A Review of Tai Chi’s Health Benefits and Its Potential Mechanisms for Chronic Diseases

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Abstract

Tai Chi (TC) is a unique form of exercise that entails focused mindfulness and physical movement and hence belongs to the category of mind-body exercises. Practiced in China for many centuries, it recently became popular in the western world due to its ability to prevent falls for elderly people that practice TC. Numerous studies show that Tai Chi is an effective mind-body medicine for chronic inflammatory diseases, such as arthritis, heart disease, diabetes, and obesity. However, few studies examined its mechanism for health. Modulation of inflammation and the immune system in general seems to provide one plausible mechanism on how the practice of TC leads to testified improvements in a person’s vitality, longevity, and mental health. Hence, this review aims at summarizing the current mechanistic evidence of TC in controlling chronic diseases. We first present the chronic diseases that have shown improvements with TC and in the second section focus on mechanistic TC studies. We conclude that the existing scientific evidence of TC’s health benefits from low- and mid-scale studies justifies investment in large-scale clinical trials for this mind-body exercise with no known negative side effects.

Introduction

This review presents the current scientific evidence of the health benefits of Tai Chi (TC), a form of mind-body exercise. In our world characterized by a rise in the proportion of older people, of people with chronic diseases, and of obese people, the most widely agreed on recommendation to maintain the health of the society is exercise. TC is considered a mild to moderate form of exercise as judged by the energy expenditure of 1.5 to 4.6 metabolic equivalents (METs).1 In comparison, swimming has 4.5 to 10 METs and running 6 to 16 METs. It also has low impact on the joints. Hence, TC has been suggested as a good fit for the sedentary population and the population with chronic disease, which both often deal with physical barriers to increase their physical activity.2 Moreover, TC can be done without special equipment or minimal space requirement, which makes it suitable for people with economical barriers. This might also be one reason for the findings in recent studies of the United States 3 and Australia 4 that show that TC is as well received in rural communities, as in urban areas. Last, TC is best done in a group setting and with sedative music, which may serve to offer extra psychosocial and emotional support.

But TC is not only about exercise. TC is a combination of physical movements and focused mindfulness, and hence addresses both body and mind. There has been a lot of testimonials and demographic evidence that TC not only improves a person’s physical health, but also its vitality, mental health, and longevity. This makes TC belong to the class of mind-body medicine. TC’s unique style developed by the end of the Chinese Ming Dynasty around 1368-1644.5 In
Western countries, it became increasingly more popular after Wolf et al. demonstrated its efficacy for preventing falls.6 There, it is often characterized as a form of moving meditation.

TC’s increasing popularity in the Western world and the increasing number of scientific studies that testify to its promotion of health, increased the interest for better understanding of TC’s mechanism(s) of action. This paper aims at summarizing the current mechanistic knowledge of TC as efficient exercise to benefit mind and body. For that, we screened about 600 studies published in Ovid Medline and Pub med and summarized their findings. The fact that these studies are less than 0.3 percent of the number of scientific studies that result from a search on the term “exercise” indicates the need to draw more attention to this health intervention with known benefits and no known adverse side effects. In this review, we first present the scientific evidence of TC for improving chronic health conditions, and then present studies aimed at understanding the mechanisms of how TC affect the body, from gross body changes to changes in immunological parameters.

Evidence of TC for Improving Chronic Health Conditions

Rheumatic Diseases

There is some evidence that TC has positive effects on the symptoms of rheumatic diseases. In a 2011 review article, Wang comes to the conclusion based on about 80 studies that TC can be a primary exercise therapy for older people with osteoarthritis, and fibromyalgia, and an adjunctive therapy for rheumatoid arthritis with other co-morbidities.7 Evidence for TC as safe complementary therapy for adults with functional class I and II rheumatic arthritis had been previously presented by the same author and his colleagues8 . Similar conclusions were made by Uhlig et al in a 2010 study of rheumatoid arthritis, where a 12-week TC program led to improved lower-limb muscle function and reduced swollen joints during a 12-week follow-up investigation.9

Pain in Musculoskeletal Conditions

In 2007, Morone et al. found minimal or no support of TC for chronic pain in older adults10. Hall et al. came to the same conclusion in a review published in 2010, while they reported significant benefit of TC for muscle tension and self-reported general health.11 On the other hand, a pilot, single-blinded, and randomized control trial by Wang et al. in 2008 revealed that TC did improve pain in people with class I or II rheumatoid arthritis, accompanied with improvements in their general functional status and reduction of joint tenderness and swelling.12 The group followed up with a randomized controlled trial, published in 2010, and confirmed TC’s effect on pain reduction, this time in people with fibromyalgia pain.13 One other study from an Australian randomized controlled trial showed that 18 sessions of TC, 40-minutes each, and spread over 10 weeks, effectively lowered the pain for people with persistent low back pain.14 Tamim et al. reported significant improvements in the musculoskeletal fitness of women with a computer work place in Canada when regularly practicing TC.15

Parkinson Disease

A review by Lee et al. in 2008 addresses the potential impact of TC on Parkinson Disease (PD).16 They concluded that there was emerging evidence for TC helping PD patients, but that the number and quality of studies needed to be improved for conclusive evidence. Since Lee’s review article, one study has reported that TC significantly improves balance and mobility as evidenced by a Unified PD rating scale and other measures.17 Yet in another study, the same group compared the efficiency of performing Tango, Waltz/Foxtrot, TC, with no activity and found that only Tango showed significant improvements on mobility, social support and health related quality of life.

Diabetes Mellitus

There is evidence that TC’s has benefits for people with type 2 diabetes mellitus (T2DM). Xin et al published in 2007 a qualitative review of Qigong and found evidence that regular TC practice can improve the participants’ diabetic symptoms. These include blood levels of glucose, triglycerides and total cholesterol, as well as results from fasting and 2-hour oral glucose tolerance tests.18 On the other hand, Xin reported inconsistent effects of TC on insulin and hemoglobin A1C levels. Moreover, they alerted to the fact that several reviewed studies had limitations such as their short duration, small sample size, or missing appropriate control groups. A review paper of the Chinese literature including over 35 studies reported mainly positive impacts of TC on diabetics.19 From 2007 to 2009, five well controlled, though small studies confirmed the promise of TC to benefit people with T2DM. Two studies showed significant improvement in fasting blood glucose after 8 to 12-week of TC practice,20, 21 while three studies from two laboratories demonstrated a significant decrease in hemoglobin A1C with 12-week TC practice.22-24 Richerson et al. reported in 2007 significant improvement in plantar sensory ability of T2DM patients practicing TC.25

Blood Pressure and Cardiovascular Diseases:

Yeh et al., 2008, systematically reviewed the literature on the effect of TC on blood pressure (BP). The authors reported that 85% of 26 referenced studies showed reductions in BP in the range of 3-32 mmHg for systolic BP and 2-18 mmHg
for diastolic BP. They judged that five randomized controlled trials were of appropriate quality to lead to valid results.

The same research group reviewed in 2009 the effects of TC for patients with cardiovascular conditions and risk factors and included 29 studies. Again, most of the studies, including nine randomized controlled trials, showed decreases in BP. Moreover, increases in the exercise capacity of the participants were reported. Lowered systolic and diastolic blood pressures after TC practice were confirmed by four more studies. In addition to blood pressure, resting heart rate dropped after 12-48 weeks TC program in two studies, one involving female computer users, the other transitionally frail elderly. Taylor-Piliae reviewed in 2008 in a meta-analysis the effectiveness of TC in improving aerobic capacity. The author concluded that TC is effective in improving aerobic capacity when practiced long term, with the largest significant effects being found for women and men, 55 years and older, when compared to sedentary age-matched subjects in a cross-sectional study.

Cancer

Several groups have summarized the effects of TC as exercise intervention or therapy for cancer survivors. Cancer survivors are a population with multiple therapeutic needs such as pain control, de-conditioning of nauseas, monitoring of aerobic capacity and metabolic abnormality, and stress and anxiety reduction. Three pilot studies by Mustian and his colleagues from 2004 to 2008 included significant improvements in aerobic capacity, muscular strength, and musculoskeletal flexibility as well as improvements in quality of life and self-esteem. It is worth mentioning that there were also positive effects within some control groups such as improved flexibility of breast cancer survivors who received psychosocial therapy only.

Chronic Obstructive Pulmonary Disease

A pilot study on patients with chronic obstructive pulmonary disease (COPD) showed two hour TC sessions per week for 12 weeks on average significantly improved the scores of the Chronic Respiratory Questionnaire of the members in the TC group as compared to the members of the traditional-care group. A second, larger single-blind clinical trial conducted in Hong Kong by Chan et al. also found significant differences. Compared with people performing breathing exercises and routine activities, people practicing TC for 3 months had significantly improved COPD patient scores in their health-related quality of life questionnaires.

Psychological Well-being and Mental Disorders

In 2001, Li et al hypothesized that TC is an effective exercise for enhancing the psychological well-being of elderly individuals and supported the hypothesis via latent growth curve modeling, a method widely used in the field of behavioral and social science. The study of Esch et al in 2007 used the reduction of the stress hormone cortisol, directly and 4 weeks after a 14-week TC program, as evidence of TC’s beneficial impact on the psychological being of the participants. The review of Wang et al. in 2010 confirmed the benefits of TC for the participants’ well-being, such as improvement in stress management, reduction in anxiety, depression, and mood disturbances, and increase in self-esteem. TC has been effective for improving the sleep quality of a wide range of people, from college students to people suffering from fibromyalgia to people with chronic heart disease.

Balance Disorders and Dizziness

TC has shown decreases in falls and increases in balance, 49 in people without vestibular illnesses, independent of their previous level of activity and their weight status. This effect is even more pronounced in people with mild balance disorders as shown by Hain et al in 1999. Both, qualitative posturography measures and questionnaires on the Dizziness Handicap Inventory improved after 8 weeks of TC training.

Potential Mechanisms of how TC Affect the Body

In the previous part of this review, we reported that compelling evidence is accumulating, especially from well controlled studies with sufficient participants and length, that TC beneficially influences the progression of a wide variety of inflammatory diseases and improves mental ability and overall well-being. The improvement magnitude is comparable with improvements seen with other mild exercise modalities such as 10 weeks of walking. In the following part, we look at potential mechanisms of how TC might achieve these benefits. We reveal metabolic effects comparable to other energy-matched exercises and present the current status on how to connect the energy training effects to immune and neurological pathways.

Mechanisms Related to the Body’s Energy Metabolism

Body weight: In various study groups TC is reported to decrease body weight, BMI, and waist circumference. This seems to be independent of the type of TC that had been practiced. For instance, a type of TC specifically adapted to diabetics, showed decreased body fat and increased fat-free mass of the participants in a comparable way to other studies in which other TC styles were practiced. The fat loss is greatest at the typical fat accumulation sites, abdominal areas for men and sub-abdominal areas for women. The weight losses are comparable to weight losses seen with other mild to
moderate exercise over weeks, and hence confirms TC’s metabolic characterization amongst exercise modalities.

**Muscle strength:** TC is performed in a semi-squat posture that places a larger load on the muscles of the lower extremities, thus generating more torque in the ankle dorsiflexors. The increased load bearing activity can be evidenced as higher endurance of knee extensor muscles and as reduction in fat of the thighs. Increased strength of the lower body muscles can translate into a benefit for the frail elderly, which can complete 3-chair-rises in a shorter time after a 48-week TC program. In addition to strength increase of lower extremity muscles, there have been two reports on strength increases of upper extremities such as handgrip strength. Again, TC-induced improvements in strength are comparable to the improvements seen with other mild to moderate strength training. It is believed that the underlying mechanisms involve increased motor-neuron output and to a lesser extent muscular adaptations.

**Oxygen consumption:** Using the body’s oxygen stores, a moderate exercise can be sustained for about 30 seconds. After that, if activity is to persist, oxygen must be continuously delivered to the muscle mitochondria at a rate equivalent to the muscle oxygen consumption. As exercise intensity increases, so does oxygen consumption. One parameter to determine oxygen consumption is VO2 max, or VO2 peak, the highest rate of oxygen consumption attainable during maximal exercise. It is used as measurement of cardio-respiratory endurance and aerobic fitness, since it is generally believed that oxygen delivery is limited by the oxygen transport of the cardiovascular system. For TC, there has been one negative and two positive reports. Yet et al. did not find significant improvements of VO2 max in patients with chronic heart failure in a 12-week long study with small sample size, while significant improvements have been seen in larger-scale 12-week study when comparing the TC group with the sedentary group and in a 12-month study with larger sample size. In a five-year follow up study, it has been shown that long-term practice of TC had slowed the age-related decrease in VO2 max.

**Ventilatory threshold:** Lan et al. showed an increase in the ventilatory threshold with TC. The ventilatory threshold is another cardiovascular fitness parameter and measures the point where the exercise-dependent increase in ventilation deviates from the previous linear relationship. Compared to VO2 max which measures peak performance, the ventilatory threshold is a measure to estimate fitness at sub-maximal work.

**Blood glucose and lipid profile:** At rest, skeletal muscle has a low metabolic rate, but when contracting, the energy consumption rises enormously, with the fuel coming from local energy stores and systemic energy stores such as liver glycogen and adipose tissue triacylglycerols. Liver glycogen is in equilibrium with blood glucose, an easily measurable and clinically relevant parameter. Two studies showed that long-term TC exercise (8-12 weeks) significantly lowered fasting blood glucose. Wang also reported increases in serum insulin, numbers of high-and low-affinity insulin receptors, and low-affinity receptor binding capacity after 8-week
They found that the intensity of a single bout of acute TC can stimulate glucose release and utilization by increasing the number of insulin receptors and their binding capacity. For the lipid blood profile, after 12-months of TC, total cholesterol, low density lipoprotein cholesterol, and triglycerides were decreased in dyslipidemic patients, while triglycerides and high density lipoprotein cholesterol had improved in obese type II diabetic patients.

Another glucose-related, clinically relevant parameter is hemoglobin A1C, which is the glycated form of hemoglobin and gives information about a person’s average blood glucose levels of the past three months. Five studies detected significant reductions, while one study reported a trend only. However, this latter study found significant decreases in central body fat, and increases in fat-free mass. Interestingly, one study used TC as placebo control to evaluate the efficiency of Kung Fu in overweight and obese adolescents but found in both groups a trend of decreasing hemoglobin A1C.

**Mechanisms Involving the Immune System**

**Blood immune parameters:** In the Kung Fu/TC study, both groups not only showed changes in metabolic parameters, but also in the immune system in the form of decreased C-reactive protein (CRP), an acute-phase inflammatory protein. While the correlation between metabolism and immune parameters has been increasingly studied for various types of exercise, there is minimal information with TC. One additional study confirmed the decrease in CRP for obese and diabetic people performing TC. Yang et al. reported a better antibody response to the influenza vaccine in the elderly by measuring anti-influenza hemagglutination inhibition (HI) titers. Serum malondialdehyde, an indicator of oxidative stress, had significantly decreased for participants performing TC but not for the group practicing conventional exercise. TC showed increased complement factor H and decreased factor B by proteomic differential displays. Complement factor H has been shown to bind to malondialdehyde, which ultimately protects the body...
from oxidative stress such as present for inflammatory diseases. In our own pilot study, we found in 7 healthy participants who practiced TC for one hour changes in key inflammatory mediators such as increased IL-13, IL-5, and some chemokines, as well as decreased IL-17C mRNA.

**T cells:** IL-13 and IL-5 are produced by a variety of cells including T cells. Hence, consistent with our findings, Yeh and collaborators reported changes in T cells. They found that the percentages of CD4+ and CD8+ decrease but not the absolute count after a 12-week TC exercise, while the proportion and/or the count of T regulatory cells (CD4+CD25+) increase.67 or transcription factor FoxP3 mRNA level increase.23 The up-regulation of T regulatory cells at cells and its transcription factor mRNA levels was found in normal adults67 and in type II diabetics.22, 23 Possibly, memory T cells (CD4+CD45RO+ T cells) increase as well, as can be hypothesized from the fact that cellular immunity to varicella zoster virus was strengthened with TC.68, 69

**Monocytes:** Thus far, the reports on monocytes after TC practice are contradictory. While Yeh et al. showed a decrease of monocytes in peripheral blood after 12-week of TC practice,67 Lee et al. found that in a 12-week self-help education program plus 24-weeks of TC for Korean gastric cancer survivors, an increase in the total white blood cell counts and an increase in the proportion of monocytes.70

**Peripheral nerves:** Hung et al. reported that 12 weeks of TC, three times a week, significantly improved the motor nerve conduction velocities, but not the amplitudes, of the median and tibial nerves and the sensory latencies of ulnar nerves in diabetic patients.21 While this could be a direct effect on the nerves, it is also possible that the improved
glucose metabolism of the participants reverses the high-blood glucose induced damage to the nerves. There is no mechanistic information available at this point. The same is true for the modulation of autonomic nerves which is seen as decreased resting heart rate15, 28 or increased heart rate variability as described above.

**Mechanistic Overlaps Between Immune, Neuronal and Humoral Systems**

**Neuro-immunological pathways:** The immune and the neuronal system do not operate independently, but have a lot of mechanistic overlaps. Re-setting complex control mechanisms is one likely way how an exercise such as TC could exert systemic effects on body and mind. 82 But this also brings up the challenge of mechanistically understanding TC since the knowledge of neuro-immunological pathways is still in its infancy. One established overlap is the influence of the vagus nerve on the innate and adaptive parts of the immune system.

The immune system is under the direct control of the vagus nerve via cholinergic anti-inflammatory pathway, thus it’s not autonomous as we speculated before. The vagus nerve can modulate both innate and adaptive immune arms and help maintain the homeostasis.79, 80 In the spleen, this mechanism depends on nicotinic acetylcholine receptor subunit α7 (α7nAChR). Increased of vagal control of heart rate can be achieved through paced breathing, thus reduce the pro-inflammatory cytokine IL-1β, TNF-α and IL-6 production, but not anti-inflammatory cytokine IL-10.81 This and other inflammatory reflex could be the neurological basis of previous unrecognized techniques in complementary and alternative medicine.82 Mind-body exercise such as TC is a walking meditation, thus it is purported to increase vagal activity.

**Neurohumoral activation:** Yeh’s group did a series of studies on chronic heart failure patients, in a randomized controlled trial; they found that two hourly TC classes for 12 weeks can significantly decrease serum B-type natriuretic peptide level along with improved the quality of life, 6-minute distance walking. A decreased B-type natriuretic peptide level suggests decreases in neurohumoral activation.83

**Hypothesized Comprehensive TC Mechanisms**

The data from these immune studies, though low in number, indicate that TC can modulate ongoing immune processes in a beneficial way. For instance, it has an anti-inflammatory character in people with chronic inflammation such as in obese people, while it strengthens the immune response in people recovering from cancer. Interestingly, while the lack of a TC effect is often discussed as being due to the insufficient length of the exercise, there are a few studies which demonstrate immune modulation after one single bout of exercising, indicating that the changes can happen fast but require repetition for making a relevant impact on health.

While the exact immune-modulatory mechanisms are still unclear, in the following, we present three hypotheses to stimulate discussion: IL-6 from muscle and immune cells mediating changes to inflammatory blood parameters; cholinergic neurotransmitter modulating immune cells; and modulation of respiratory control mechanisms affecting the autonomic and the immune system.

**First,** IL-6 and other myokines could be involved in some of the complex TC immune responses. Once thought only to be a pro-inflammatory cytokine released by immune cells such as monocytes and lymphocytes, it is also now recognized for its anti-inflammatory character.63, 64 The anti-inflammatory effects of TC could be a results of accumulating acute IL-6 secretion from non-immune tissue such as muscle after a bout of practice. Resting muscle contributes small amount of the plasma IL-6 levels, while the level increases up to 100-fold after intense exercise such as running.84 As a result of this acute IL-6 increase, good things happen such as increases in glucose uptake, lipolysis, and fatty acid oxidation and turnover.85, 86 This does not happen with inflammatory IL-6 due to different signaling pathways, in the inflammatory case via NFκB, in the myokine case via Ca2+/NFAT and glycogen/p38 MAPK.87 Repetitive acute effects could transition into long-term effects through a negative feedback or Toll-like receptor mechanism.

**Second,** the secretion of anti-inflammatory cytokines through the cholinergic anti-inflammatory regulation might be another mechanism. Paced the breathing and meditation could certainly increase the vagal tone; through the cholinergic anti-inflammatory pathway, immune cells could release anti-inflammatory cytokines such as IL-13, IL-5 and IL-10 etc.

**Third,** the TC environment including the music, the social support in the group setting plays a role in assisting the anti-inflammatory effect. Tai Chi music has sedative qualities such as slow tempi, minor tonalities, smooth melody lines, and no dramatic changes in each selection, thus it should have a trend of increasing a sense of well-being. 88 Schein et al. found that synchronizing respiration voluntarily to musical tones for 15 minutes daily for an 8 week period could reduce both systolic and diastolic blood pressures (BP) significantly in T2DM patients 89. Another group, Logtenberg et al. found that while both device-guided breathing and music groups reduced systolic BP at the end of the study (but no difference between the two groups), music could reduce the diastolic blood pressure significantly compared with device-guided breathing in individuals with T2DM 90.
Conclusion
While there are still many less well-controlled scientific TC studies compared to studies for traditional exercise modalities of the Western world, there is an emerging consensus in the scientific community that TC is beneficial for human health. It causes metabolic body changes comparable to changes with other mild to moderate exercises. It improves mental abilities and it increases the general well-being of a person, healthy, obese, or chronically ill, with no reported adverse effects. When looking at the underlying mechanisms, one finds altered metabolic, immunological, and neurological processes. Understanding the loops between the brain, the immune system, and the muscles because of scientific studies in the area of neuropsychimmunology will take a few more decades, but we conclude that there is already enough evidence to call TC a true mind-body intervention which is worth exploring for the benefit of our stress dominated Western society.

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