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Evaluation of energy expenditure and cardiovascular health effects from Tai Chi and walking exercise

Key Messages

1. A 12-week Tai Chi or walking exercise intervention produced significant and similar beneficial effects on body composition, aerobic fitness, muscular fitness, fasting blood glucose, resting metabolic rate, and perceived health in middle-aged Chinese.
2. While Tai Chi and walking both elicited significant cardiorespiratory responses and energy expenditure to the moderate intensity level, walking exercise elicited about 46% higher metabolic cost than Tai Chi exercise.

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Introduction

Other than cancer, cardiovascular diseases (CVD) account for major mortality and morbidity rates in Hong Kong. Increasing energy expenditure through regular exercise has been found to lower the risk of CVD and to control hyperlipidaemia and obesity. A cross-sectional survey revealed that Tai Chi (TCC) and walking exercises (WLK) are widely practised by Hong Kong citizens.[1] However, there have been limited studies to compare the health benefits of the two.

An influential medical report confirmed that daily accumulation of 30 minutes of moderate physical activity significantly lowered the risk of developing many chronic diseases. Some studies demonstrated various health benefits from regular WLK. The most recent study by Murphy et al[2] provided an excellent example. This reported that in a 6-week WLK programme (5 days per week), a single bout of continuous 30 minutes of WLK per day yielded similar health benefits to three 10-minute walk per day.

Tai Chi is an ancient form of Chinese fitness exercise. A number of studies have investigated the positive health effects of TCC for patients,[3] as well as for healthy individuals.[4] Such health benefits include improvement in: aerobic fitness and energy metabolism, muscular strength and balance, and mental control. Compared to WLK, it is intuitively perceived to be of lower exercise intensity and metabolic cost. Surprisingly, Lan et al[4] reported that the exercise intensity of a typical session of TCC (24 minutes Yang style) exceeded 70% of maximal heart rate. However, the energy cost of this single bout of TCC has not been investigated. Tai Chi and WLK seem to provide similar benefits but have not been compared simultaneously except in one study. Heart rate, blood pressure, and urinary catecholamine changes for TCC and WLK at 6 km/h are similar. However, currently there are no scientific data in this respect on Hong Kong Chinese population. Results from our study would therefore be valuable for practitioners to provide quantifiable weight control prescriptions for obese individuals, as well as for those who need to improve cardiovascular health.

Methods

This study was conducted from September 2004 to August 2006.

Subjects

A total of 374 sedentary, middle-aged subjects (men and women) from large housing estates in Shatin (New Territories, Hong Kong) who had no known cardiovascular and pulmonary diseases, neurological disorder, or musculo-skeletal disorders were recruited. Informed consent was obtained from participants prior to recruitment. Subjects were then randomly assigned into either a TCC, WLK, or control (CTL) group. To avoid contamination of recruits from excessive numbers in any one of the nine geographical locations, subjects were randomised by locations using a simple random drawing procedure. As a result, three locations were assigned TCC, three for WLK and the remaining three locations as control. For each treatment group, the minimal sample size was pre-determined at not less than 100, resulting in a total of not less than 300. Meanwhile, in order to match the age and gender distribution among the three groups, an effort was made to recruit

approximately 10 subjects of each gender and for each 5-year age-group between the ages of 36 and 60 years.

Exercise intervention

After the initial measurements of resting and exercise metabolic costs and CVD risks, the TCC and WLK groups were prescribed a 12-week training programme, with 5 days of exercise per week (led by qualified instructors for 3 days, and on their own for 2). A modified 32 Yang style TCC was selected. For the WLK group, subjects were required to walk 5 times per week. Upon completion of the 12-week exercise intervention programmes, all the tests were repeated. For the control group, the pre- and post-exercise assessments were conducted in the same way, however, there was no exercise intervention.

Measurement of energy expenditure

All subjects were instructed to lie on a bed for 20 minutes in an environment with a comfortable temperature and humidity. Resting metabolic rate, in terms of oxygen consumption (VO_2 in mL/kg body weight/min), and energy expenditure (KCal in KCal/min), were measured by the Cosmed K4b2 metabolic measuring system. The lowest metabolic value for a continuous 10-minute period was taken to be the resting metabolic rate. To compare the metabolic cost between TCC and WLK, another 30 TCC practitioners of similar age as the intervention participants were recruited to perform 10 min of TCC, 10 min of WLK in self-selected pace, and 10 min of WLK at a controlled heart rate similar to those encountered with TCC. Each form of exercise was performed three times in a random order. Metabolic cost, in terms of VO_2, KCal, and heart rate (HR) were measured using the Cosmed K4b2 analyser.

Measurement of cardiovascular disease risks

These risk factors were determined by blood tests (total, low- and high-density lipoprotein cholesterols, triglycerides, fasting blood glucose). Body composition was measured by bioelectrical impedance analysis. Criteria of CVD risks were adopted from the American Heart Association and the American College of Sports Medicine. Cardio-respiratory fitness, in terms of VO_2max, was measured using a symptom limited treadmill exercise test. Subjects were also required to answer a 'typical 1-week food frequency' questionnaire for diet analysis.

Other measures

Perceived health status was measured by a Chinese version Short-form (12 items) Health-related Quality of Life questionnaire. Six months after the intervention, exercise compliance after the cessation of the 12-week exercise training programme was enquired into by a questionnaire.

Statistical analysis

Age-adjusted repeated measures multivariate analysis of covariance, and subsequent univariate analysis of covariance and Scheffee tests were performed to examine changes in outcome measures between TCC, WLK and CTL groups.

Results

Descriptive statistics

Upon recruitment, there were 129 TCC, 121 WLK and 124 CTL participants. Due to voluntary drop-out and elimination of subjects with low attendance (<70%) in classes, the final sample size for analyses entailed 104 TCC (completion rate 81%), 91 WLK (completion rate 75%), and 121 CTL (completion rate 98%) participants.

Body composition

Statistically significant reductions in body composition measures (body weight, body mass index [BMI], waist circumference, hip circumference, waist:hip ratio, % body fat, and sum of skinfolds) for both WLK men ($P<0.05$ to $P<0.001$) and women ($P<0.01$ to $P<0.001$) were noted. Similar findings were observed for waist circumference, waist:hip ratio, % body fat, and sum of skinfolds in both TCC men ($P<0.001$) and women ($P<0.001$). In addition, TCC men had significant body weight and BMI reductions ($P<0.001$), while the reductions for TCC women were not significant. By contrast, most of the body composition measures in the CTL group increased slightly, although not to a statistically significant extent. Waist ($P<0.01$) and hip ($P<0.001$) circumference, and % body fat ($P<0.05$) of CTL men increased significantly. Sum of skinfolds in CTL women decreased slightly ($P<0.05$). The pre-post changes in BMI for the subjects are shown in Figure 1.

Physical fitness

For men, items that showed improvements post exercise were: back lift strength ($P<0.01$ for TCC and $P<0.01$ for WLK); right leg balance ($P<0.05$ for WLK only); curl-up ($P<0.001$ for both TCC and WLK); and sum of sit-and-reach ($P<0.001$ for both TCC and WLK). For women, corresponding items showing improvements were: back lift strength ($P<0.001$ for WLK only); sum of balance test ($P<0.01$ for WLK only); curl-up ($P<0.01$ for TCC and $P<0.05$ for WLK); and sum of sit-and-reach ($P<0.001$ for TCC, $P<0.01$ for WLK). For CTL men, diastolic blood

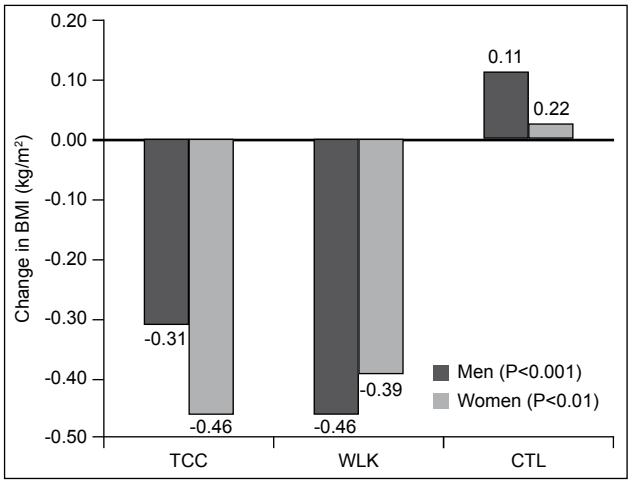

Fig 1. Mean changes in body mass index (BMI) in Tai Chi (TCC), walking exercises (WLK) and control (CTL) subjects

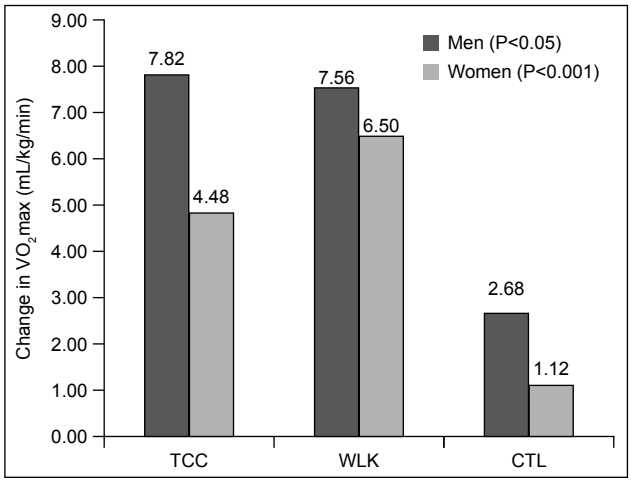

Fig 2. Mean changes in VO_2max in Tai Chi (TCC), walking exercises (WLK) and control (CTL) subjects

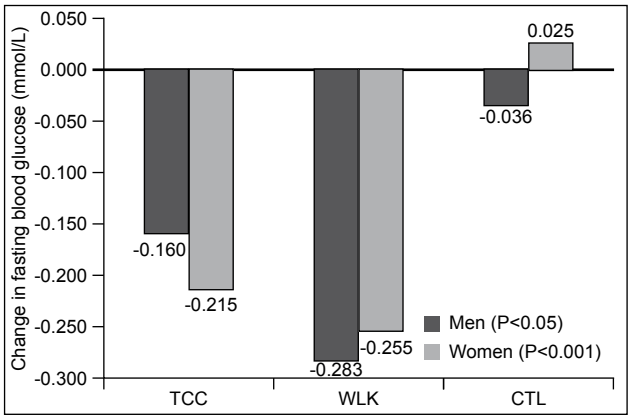

Fig 3. Mean changes in fasting blood glucose in Tai Chi (TCC), walking exercises (WLK) and control (CTL) subjects

pressure (DBP) (P<0.01) and leg lift (P<0.01) decreased slightly, whereas arm lift, back lift and curl-up increased slightly (P<0.01). For CTL women, DBP (P<0.05), arm lift (P<0.01) and shoulder lift (P<0.05) decreased slightly, but back lift (P<0.001) and curl-up (P<0.05) increased slightly. Post-hoc pairwise comparison suggests that both TCC and WLK improved hamstring flexibility compared to CTL as reflected by changes in sit-and-reach scores. However, post-hoc comparison showed non-significant difference between TCC and WLK subjects.

Aerobic fitness

The VO_2max for both exercise groups improved significantly after the exercise (P<0.001 for all TCC and WLK subjects) when compared to the CTL group (Fig 2). Post-hoc comparison showed non-significant difference between TCC and WLK participants.

Resting energy expenditure

There were significant increases in resting energy expenditure (REE)–VO_2 (mL/min/kg) [P<0.001] and REE-KCal (KCal/min) [P<0.01] post exercise, in both TCC and WLK men in comparison to CTL men. No such trend was observed for women.

Blood profiles

In both TCC and WLK men and women, fasting blood glucose levels decreased significantly post exercise (P<0.001, Fig 3).

Dietary intakes

In both men and women, the KCal intake from all of carbohydrates, fat and protein showed no significant differences post exercise, except that for TCC women KCal intake from protein was higher (P<0.01).

Changes in perceived health

The SF-12 questionnaire showed that there was generally an improvement of perceived health status in both TCC and WLK subjects. No such trend was observed for the CTL subjects.

Six-month maintenance

In the respective TCC and WLK subjects, 64% and 77% of the subjects continued to perform their TCC and WLK exercises in the ensuing 6 months, 60% and 68% did so in the ensuing month, and 53% and 65% did so in the ensuing week. Regarding the respective mean frequencies of exercise being performed per week, they were: 2.5 and 3 times in the ensuing 6 months, 2.1 and 2.8 times in the ensuing month, and 2.2 and 2.8 times in the ensuing week.

Metabolic cost

To evaluate the metabolic cost of TCC and WLK, 30 more TCC practitioners were recruited to perform three types of exercises in a randomised order: (1) simplified 33 Yang style TCC performed at a regular pace; (2) brisk walking (BW) at a self-selected pace (WLK-BW); and (3) walking under controlled heart rate (HRC) similar to the TCC exercise (WLK-HRC). Repeated measures analysis of variance revealed that VO_2, HR, ratio of work metabolic rate to resting metabolic rate (MET) and energy expenditure (EE) in the WLK-BW group were significantly greater than those in the TCC and WLK-HRC (P<0.05, Table) groups, whereas no differences were noted between the TCC and WLK-HRC (P>0.05) groups. The exercise HRs for TCC, WLK-BW, and WLK-HRC were about 56%, 65%, and 57% of maximum, respectively. These figures revealed that WLK-BW produced approximately a 46% higher metabolic cost than TCC. Post hoc comparison showed non-significant difference between TCC and WLK-HRC groups. No interaction was found for women. Notably, TCC, WLK-BW, and WLK-HRC elicited significant cardiorespiratory and EE responses to the moderate intensity exercise.

Discussion

This study is perhaps the first to provide a comprehensive comparison of health and fitness in middle-aged, Chinese TCC and WLK subjects. Encouragingly, both 3-month TCC and WLK exercise training produced similar levels of weight reduction, improvement in blood profile and physical fitness, and significantly increased the resting metabolic rate. Both TCC and WLK resulted in reductions

Table. Cardiorespiratory and energy expenditure responses in Tai Chi (TCC), brisk walking (WLK-BW), and walking under controlled heart rate (WLK-HRC) subjects

Measurement*	TCC	WLK-BW	WLK-HRC
VE (mL/min)	18.6 ± 4.1	29.3 ± 7.4†	21.7 ± 5.4
VO_2 (mL/min)	681.9 ± 183	993 ± 279.8†	731.6 ± 238.6
VO_2 (mL/kg/min)	11.3 ± 2.5	16.6 ± 4.2†	12.2 ± 3.7
EE_{total} (KCal)	32.8 ± 8.9	48.1 ± 13.4†	34.8 ± 11.3
EE (KCal/min)	3.2 ± 0.9	4.8 ± 1.3†	3.5 ± 1.1
METS	3.24 ± 0.7	4.7 ± 1.2†	3.5 ± 1.0
$HR_{exercise}$ (bpm)	98 ± 16	114 ± 16†	100 ± 15
RER	0.82 ± 0.09	0.84 ± 0.07†	0.8 ± 0.09
RPE	10.1 ± 1.1	11.2 ± 1.4	10.3 ± 1.0

* VE (mL/min) denotes minute ventilation, VO_2 (mL/min) minute oxygen uptake, VO_2 (mL/kg/min) minute oxygen uptake relative to each kg of body weight, EE_{total} (KCal) total energy expenditure for 10 min of exercise, EE (KCal/min) total energy expenditure per minute, METS the ratio of work metabolic rate to the resting metabolic rate, $HR_{exercise}$ (bmp) heart rate in exercise (beats per minute), RER respiratory exchange ratio, RPE rate of perceived exertion on a 6-20 scale

† P<0.05, TCC versus WLK-BW, WC versus WLK-HRC

of approximately 1 kg in body weight and 2.5 cm in waist circumference in men. In women, corresponding reductions were 0.33 kg after TCC and 0.87 kg after WLK and about 5 cm of waist circumference for both forms of exercise. Similar significant reductions in % body fat and sum of skinfolds were also noted after TCC and WLK in both men and women. In all three groups, some muscular strength tests and curl-up endurance improved in both men and women, however there was no significant interaction. These improvements were probably due to enhanced experiences compared to the pre-exercise status. However, some muscular strength tests in CTL subjects revealed significant decreases (leg lift in men, and arm and shoulder lifts in women). Only the interaction of sit-and-reach flexibility was significant, which suggested that both TCC and WLK improved hamstring flexibility compared to CTL activity. Regarding aerobic fitness in men, after TCC VO_2max improved 22% and after WLK it improved 21%. In women, corresponding figures were 15% after TCC and 20% after WLK. Similar results were noted for changes in fasting blood glucose. More importantly, other than the physiological parameters described above, perceived health status also improved significantly (24-29% after WLK, and 13-14% after TCC). Moreover, 60% to 70% of the exercise participants continued to practise regular exercise training 6 months after the intervention.

Regardless of the similar levels of health improvement from TCC and WLK, the mean exercise HR was 33% higher in WLK than TCC in men, and 34% higher in women. The experiment in metabolic cost comparison revealed that WLK elicited 46% higher VO_2 and EE. When exercise intensity and safety is a concern, TCC appears more desirable than WLK, since it elicits lower metabolic demands but yields similar levels of health benefits. Why TCC produces similar health and fitness benefits at a lower metabolic demand compared to WLK is not known. However, it is the belief of Chinese martial arts practitioners that there is an internal energy called 'qi' that circulates inside the body when practising Tai Chi. The slow and regular breathing technique combined with slow but steady muscular movement is believed to produce 'qi' that stimulates long-term changes in physical fitness.

Although TCC elicits lower metabolic demand, the present study recorded that it produced 56% of age-predicted HR max and 3.3 METs (VO_2=11.5 mL/kg/min) of exercise intensity, which is considered to be an aerobic exercise at a moderate intensity. Li et al[5] reviewed 31 TCC studies and found that nine of them were reported to entail moderate intense exercise, with no more than 55% of VO_2max. The present study recorded that the exercise HR following TCC ranged from 86 to 98 bpm, which are fairly consistent with the findings in a previous study recording a peak HR of 95-98 bpm after TCC.[6]

Although the present study reports a number of significant health improvements from TCC and WLK, arguably the magnitude of improvement was small. It is important to note that, in both the TCC and WLK interventions, the exercise volume was not large; the active exercise time was only 30 minutes per session, 3 times a week and its intensity was only low to moderate. Tai Chi is a low-intensity activity, which yields significant health improvement similar to WLK. This result provides insight showing that even a low intensity of activity (~3 METs, 56% HR max) produces significant health improvement.

The present study reports similar health and fitness improvement for TCC and WLK. However, when the magnitudes of the measured variables are observed, some parameters after WLK did elicit slightly higher improvements than TCC, although not statistically significant. The present study failed to reveal improvements in blood lipid profiles. The latter findings should be viewed as pertaining to relatively short periods of exercise intervention; limited studies have found changes in blood lipid profiles associated with TCC. Further studies with longer intervention periods are suggested.

Acknowledgement

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