Tai Chi Training for Patients with Coronary Heart Disease

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Abstract

Coronary heart disease (CHD) is the leading cause of death in the developed countries and many developing countries. Exercise training is the cornerstone of cardiac rehabilitation program for patients with CHD, and exercise intensities in the 50–70% heart rate reserve have been shown to improve functional capacity. However, recent studies found exercise with lower intensity also displayed benefits to CHD patients, and increased the acceptance of exercise program, particularly unfit and elderly patients. Tai Chi Chuan (TC) is a traditional conditioning exercise in the Chinese community, and recently it has become more popular in the Western societies. The exercise intensity of TC is low to moderate, depending on the training style, posture and duration. Participants can choose to perform a complete set of TC or selected movements according to their needs. Previous research substantiates that TC enhances aerobic capacity, muscular strength, endothelial function and psychological well-being. In addition, TC reduces some cardiovascular risk factors, such as hypertension and dyslipidemia. Recent studies have also proved that TC is safe and effective for patients with myocardial infarction, coronary bypass surgery and heart failure. Therefore, TC may be prescribed as an alternative exercise program for selected patients with cardiovascular diseases. In conclusion, TC has potential benefits for patients with CHD, and is appropriate for implementation in the community.

Cardiovascular disease (CVD) is the leading cause of morbidity and mortality in developed countries. In developing countries, the prevalence of CVD also increases rapidly owing to fast economic growth and lifestyles change. Coronary heart disease (CHD), the major category of CVD, is manifest as
angina pectoris, acute myocardial infarction (AMI) and sudden cardiac death. From 1985 to 1992, the CHD mortality rate in men aged 35–44 years increased from 4.3/100,000 to 11.4/100,000 in South Korea, and from 4.1/100,000 to 7.8/100,000 in Taiwan [1]. Since 1992, the mortality related to CHD slightly decreased in Taiwan due to improved cardiac care, but the hospitalization rates for CHD significantly increased from 1996 to 2001 [2]. In China, a recent study reported that the rates of CHD mortality in Beijing increased by 50% in men and 27% in women from 1984 to 1999, and 77% of this increase might be attributed to substantial rises in cholesterol levels [3].

Exercise training is the core component of cardiac rehabilitation for patients with CHD. The prescribed exercise intensity should be above a certain level to induce an effective training effect, yet below the metabolic load evokes abnormal clinical signs and symptoms [4]. Moderate-intensity exercises have been shown to improve functional capacity in cardiac patients, and it also provides suitable safety during unsupervised training. However, lower intensity exercise increases the acceptance of training, particularly for unfit and elderly patients. From the standpoint of exercise promotion, some oriental conditioning exercises deserve more attention because they are less intense, easily accessible, low cost and therefore suitable for implementation in the community.

Tai Chi Chuan (TC) is a Chinese mind-body exercise. Recent studies have shown that TC is beneficial to aerobic capacity [5–7], muscular strength [8, 9], and some cardiovascular risk factors [10–14]. Further, TC appears to be safe and effective for patients with AMI, coronary artery bypass grafting (CABG) surgery and congestive heart failure (CHF). Therefore, TC may be prescribed as an alternative exercise program for patients with CHD. This chapter reviews the effect of TC on cardiovascular health based on the existing literature, and introduces the potential application of TC in patients with CHD.

**Tai Chi Training**

*Training Characteristics*

TC is a branch of ancient martial arts that has been popular in the Chinese society for several hundred years. TC is well known for its slow and graceful movements, and the training doctrine is deeply rooted in Taoism. The goal of Taoism is to achieve longevity through mind and body training. During the practice, deep diaphragmatic breathing is integrated to complex body motions to achieve a harmonious balance between body and mind. There are many TC styles, among them Chen TC is the oldest, and Yang TC is the most popular [15]. TC is performed in a semi-squat posture, and the exercise intensity can be easily adjusted by controlling the postural height (fig. 1). The characteristics of
TC are: mind concentration with breathing control; whole body exercise in semi-squat posture; continuous, curved and spiral body movements [15]. Each training session of classical Yang TC includes 20 min of warm-up, 24 min of TC practice, and 10 min of cool-down. Warm-up exercises usually include 10 movements including range of motion exercises, stretching, and balance exercises with 10–20 repetitions.

Exercise Intensity

The exercise intensity of TC depends on the training style, posture and duration. Variation in training approaches results in substantial differences in exercise intensity. Participants may practice selected movements instead of a complete set of TC to improve balance or flexibility. However, if the training goal is to increase aerobic capacity or muscular strength, a complete set of classical TC is recommended.

In a recent study, we used a K4 telemetry system to measure heart rate (HR) responses and oxygen uptake (VO$_2$) while performing classical Yang TC in middle-aged men [16]. The HR during TC practice was 58% of the HR reserve, and the VO$_2$ during practice was 55% of the peak oxygen uptake.
Additionally, we found the HR during TC practice was 50–58% of HR reserve in males and females aged 25–80 years, which indicated its exercise intensity was similar across different ages in each gender [17]. TC is an aerobic exercise with moderate exercise intensity, and it fulfills the recommendations of the American College of Sports Medicine regarding exercise to develop and maintain cardiorespiratory fitness [18]. Other studies reported the energy cost during TC practice was between 4.1 and 4.6 metabolic equivalents in young participants [19]. For a simplified form of TC, the estimated exercise intensity may decrease to 2.9 metabolic equivalents [19]. Because age and functional capacity in CHD patients vary significantly, choosing a TC program with suitable exercise intensity is important to obtain a suitable training effect.

## Training Effects of TC

### Aerobic Capacity

Aerobic capacity is a strong predictor of cardiac and all-cause mortality in patients with CVD. In a long-term follow-up for 12,169 patients with CHD, Kavanagh et al. [20] compared the risk of death according to their \( \text{VO}_{2\text{peak}} \) values during graded exercise testing. \( \text{VO}_{2\text{peak}} \) values of 15, 15–22, and >22 ml · kg\(^{-1}\) · min\(^{-1}\) yielded hazard ratios of 1.00, 0.62, and 0.39 of cardiac death, respectively. Therefore, exercise training is the core component in cardiac rehabilitation because it significantly improves the aerobic capacity and hence reduces mortality.

Long-term TC training may enhance aerobic capacity. In cross-sectional studies, Lan et al. [5] reported that the middle-aged TC group displayed 15.6–26.8% higher \( \text{VO}_{2\text{peak}} \) than the control group [21], while elderly TC practitioners showed 18–19% higher \( \text{VO}_{2\text{peak}} \) than their sedentary counterparts. Further, long-term TC practitioners displayed slower age-related decline of aerobic capacity than their sedentary counterparts. In a 2-year follow-up study [22], the annual decrease in \( \text{VO}_{2\text{peak}} \) was 0.55 in the male TC group and 0.8 ml · kg\(^{-1}\) · min\(^{-1}\) in the control group. In the females, the TC groups displayed only half of the decline in \( \text{VO}_{2\text{peak}} \) compared to the control group (0.3 vs. 0.6 ml · kg\(^{-1}\) · min\(^{-1}\)). For sedentary individuals, Lan et al. [6] also reported that entering a TC program significantly enhance the aerobic capacity. After 1 year of TC training, elderly men and women might increase \( \text{VO}_{2\text{peak}} \) by 16.1 and 21.3%, respectively.

### Muscular Strength

Muscular strength and muscular endurance are important to the activities of daily living. However, maximal muscular strength gradually declines after 50 years of age, thus many deconditioned cardiac patients lack the physical
strength to perform daily activities. Improvement of muscular strength and endurance enables cardiac patients to perform certain tasks with less physiological stress and aids in maintaining their functional independence. Resistance training appears to decrease cardiac demands during daily activities like carrying or lifting heavy objects [23]. Additionally, resistance training provides an effective method for improving muscular strength, preventing chronic medical conditions, modifying coronary risk factors, and enhancing functional dependence [24].

TC is performed in a semi-squat posture, and combined concentric and eccentric contractions are needed in this posture. The lower the posture, the higher demand will be put on quadriceps, thus significantly improving muscular strength of the lower extremities. Jacobson et al. [25] reported that a 12-week TC program increased muscular strength of knee extensors. We also proved that a 6-month TC program was effective in enhancing isokinetic strength of knee extensors [8]. In that study, the male TC group increased by 15.1–20.0% of the concentric peak torque in knee extensors, while the eccentric peak torque increased by 15.1–23.7%. In the female TC group, the concentric and eccentric peak torque increased by 13.5–24.2 and 18.3–23.8%, respectively. Both TC groups also showed significant increase in the endurance ratio of knee extensors. In a recent study, Wu et al. [9] measured isokinetic muscular strength of knee extensors, and reported that the TC group had higher muscle power than the control group.

**Endothelial Function and Microcirculation**

Nitric oxide (NO) is an endothelium-dependent vasodilator that has an important role in the vasodilatory response during exercise [26]. Lack of exercise may predispose the coronary arteries to endothelial dysfunction and artherosclerosis due to low shear stress status. Low shear stress to the vessel wall has been associated with endothelial proliferative status in animal studies [27], and may contribute to the pathogenesis of artherosclerosis [28, 29]. However, physical conditioning may enhance vascular responsiveness to endothelium-dependent vasodilators, i.e. NO, in skin and skeletal muscle [30].

Regular practice of TC may enhance endothelium-dependent dilation in skin vasculature of older individuals. In a recent study, Wang et al. [31] reported that older TC practitioners displayed a higher skin blood flow and level of plasma NO metabolite than sedentary subjects at rest and after maximal exercise. In addition, TC subjects had higher arterial blood flow and acetylcholine-induced cutaneous perfusion than the sedentary controls.

TC training is also beneficial to microcirculation. By using impedance plethysmography, we measured skin blood flow and vascular conductance in elderly men before and after a maximal exercise [32]. The results showed that
the TC group had higher hyperemic arterial inflow, venous capacity, and venous outflow than their sedentary counterparts. The results implied that TC could delay the age-related decline of venous compliance and hyperemic arterial response.

**Blood Lipids**

Dyslipidemia, or abnormalities in blood lipid and lipoprotein, is a major risk factor of CHD [33]. The prevalence of dyslipidemia increases with age and westernized lifestyle, but regular exercise may ameliorate the trend toward abnormal blood lipid profile. A recent meta-analysis [34] of 31 randomized controlled trials with exercise training reported a significant decrease in total cholesterol, low-density lipoprotein cholesterol (LDL-C), and triglyceride (TG), and an increase in high-density lipoprotein cholesterol (HDL-C). Typically, the changes in blood lipids were small and it was difficult to separate the effects of exercise from confounders. This may be attributed to differences in baseline lipid concentrations, training amount and intensity, changes in body composition, or the adjunctive interventions such as diet or lipid-lowering agents.

In a study reported by Jiang [35], 1 month of TC training induced an increase in HDL-C and HDL-C/TG, but the level of total cholesterol was unchanged. However, Tsai et al. [13] reported that TC might improve whole blood lipid profile in mild hypertensive patients. In that study, 88 patients were randomized into a TC group and a sedentary control group. After 12 weeks of classical Yang TC training, total cholesterol, TG and LDL-C concentration decreased by 15.2, 23.8 and 19.7 mg/dl, respectively. Further, HDL-C increased by 4.7 mg/dl. In a recent randomized controlled study, Thomas et al. [36] reported no significant change in total cholesterol, TG, LDL-C and HDL-C after 12 months of TC training. Nevertheless, these subjects practiced 24-form simplified TC, the exercise intensity and energy expenditure were lower than for the classical 108-form TC, and this might have influenced the training effect. In the future, more studies are needed to elucidate the effect of TC on blood lipids.

**Hypertension**

Hypertension is the most prevalent form of CVD affecting approximately 1 billion patients worldwide. Hypertension is the major factor contributing to more than one million heart attacks and 500,000 heart attack deaths annually in the United States [37]. Hypertension is also a risk factor for heart failure and peripheral vascular disease. Therefore, lowering BP benefits hypertensive individuals and significantly reduces the morbidity and mortality of CVD. Regular exercise and lifestyle change are the core of current recommendations for
could reduce tension, depression, and anxiety. Moreover, the stress reduction
effect of TC was similar to walking at a speed of 6 km/h [46]. Brown et al. [47]
also reported a 16-week TC program could reduce mood disturbance and
improve general mood in women. In the Atlanta subgroup of the clinical trial of
FICSIT, Kutner et al. [48] randomized elderly subjects into the Tai Chi, balance
training, and exercise education groups. After 4 months of training, the follow­
up assessment found only TC subjects reported that their daily activities and
their overall life had been affected, but participants of the other two groups did
not. The data suggest that when mental as well as physical control is perceived
to be enhanced, with a sense of improvement in overall well-being, the motiva­
tion to continue exercising also increases.

**TC Application in Patients with CHD**

Exercise training cardiac rehabilitation for patients with CHD has not been
widely implemented in the developing countries. Traditional exercise training
highly relied on equipment training, but non-equipment-based rehabilitation
programs are the most practical option for developing countries. Furthermore,
the type of rehabilitation program should be matched to the needs and resources
of each community [49]. Therefore, TC may be used in cardiac rehabilitation
programs because it does not need any equipment and can be easily imple­
mented in communities.

*Acute Myocardial Infarction*

AMI is the most common cause of mortality in patients with CHD. An
overview of randomized trials of cardiac rehabilitation with exercise involv­
ing 4,554 patients with AMI indicated a 20% reduction of risk for total mort­
ality, a 22% reduction for cardiovascular mortality, and a 25% reduction in
the risk for fatal reinfarction [50]. Therefore, patients recovering from AMI
are recommended to receive cardiac rehabilitation services. However, most
patients find it inconvenient to attend exercise training courses in hospital
three times per week, and thereby the participation rate in rehabilitation pro­
gram is low. TC is easily accessible, and can be practiced in the community as
a group exercise. In addition, TC is an exercise with low to moderate inten­sity,
thus patients with AMI may choose TC as an alternative exercise pro­
gram according to their fitness level. Channer et al. [10] designed an 8-week
low-intensity TC program and applied it to patients with AMI. The results dis­
played that TC was effective in reducing blood pressure, and was safe for
patients after AMI.
Coronary Artery Bypass Graft

Patients with CHD who suffer persistent symptoms while receiving medical therapy may be considered for revascularization procedures, such as CABG. CABG for coronary patients aims to increase blood flow to ischemic myocardium beyond an obstructive lesion, and reduce cardiovascular morbidity and mortality. Nevertheless, CABG patients exhibited a 30% decline in VO$_2$peak compared to normal subjects owing to the severity of disease, longer deconditioning and postoperative recovery required [7, 21]. The significant decrease in VO$_2$peak in patients after CABG may be detrimental to their life adaptation, and hence exercise is important to patients who undergo CABG.

In order to evaluate the training effect of TC, we underwent a 12-month TC program for low-risk patients after CABG. CABG patients participated in a TC program as a maintenance (phase III) rehabilitation program [7]. The TC group practiced classical Yang TC every morning in the community setting, and the control group was advised to walk at least 30 min three times per week. During the performance of TC, the mean HR while performing TC was 48–57% of their HR reserve. After 12 months of training, the TC group showed significant improvement of oxygen uptake at the peak exercise and the ventilatory threshold (VeT). At the peak exercise, the TC group showed a 10.3% increase in VO$_2$peak (from 26.2 ± 4.4 to 28.9 ± 5.0 ml · kg$^{-1}$ · min$^{-1}$) and 11.8% increase in peak work rate (from 135 ± 26 to 151 ± 28 W), while the control group did not show any improvement. Further, the TC group also increased 17.6% in VO$_2$ at the VeT, while the control group did not display significant change. The VeT was used initially to assess the endurance with CVD, and it could be used as a noninvasive estimate of lactate threshold [51]. Coyle et al. [52] reported that the VO$_2$peak increased less than VO$_2$ at the lactate threshold in patients with CHD. It should be noted that even a small increase in VO$_2$ at VeT is beneficial to cardiac patients, because it could raise the functional level in activities of daily living.

Congestive Heart Failure

CHF is characterized by the inability of the heart to deliver sufficient oxygenated blood to tissue owing to impairment of cardiac output. CHF can result in abnormalities in skeletal muscle metabolism, neurohormonal responses, vascular and pulmonary function [53]. Exercise training improves functional capacity and symptoms in patients with heart failure and left ventricular systolic dysfunction, but these changes usually occur without changes in left ventricular function [54]. The increase in exercise tolerance may be attributed to increased skeletal muscle oxidative enzymes and improved mitochondrial density [55]. Recent studies proved that low-intensity TC training might be beneficial to patients with CHF. In a noncontrolled study of 5 patients, Fontana et al. [56] reported that Tai Chi Chih could improve quality of life, 6-min walk and
symptoms. In another study, Yeh et al. [57] randomized 30 patients into a TC group (with mean ejection fraction of 24 ± 7%) and a control group, and TC participants practiced 5 basic simplified Yang TC movements twice weekly. After 12 weeks of training, patients’ functional capacity and quality of life significantly improved. Further, the TC group showed a decrease in serum B-type natriuretic peptide levels, which implied the severity of heart failure might improve after TC training. For patients with CHF, low-intensity exercise such as simplified TC may increase the acceptance. Intermittent training protocol by using selected TC movements is suitable for patients with very low endurance.

**Conclusion**

There are several reasons to recommend TC as an alternative exercise program for patients with CHD. First, TC does not need special facilities or expensive equipment, and it can be practiced anytime and anywhere. Second, TC is effective in enhancing aerobic capacity, muscular strength and improving cardiovascular risk factors. Third, TC is a low-cost, low-technology exercise, and it can be easily implemented in the community. It is concluded that TC is effective in promoting cardiovascular health, and it can be prescribed as a maintenance exercise program for patients with CHD.

**References**


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