Research Paper

The changes in brachial artery stiffness, hemodynamics and blood lipid after 3-month Tai Chi Chuan training in the elder adults

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ABSTRACT

Arterial stiffness is increased with aging and cardiovascular disease such as hypertension and atherosclerosis. Tai Chi Chuan (TCC) is beneficial to cardiovascular health and longevity. The aim of the study was to examine the effect of 3 months of TCC training on arterial stiffness, hemodynamics and blood lipids in the elder adults. Seventeen TCC practitioners (7 males and 10 females, age 58.3 ± 9.6) and twenty TCC trainees (7 males and 13 females, age 58.0 ± 11.8) were recruited in this study. The TCC trainees exercised the classical Yang's TCC for 40 min per session, 7 times per week over a course of 3 months. The brachial artery distensibility (BAD), brachial artery compliance (BAC), hemodynamics and blood lipids before and after 3 months of TCC trainees were compared. The systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse pressure (PP) and the total cholesterol (TC) all decreased significantly after 3-month training; in contrast, the high-density lipoprotein-cholesterol (HDL) and the ratio of HDL-C over TC (HDL-C/TC) significantly increased after 3-months of training in the trainees group. BAD and BAC were all significantly increased from 5.28 ± 1.69%/mmHg before TCC training to 6.35 ± 2.54%/mmHg after three months of TCC training (p = 0.008), and from 0.05 ± 0.01 ml/mmHg before TCC training to 0.06 ± 0.02 ml/mmHg after three-months of TCC training (p = 0.008) respectively. The 3-month TCC training program for new comers and trainees significantly improved both arterial stiffness (increasing BAD and BAC) and other cardiovascular factors (lowing SBP, DBP, PP and TC, and increasing HDL and HDL-C/TC). TCC training is a good health-improving calisthenics for elderly individuals and can be beneficial to their cardiovascular system. We highly recommend it to elders as their routine daily exercise, or a program for preventions of hypertension and cardiovascular diseases.

Key words: Tai Chi Chuan, hemodynamics, total cholesterol, high-density lipoprotein-cholesterol, the ratio of HDL-C over TC, brachial artery distensibility, brachial artery compliance, exercise.

INTRODUCTION

The concept of arterial stiffness (also called elastic resistance, an antonym of compliance or distensibility) indicates a pathologic condition of deteriorated Windkessel function due to loss of elastic fiber and increase in collagen tissue during aging or atherosclerotic process (Bader, 1983). Atherosclerosis, hypertension and diabetes produce vascular changes that are reflected in arterial function and vascular physical properties before the development of clinical disease (Mikola et al., 2017; Fu et al., 2014; Zhang et al., 2017; Urbina et al., 2002). Measurement of these changes may therefore prove useful for identifying subjects at a particular risk of cardiovascular complications.
A reproducible, non-invasive method for measuring atherosclerotic and hypertensive vascular changes in TCC exercise was used in this study. The new device records a brachial artery pressure waveform from a cuff sphygmomanometer and estimates brachial artery distensibility (BAD), systemic vascular compliance and left ventricular work using proprietary pulse waveform analysis algorithms (Fu et al., 2014; Brinton et al., 1994). As both hypertension and atherosclerosis are associated with structural and functional vascular changes, it was suggested that this method of compliance and distensibility measurement could be of value in the early detection and management of these diseases (Fu et al., 2014; Urbina et al., 2002; Budoff et al., 2003).

Tai Chi Chuan (also known as Tai Chi Quan, Tai Chi, Taijiquan, or Shadow Boxing) was originally used as a martial arts form for centuries, and practiced in many Asian countries as an exercise predominantly by older individuals. It combines deep relaxation with many fundamental postures that flow imperceptibly and smoothly from one to the other through slow, gentle and graceful movement. It has been advocated for development of mind-body interaction, breath regulation with body movement and hand-eye co-ordination (Li et al., 2001).

Many studies revealed that Tai Chi Chuan (TCC) appears to be safe and effective in promoting balance control (Wolfson et al., 1996), enhancing joint extensibility for arthritis (Hartman et al., 2000), increasing musculoskeletal strength (Lan et al., 2000), and improving cardiopulmonary function (Lai et al., 1993). Besides, it was reported that TCC also has favorable effects on the function of immune system (Sun et al., 1989), modulation of autonomic nervous system (Lu and Kuo, 2003), lipid profiles (Tsai et al., 2003), hypertension (Channer et al., 1996; Thornton et al., 2004; Young et al., 1999), and psychological disorders (Jin, 1992).

Hyperlipidemia has been shown to play a significant role in the pathogenesis of coronary artery disease and the impact of physical exercise on the high-density lipoprotein metabolism has been recognized as the major mechanism involved in the reduction of the risk of coronary artery disease. For instance, a study showed that exercise significantly increased the plasma pre-β high-density lipoprotein (HDL) and decreased the plasma HDL-triglycerides (Jafari et al., 2003).

Another study also pointed out that exercise significantly increased the plasma concentration of pre-β1-HDL, and that the pre-β1-HDL concentration was significantly higher in the venous as compared with the arterial blood both before and after exercise in both diabetics and controls (Sviridov et al., 2003). Besides, weight loss and improved lipid profile could be accomplished through diet and exercise (Melanson et al., 2003). Since TCC training has been shown to be beneficial to the cardiopulmonary function of the subject (Lai et al., 1995, 1998), TCC may also have an effect on the lipid profile of the subject.

Stiffer vessels with decreased distensibility have been seen in subjects with higher levels of cardiovascular risk factors (Urbina et al., 2002; Budoff et al., 2003). Additionally, brachial artery stiffness, measured non-invasively as percent mean pulse amplitude can predict the presence of coronary artery stenosis (Yufu et al., 2004).

Furthermore, flow-mediated dilation studies of the brachial artery have also been proved to predict coronary events (Chan et al., 2003). The predictive relationship of brachial artery stiffness to future risk of cardiovascular events in TCC exercise has not been well studied.

The aim of this study was to examine the effect of TCC on brachial arterial distensibility, brachial arterial compliance, lipid profile and hemodynamics of the aged subjects.

### MATERIALS AND METHODS

#### Study subjects and study design

Two groups of subjects were included in this study, the TCC advanced practitioners of Yang's TCC, and TCC trainees without TCC experience. The TCC advanced practitioners were recruited from the TCC training center in Taiwan and the TCC trainees without TCC experience were recruited from the community. The subjects in the trainee group received 3-month TCC training of classical Yang's Tai Chi Chuan. Each subject completed a questionnaire of medical history and also received a brief physical check-up by a physician. All subjects had a regular lifestyle and were capable of daily activities without apparent limitations. Subjects who had cardiopulmonary disease such as arrhythmia, coronary artery disease, stroke and orthopedic problems, or was on regular medicine for diabetes mellitus, cardiovascular, renal or liver disease was not included in this study. The whole procedure, risks as well as, benefits of the study were well explained to all subjects. Written informed consents were obtained before the study. The protocol was conducted in accordance with the Declaration of Helsinki with the approval of The Institute Review Board of Taipei City Hospital.

#### Equipment and measurement

Brachial artery distensibility measures, including validation studies, as well as, the method to derive arterial compliance, have been previously published (Brinton et al., 1994, 1998). This non-invasive instrument derives BAD using waveform analysis of the arterial pressure signals obtained from a standard cuff sphygmomanometer. For BAD measurements, subjects had a special blood pressure (BP) cuff placed around their upper arm with the subject in a sitting position after resting for 10 min. Three recordings were performed sequentially and measurements obtained for systolic, diastolic and mean arterial BP as well as, heart rate at 20-ms sampling intervals by oscillometric cuff signal...
pattern recognition. Subject data were entered into a personal computer interfaced to the DynaPulse 2000A non-invasive BP and hemodynamic monitoring instrument (Pulse Metric, Inc, San Diego, CA, USA). Off-line analyses of brachial artery pressure curve data were performed by Pulse Metric, Inc. using an automated system to derive parameters from the pulse curves to calculate BAD.

The pressure waveform was calibrated and incorporated into a physical model of the cardiovascular system that had been validated against separate data collected in the cardiac catheterization laboratory (Brinton et al., 1994), assuming a straight tube brachial artery and T-tube aortic system. The method assumed that the systolic phase of the suprasystolic cuff signal and the diastolic phase of the subdiastolic cuff signal was most closely approximate to systolic and diastolic aortic pressure, respectively. Brachial artery compliance was derived from waveform parameters: Arterial compliance \( (C_p) = \pi^2 \cdot D_0^2 \cdot (D_0 + L_c)/(dp/dt_{pp} \cdot t_{pp}) \), where \( dp/dt_{pp} \) is the amplitude from peak positive pressure derivative to the peak negative pressure derivative, and \( t_{pp} \) is the time interval between the peak positive and peak negative pressure derivatives. The effective cuff width \( (L_c) \) is defined as the cuff width divided by the square root of 2.

Brachial artery diameter \( (D_0) \) is estimated using an empirically derived model based on sex, height, weight and mean arterial BP, and validated using B-mode ultrasound (Budoff et al., 2003). Brachial artery distensibility was then calculated using the following formula: Arterial distensibility \( (D) = C_p/((\pi(D_0^2/4) \cdot L_c) \approx 4\pi/(dp/dt_{pp} \cdot t_{pp}) \).

Because brachial artery diameter \( (D_0) \) appears both in the numerator and denominator of the BD equation, significant assumptions regarding baseline arterial size were avoided. This variable was equivalent to other measures of distensibility such as those measured using in that it represents the relative change in volume per unit of pressure, or \( (\Delta V/V)/\Delta P \). Therefore, it was expressed with the units of \( 1/mmHg \).

All hemodynamic parameters were obtained by a non-invasive method not only to measure blood pressure, but also brachial artery compliance and brachial artery distensibility. This new technique may provide a simple and inexpensive way to identify patients with significant atherosclerotic burden (Budoff et al., 2003). In our study, the following parameters such as systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse pressure (PP), mean artery blood pressure (MABP), brachial arterial compliance (BAC) and brachial arterial distensibility (BAD) were obtained.

The biochemistry assays for the quantitative measurements of total cholesterol (TC) (Ektachem Clinical Chemistry Slides, Johnson and Johnson), high-density lipoprotein--cholesterol (HDL-C) (INTEGRA 700, Roche), low-density lipoprotein--cholesterol (LDL-C) (INTEGRA 700, Roche), triglyceride (TG) (Ektachem Clinical Chemistry Slides, Johnson and Johnson) were performed on the blood sample obtained from each subject. After 3-month TCC training, the BAD, BAC, hemodynamic data and lipid profile of the TCC trainees were measured using the same methodology.

Validity and reliability

Previous validation studies of the DynaPulse instrument demonstrated high correlation between compliance (from which distensibility was calculated) measured with cardiac catheterization and those derived by non-invasive means \( (r = 0.83) \) (Brinton et al., 1994, 1998). The intraclass correlation coefficient for blind duplicate recordings was 0.72, including that most of the variability in measurement was due to interindividual variation (Urbina et al., 2002).

Study protocol

The measurement of BP and anthropometric data were collected by trained observers. Height and weight for each subject was included in the model of BAD measurements. Two measurements, each of height to the nearest 0.1 cm and weight to the nearest 0.1 kg, were obtained. Direct measurement of BP and pulse was also obtained using a mercury sphygmomanometer at the time of study. For BP cuff selection, measurements of right upper arm length (using anthropometric calipers) and circumference were obtained. The subjects included in this study were requested not to take caffeinated or alcoholic beverages for at least 24 h prior to the study. The subjects were also requested not to exercise on the day of physiological measurement and blood sampling. The hemodynamic and BAD data were measured after the subject has rested quietly for 10 min, and thereafter, the blood sample was withdrawn.

After baseline recording and measurement, the TCC trainees were advised to exercise classical Yang’s TCC for 40 min. Each session of Yang’s TCC included 10 min warm-up exercise (lower back and hamstring stretching, gentle calisthenics and balance training), 20 min TCC exercise and 10 min cool-down exercise. Each set of Yang’s TCC consists of 64 successive postures (Li et al., 2001). During TCC, the TCC trainees kept the same pace in exercising the postures of TCC in sequence by performing these postures according to a pre-recorded tape to ensure that the same pace and sequence of postures were followed by the TCC trainees. The TCC trainees exercised classical Yang’s TCC seven times every week for 3 months. All procedures were performed in a bright and quiet room with a constant temperature of 25°C. For the TCC trainees, the measurement of DynaPulse and draw blood for assay was taken before TCC training. After 3-month TCC training, the DynaPulse and draw blood of the TCC trainees were measured by the same methodology. The advanced TCC practitioners also received
data of DynaPulse by the same methodology. The biochemistry assays of the blood sample and hemodynamic measures such as TG, TC, LDL-C, HDL-C, SBP, DBP, MABP, PP, BAC and BAD were obtained from every subject in the advanced TCC practitioners and TCC trainee group before TCC training and after 3-month TCC training. All data were checked on the right upper arm in the sitting position in a quiet room with a constant temperature of 25°C.

Statistical analysis

The Mann-Whitney rank sum test (SigmaStat statistical software, SPSS Inc., Chicago, Illinois, USA) was employed to compare the baseline characteristics, hemodynamics measures, lipid profile, the BAD and BAC between advanced TCC practitioners and TCC trainees before TCC training, or between advanced TCC practitioners and TCC trainees after 3-month TCC training. Wilcoxon signed rank test was performed to compare the baseline characteristics, hemodynamic measures, lipid profile, the BAD and the BAC between before TCC training and after 3-month TCC training. All data are presented as mean ± standard deviation. A p<0.05 is considered statistically significant.

RESULTS

Baseline characteristics

Twenty (20) TCC trainees (M/F = 7/13) and seventeen TCC advanced practitioners (M/F = 7/10) were included in this study. Table 1 showed that there was no significant difference in age, gender, body weight, body height and body mass index among the three groups of subjects except the years of TCC training. The TCC advanced practitioners practiced TCC at least 1 h each time, thrice per week for about 5 years.

Comparisons between TCC practitioners and TCC trainees

Figure 1 shows the changes in the BAD before TCC training and after 3-month TCC training. There was no significant difference in the BAD between TCC practitioners and TCC trainees after 3-month TCC training. The BAD of TCC practitioner was significantly higher than TCC trainee before training. Figure 2 shows the changes in the BAC before TCC training and after 3-month TCC training. There was no significant difference in the BAC between TCC practitioners and TCC trainees after 3-month TCC training. The BAC of TCC practitioner was significantly higher than TCC trainee before training. The years of TCC experience of the practitioners did not correlate with their BrachD measures.

Long-term effects of TCC on hemodynamics and lipid profile

Tables 2 and 3 showed that there was no significant difference in the TG, LDL-C and MABP among the three groups of subjects except the TC, HDL-C, ratio of HDL-C over TC (HDL-C/TC), SBP, DBP and PP. HDL-C increased significantly from 52.0 ± 2.9 mg/dl before TCC training to 54.2 ± 2.9 mg/dl after 3-month TCC. In contrast, TC decreased significantly from 207.0 ± 9.6 mg/dl before TCC training to 191.0 ± 2.9 mg/dl after 3-month TCC. Due to the increase in HDL-C and decrease in TC, the HDL-C/TC increased significantly from 0.24 ± 0.09 before TCC training to 0.28 ± 0.09 after 3-month TCC. The SBP, DBP and PP were all decreased significantly after 3-months TCC training.

Long-term effects of TCC on brachial artery distensibility and compliance

After three-month TCC training, the BAD and BAC of TCC

Table 1: General characteristics of TCC practitioners and TCC trainees before and after 3-months TCC training.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>TCC practitioners (n = 17)</th>
<th>TCC trainees (before training) (n = 20)</th>
<th>TCC trainees (after training) (n = 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>58.3 ± 9.6</td>
<td>8.0 ± 11.8</td>
<td>58.0 ± 11.8</td>
</tr>
<tr>
<td>Gender (M/F)</td>
<td>7/10</td>
<td>7/13</td>
<td>7/13</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>57.3 ± 11.5</td>
<td>60.5 ± 10.7</td>
<td>60.5 ± 10.7</td>
</tr>
<tr>
<td>Body height (cm)</td>
<td>159.9 ± 8.7</td>
<td>162.2 ± 9.7</td>
<td>162.2 ± 9.7</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.3 ± 2.9</td>
<td>22.9 ± 2.6</td>
<td>22.9 ± 2.6</td>
</tr>
<tr>
<td>Length of TCC practice (years)</td>
<td>5.0 ± 5.3</td>
<td>0.0*</td>
<td>0.3 ± 0.0*</td>
</tr>
</tbody>
</table>

Data are presented as mean ± SD. * p<0.05 when comparing the TCC trainees group (before training) with the TCC practitioners group (Mann-Whitney rank sum test); † p<0.05 when comparing the TCC trainees group (after training) with the TCC practitioners group (Mann-Whitney rank sum test); # p<0.05 when comparing the TCC trainees group (before training) with the TCC practitioners group (Wilcoxon signed rank test). BMI = body mass index.
trainees were all significantly increased. The BAD increased significantly from 5.28 ± 1.69%/mmHg before TCC training to 6.35 ± 2.54%/mmHg after three-month TCC training with p value = 0.008 (Figure 1). Similarly, the BAC increased significantly from 0.05 ± 0.01 ml/mmHg before TCC training to 0.06 ± 0.02 ml/mmHg after three-month

Figure 1: The changes in the brachial artery distensibility before TCC training and after three-months TCC training. Data are presented as mean ± SD. *p<0.05 vs. before TCC (Wilcoxon signed rank test); #p<0.05 vs. TCC practitioner (Mann-Whitney rank sum test).

Figure 2: The changes in the brachial artery compliance before TCC training and after 3-month TCC training. Data are presented as mean ± SD. *p<0.05 vs. before TCC (Wilcoxon signed rank test); #p<0.05 vs. TCC practitioner (Mann-Whitney rank sum test).
DISCUSSION

TCC is a traditional oriental mind-body calisthenics that is unique for its slow and graceful movement. TCC consists of a sequence of postures that are smooth, harmonic and relaxing. TCC is performed in semi-squat postures with varying degrees of concentric and eccentric contractions. Thus, TCC can significantly enhance the strength of lower extremities, while the upper extremities are in a relaxed state during TCC practice. It was evident from a two-year study trend in the cardiovascular function among elderly TCC practitioners and sedentary subjects that regular TCC might delay the decline of cardiovascular function in the elderly individuals and might be prescribed as a suitable aerobic exercise for the elderly individuals (Lai et al., 1995).

TCC training has benefits for health-related fitness, and might be prescribed as a suitable conditioning exercise for the elderly (Lan et al., 1996). A 12-month TCC program was effective to improve cardiorespiratory function, muscle strength and flexibility in the elderly (Lan et al., 1998). TCC could significantly increase the VO<sub>2peak</sub> and peak work rate in patients with coronary artery bypass surgery (Lan et al., 1999). Similarly, long-term regular TCC exercise has favorable effects on the promotion of balance control, flexibility and cardiovascular fitness in the elderly (Hong et al., 2000). From these studies, it is evident that TCC is a suitable conditioning exercise for elderly individuals and patients with coronary artery disease.

An 8-week, low-intensity TCC program was effective for reducing blood pressure in patients with acute myocardial infarction (Channer et al., 1996). The effects on blood pressure of a 12-week moderate-intensity aerobic exercise program and a T’ai Chi program of light activity was observed (Young et al., 1999). For systolic blood pressure, adjusted mean (SE) changes during the 12-week intervention period were: 8.4 (1.6) mmHg and -7.0 (1.6) mmHg in the aerobic exercise and T’ai Chi groups, respectively (each within-group P < 0.001; between-group P = 0.56).

Furthermore, a study showed significantly improved following 12-week Tai Chi exercise in seventeen relatively sedentary but healthy normotensive women aged 33 to 55 years, with significant decreases in both mean systolic (9.71 mmHg) and diastolic (7.53 mmHg) blood pressure (Thornton et al., 2004). Some colleagues showed that 12-week Tai Chi Chuan exercise training could decrease blood pressure and results in favorable lipid profile changes and improve subjects’ anxiety status (Tsai et al., 2003).
Chronic and dynamic exercise is associated with increased circulating levels of HDL and reduced LDL such that the ratio of HDL to TC is increased and that these changes in cholesterol fractions occur at any age if exercise is regular (Martin, 2003). Tai Chi exercise may be a beneficial adjunctive therapy for some patients with cardiovascular disease (CVD) and CVD risk factors (Yeh et al., 2009).

Another study further demonstrated that the TC/HDL-C, apoB/apoA-I and LDL/HDL ratios were similarly associated with components of the metabolic syndrome and coronary heart disease risk (Arsenault et al., 2010). The change in the ratio of HDL to TC that takes place with regular physical activity can reduce the risk of atherogenesis and coronary artery disease in active people, as compared with those of sedentary people.

In accordance with the above-mentioned studies, we found that HDL-C increased significantly and TC decreased significantly after 3-month TCC training. Thus, the ratio of HDL-C to TC was increased significantly after 3-month TCC training. It was also observed that after three-month TCC training in the trainees group, systolic blood pressure, diastolic blood pressure and pulse pressure all decreased significantly. Our observation suggested that the effect of three-month TCC training might be beneficial in the blood pressure of the subject.

Increased arterial stiffness has recently been proposed as a powerful and independent risk factor for cardiovascular disease (Boutouyrie et al., 2002; Franklin et al., 1999; Meaume et al., 2001). Reduced arterial compliance and distensibility can contribute to the development and progression of hypertension, left ventricular afterload, left ventricular hypertrophy and dysfunction and to decreased myocardial perfusion and vasculopathy (Boutouyrie et al., 2002; Dart and Kingwell, 2001).

Since increased arterial stiffness is a dysfunctional property of the arterial circulation that precedes the development of clinical cardiovascular disease (Mikola et al., 2017; Fu et al., 2014; Zhang et al., 2017; Urbina et al., 2002), the study of this early change is of interest. Non-invasive devices to measure vascular stiffness, such as arterial compliance and distensibility to reflect these changes were developed and are commercially available. These new techniques, which utilize different aspects of the pulse pressure waveform are simple and reliable and correlate with development of atherosclerosis in non-human primates and humans (Farrar et al., 1991; Herrington et al., 2003; Willens et al., 2003) and may identify patients at increased risk of developing cardiovascular complications (Brinton et al., 1994; Blacher et al., 1998; Laurent et al., 2001; London et al., 2001).

Pulse pressure is also influenced by left ventricular ejection and intensity of wave reflections returning to the heart (Kheder-Elfekih et al., 2015) which may be influenced by height (London et al., 1995). Therefore accurate independent assessment of vascular function becomes important, even in the absence of BP change, a salt load produces abnormalities in vascular function (Safar et al., 2000) and cardiovascular risk due to reduced hypertension, regardless of the magnitude of BP reduction (Viberti and Whelton, 2002). However, these changes in the arterial pulse wave need to be explored for their relation to other cardiovascular risk factors and their predictive value for future cardiovascular events in asymptomatic, apparently healthy subjects.

Physical activity is known to lower the incidence of cardiovascular diseases and stroke, probably due to the beneficial changes in blood pressure (Paffenbarger et al., 1991), obesity (Buemann and Tremblay, 1996), lipid profiles (Berg et al., 1997), insulin resistance (Helmreich et al., 1991) and thrombogenic factors (Scarabin et al., 1998). As a result, regular aerobic activity is frequently incorporated into primary and secondary prevention programs (Pate et al., 1995).

It is generally accepted that moderate-intensity activity seems to lower blood pressure as much as higher intensity exercise in middle-aged and older adults (Rogers et al., 1996). Tai Chi Chuan can be classified as moderate exercise, as its intensity does not exceed 55% of maximal oxygen uptake and 60% of the individual maximal heart rate (Zhuo et al., 1984).

In this study, we observed the clinical utility of one of these methods for estimating brachial arterial compliance and distensibility by recording a brachial artery pressure waveform from a cuff sphygmomanometer and using proprietary pulse waveform analysis algorithms (Fu et al., 2014; Brinton et al., 1994). This method has been suggested as a screening tool for coronary artery disease, particularly in asymptomatic individuals with coronary risk factors (Fu et al., 2014; Urbina et al., 2002; Budoff et al., 2003). We observed that the brachial arterial compliance and distensibility of TCC practitioners were significantly higher than TCC trainees before TCC training, while the brachial artery distensibility and compliance were all significantly increased after three-month TCC training. In accordance with the earlier mentioned studies, our observation suggested that the long-term or accumulated effect of TCC might be beneficial to the blood pressure, brachial artery distensibility and compliance of the subject.

The antihypertensive mechanism of exercise can be explained in the following phenomena. Arterial compliance and distensibility play an important role in regulating blood pressure. Strong evidences suggest that endothelial dysfunction in atherosclerogenesis is linked to the clinical manifestation of established cardiovascular diseases. Impaired endothelium function causes less arterial distensibility in variant situations including diabetes mellitus (Calver et al., 1992), hypertension (Cardillo et al., 1998), and hyperlipidemia (Creager et al., 1990). In contrast, regular exercise training has been shown to enhance endothelium-dependent dilation (flow-dependent dilatation) in healthy persons (Clarkson et al., 1999), and
patients with chronic heart failure (Hornig et al., 1996), type 1 diabetes mellitus (Fuchsjager-Mayrl et al., 2002), or hypercholesterolemia (Lavrnicic et al., 2000). Augmented blood flow and shear stress result in increased nitric oxide (NO) production and upregulation of endothelial NO synthase activity (Kingwell et al., 1997). We considered that TCC might result in improvement of arterial distensibility based on our measured data and findings. To explain why TCC could increase arterial distensibility in our study, the phenomenon of increased brachial artery distensibility after TCC training might be related to the same mechanisms. TCC practitioners had higher cutaneous microcirculatory function and higher level of plasma NO metabolite than sedentary group (Wang et al., 2001), and this also proved that regular TCC practice was associated with enhanced endothelium-dependent dilation in skin vasculature.

The associates also demonstrated that practice of TCC might delay the age-related decline of venous compliance and hyperemic arterial response (Wang et al., 2002). In addition to elevated level of nitric oxide (NO), the potential effects of other vasodilative molecules related to exercise training, such as prostaglandins (Koller et al., 1995) and adenosine (Gielen et al., 2001) cannot be discounted. Nevertheless, decreased sympathetic drive (O'Sullivan and Bell, 2000), plasma rennin activity, or endogenous ouabain-like substances (Koga et al., 1992) following regular exercise have also been proposed to play a role in lowering blood pressure.

Powerful evidence pointed that isolated systolic hypertension is a major risk factor for cardiovascular disease and results primarily from elastic artery stiffening especially in the elderly (Mackenzie et al., 2009). The increase in pulse pressure accompanying a reduction of arterial distensibility was a great clinical significance because accumulative evidences of the above mentions indicated that high pulse pressure may represent an important independent risk factor of cardiovascular morbidity and mortality. Therefore, it is important not only to lower blood pressure, but also to improve the distensibility of systemic arteries.

Conclusion

Long-term effect of TCC was beneficial to cardiovascular system in the elderly. Since aging and other cardiovascular risk factors are associated with impaired arterial compliance and distensibility, TCC might be a good health promotion calisthenics that can be recommended to elderly individuals.

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REFERENCES


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