.69	0.60
D	Are you satisfied with the 3-month duration of the Tai Chi exercise class?	4.13	0.89
E	Are you satisfied with the Tai Chi master's performance?	4.69	0.60
F	Are you satisfied with the procedures of Tai Chi exercise class?	4.13	0.89
G	Do you think that the Tai Chi exercise movements are suitable for you and within your exercise tolerance?	4.50	0.63
H	Overall, are you satisfied with your participation in the Tai Chi exercise class?	4.50	0.63
Item	Question	n	%
I	Will you continue practicing Tai Chi exercise in the future?	15 (Yes)	93.75
		1 (No)	6.25

Note: five-point Likert scale (1 = strongly disagree, 5 = strongly agree).

lower confidence to overcome barriers and perform Tai Chi. Future studies may consider offering a flexible class schedule or supplementary classes to facilitate class attendance, when participants have prior work commitments. Intervention adherence in our study was good (Tai Chi group = 81%). Our results are in agreement with other studies reporting adherence rates ranging between 72–100%.[35,40]

4.1. Study strengths and limitations

This study had several strengths. First, the study intervention was based on recommendations from a recent systematic review.[31] Second, the feasibility, acceptability and an exploration of the effects of Tai Chi exercise among Chinese adults with metabolic syndrome were assessed using a rigorous study design and methods, including randomization, single-blinding, along with valid and reliable outcome measures. Third, results of the Tai Chi exercise satisfaction questionnaire can be used to improve future Tai Chi interventions by incorporating participant feedback.

However, interpretation of the findings in this pilot study needs to consider some study limitations. First, the attrition rate at 35% is less desirable, suggesting a follow-up investigation among participants that dropped out of the study is needed, as they may provide additional valuable information for enhancing participation in a future study. Second, class attendance in the control group was poor; suggesting that an alternate control condition should be used. Future large scale RCTs need to identify strategies to enhance incentives for participation in

Table 3
Comparison of Changes in Completer Outcomes Within and Between Tai Chi and Control Groups.

	Tai Chi Baseline Mean (SD) (n = 18)	Tai Chi Week-12 Mean (SD) (n = 18)	$ Within-group p-value	Control Baseline Mean (SD) (n = 17)	Control Week-12 Mean (SD) (n = 17)	$ Within- group p-value	Week-12 # Between groups p-value
Cardiometabolic Risk Factors							
SBP (mmHg)	143.94 (15.48)	135.33 (15.13)	0.076	146.82 (16.11)	146.47 (15.12)	0.944	0.037*
DBP (mmHg)	84.89 (7.98)	79.00 (7.21)	0.015*	84.29 (9.12)	83.47 (7.96)	0.714	0.091
FBG (mmol/L)	7.12 (2.20)	9.32 (4.73)	0.009*	6.42 (1.78)	7.39 (1.97)	0.031*	0.130
HbA1c (%)	7.51 (1.34)	7.37 (1.71)	0.442	7.57 (0.82)	7.51 (1.16)	0.773	0.781
TC (mmol/L)	3.74 (0.96)	3.82 (0.61)	0.792	4.15 (1.84)	4.19 (1.96)	0.960	0.448
TG (mmol/L)	1.18 (0.64)	1.31 (0.54)	0.383	1.78 (1.46)	1.97 (1.39)	0.556	0.068
HDL-C (mmol/L)							
[males, n = 19]	0.94 (0.25)	1.06 (0.28)	0.285	1.39 (0.66)	1.10 (0.64)	0.429	0.857
[females, n = 16]	1.22(0.24)	1.43 (0.33)	0.065	1.34(0.33)	1.34(0.42)	0.958	0.637
WC (cm)							
[males, n = 19]	97.82 (10.69)	96.64(9.75)	0.251	95.13(16.71)	97.38 (15.73)	0.072	0.901
[females, n = 16]	89.71 (14.84)	94.57(14.99)	0.007*	87.67(6.93)	91.89 (6.07)	0.003*	0.631
Quality of Life (SF-12v2)							
Physical Functioning	49.62 (9.14)	50.50 (6.75)	0.668	50.12 (7.81)	51.50 (8.24)	0.484	0.695
Role-Physical	47.12 (9.76)	47.82 (9.04)	0.814	47.75 (10.01)	50.99 (9.11)	0.154	0.310
Bodily Pain	45.20 (10.78)	48.21 (7.87)	0.210	49.77 (7.05)	52.42 (9.60)	0.288	0.164
General Health	36.71 (10.16)	45.32 (10.64)	0.005*	35.94 (9.25)	39.57 (8.91)	0.055	0.093
Vitality	49.61 (10.38)	55.08 (8.36)	0.037	52.54 (9.80)	53.69 (11.60)	0.735	0.687
Social Functioning	50.48 (9.55)	50.48 (8.52)	1.000	48.01 (11.34)	53.76 (7.66)	0.102	0.240
Role-Emotional	45.60 (12.41)	47.33 (9.06)	0.489	49.24 (8.21)	49.25 (10.06)	1.000	0.557
Mental Health	46.04 (6.60)	50.19 (8.40)	0.015*	52.74 (13.61)	54.42 (11.25)	0.669	0.214
PCS	45.69 (9.30)	48.33 (6.39)	0.257	45.31 (8.89)	48.40 (5.83)	0.053	0.973
MCS	47.32 (8.56)	50.66 (8.70)	0.046*	13.65 (7.20)	53.16 (10.30)	0.575	0.441
Stress (PSS)							
Perceived stress	13.78 (5.87)	13.67 (5.81)	0.941	13.65 (7.20)	12.82 (5.81)	0.575	0.671

Note. $paired *t*-test; # independent *t*-test; *$p < 0.05$; DBP = diastolic blood pressure; FBG = fasting blood sugar; HDL-C = high-density lipoprotein; MCS = Mental component score; PCS = Physical component score; PSS = 10-item Perceived Stress Scale (Chinese); SBP = systolic blood pressure; SF-12v2 = 12-item Short-Form Health Survey version 2 (Hong Kong); TC = total cholesterol; TG = triglycerides; WC = waist circumference.

activities for control group. Third, despite good adherence rates in Tai Chi classes, few of these participants completed and returned the home-based Tai Chi exercise logbooks. Future studies may consider developing innovative methods to facilitate participants' completing and returning home-based exercise logbooks, such as using electronic exercise logbooks or using mobile phone apps. Fourth, no information about changes in medication, other physical activities or diet during the study period were collected, which might have hindered the interpretation and explanation of these preliminary intervention effects over time, for example, blood glucose level and waist circumference.

5. Conclusion

Tai Chi exercise was a feasible and acceptable intervention for Chinese adults with metabolic syndrome, with both positive and negative changes observed in some cardiometabolic risk factors and quality of life. Further investigation with a larger sample size and longer study period is needed to explore potential environmental factors (e.g., festivals or holidays) that may have influenced the study results. This study provides preliminary findings for the healthcare professionals to consider when integrating Tai Chi exercise as a potential strategy to manage metabolic syndrome among adults.

Appendix A

Intervention Components of Tai Chi Sessions

Parts	Contents	Time
Warm up	Upper-body, lower-body, and spinal stretching exercises to gently stretch the joints and warm up the body.	10min
24-form Yang style Tai Chi exercise	Learning and repetition of the Tai Chi movements, coordinating with breathing and mind concentration, with the following sequences:	45 min/session
	Opening	
	Parting the Horse's Mane	1st session
	White Crane Spreads Wings	2nd session
	Brush Knee and Push	3rd session
	Play the Lute	4th session
	Retreat and Repulse Monkey	5th session
	Left Grasp the Bird's Tail	6th session
	Right Grasp the Bird's Tail	7th session
	Single Whip	8th session
	Wave the Hands like clouds	9th session
	Single Whip	10th session
	Pat the High Horse	11th session
	Right Heel Kick	12th session
	Double Punch to the Ears	13th session
	Left Heel Kick	14th session
	Left Snake Creeps Down	15th session
	Right Snake Creeps Down	16th session
	Left and Right	17th session
	Pick up Needle from Sea Bottom	18th session
	Fan through the Back	19th session
	Turn Body, Deflect, Parry, Punch	20th session
	Apparent Closing	21st session
	Cross Hands	
	Closing	22nd session
	Review and practice all movements	23rd -24th sessions
Cool down	Simple upper-body and lower-body stretching exercise to relax the body	5 min

*Reference: Tai Chi BaLi. (2019) Tai Chi Chuan. Retrieved from: http://taichibali.com/tai-chi/.

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Ethical Approval and consent to participate

Ethical approval was obtained from the Joint Chinese University of Hong Kong–New Territory East Cluster Clinical Research Ethics Committee. Written informed consent was obtained from all subjects prior to commencing any study-related activities.

Declaration of Competing Interest

The research team has no conflicts of interest related to the study.

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