DOES TAI CHI INCREASE AEROBIC CAPACITY IN ADULTS WITHOUT CARDIOVASCULAR DISEASE?

A Systematic Review and Implications for Public Health and Tai Chi Practitioners

by

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BA, University of Mississippi 2007

PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF PUBLIC HEALTH

In the
Faculty of Health Sciences

SIMON FRASER UNIVERSITY

Fall 2010

Approval

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Degree: **Master of Public Health**

Title of Thesis: **Does Tai Chi Increase Aerobic Capacity in Adults without Cardiorespiratory Disease? A Systematic Review and Implications for Public Health and Tai Chi Practitioners**

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Abstract

This systematic review examined data from 19 studies to ascertain whether Tai Chi provides an acceptable level of aerobic capacity and intensity to be recommended for cardiovascular disease prevention. Two comparisons were conducted: Tai Chi vs. walking, and traditional forms of Tai Chi vs. modified versions. Out of five studies using a modified Tai Chi style, the difference between intervention and control was statistically significant in two, and of the seven studies using a traditional long form, the difference between intervention and control was statistically significant in six and favoured the traditional long form of Tai Chi. The review discussed systemic problems with Tai Chi research and made recommendations including the need to establish a dose-response relationship between a particular style of Tai Chi and energy expenditure with VO_2max, as well as between other parts of the traditional Tai Chi curriculum and energy expenditure with VO_2max.

Keywords: Tai Chi; aerobic capacity; cardiorespiratory function; oxygen consumption; energy expenditure; METs; VO_2max.

Dedication

This work is dedicated to my grandfather, Louis Robert Aloia, who was a real "wise-guy" from Brooklyn. His example of curiosity, moderation, and self-restraint helped him to survive the D-Day invasion and two bullet wounds in World War II, use a computer to video-call with his grandchildren and great-grandchildren up until his death, and, at age 93, outlive most of his peers.

Acknowledgements

To Dr. Michel Joffres, Dr. Elizabeth Dean, and Dr. Scott Lear, who supported me in choosing this topic and gave me brilliant advice to realize this project

To Dr. Wilson and Dr. Ken Sufka, who inspired in me a passion for science

To Dr. Xue Zhi Wang, Deb Magallanes, and Fong Ha, who shared their art with me and showed me the way of Tai Chi

To Dr. Joann O'Quinn, Dr. Susan Glisson, Eleanor Mattern, and Angela and Sanjay Shenoy, without whom I would not have re-entered academia

To my Tai Chi and Qigong students who let me "experiment" on them and encouraged me to grow in my own practice

To April Grayson, without whom I would not be a normally functioning human being

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Glossary

ACSM	American College of Sports Medicine
ADL	Activities of daily living
AHA	American Heart Association
BMI	Body mass index
CAD	Coronary artery disease
CAM	Complementary and alternative medicine
CRF	Cardiorespiratory function
CSEP	Canadian Society for Exercise Physiology
CVD	Cardiovascular disease
HDL	High density lipoprotein
MET	Metabolic equivalent
PHAC	Public Health Agency of Canada
Push hands	A two-person exercise in which each person uses his or her hands or arms to push the other. In doing so, the goal is to shift the opponent's centre of balance while simultaneously keeping one's own.
WHO	World Health Organization

PREFACE

When I was a child, both of my grandmothers died from chronic diseases, and a little later, one of my grandfathers died of lung cancer. This left my father's father as the only remaining grandparent. I noticed that he made certain dietary changes, like reducing fat and salt intake, cutting back on ice cream and Italian pastries, quitting smoking, and decreasing alcohol consumption. The ice cream sacrifice really got my attention. The result of those lifestyle sacrifices was that he lived 34 years longer than my other grandfather, who made no adjustments to his no holds barred lifestyle. In fact, Grandpa Aloia just died this past spring at age 93.

As I was growing up in the late 1960's and early 1970s, my parents were hippies. My father began taking Tai Chi and taught me some postures. He even took me to one of his classes, and I remember thinking it was cool because they practiced with swords. And what little boy isn't in love with swords? When I was 14 years old, I began taking karate, and I have been involved in martial arts ever since.

When I was 25, my uncle was in a hospice unit dying of lung cancer, and my mother was staying with him. She desperately needed a break, so I volunteered. It was fascinating, and I was completely overwhelmed by the experience of seeing him pass his last breath.

A few years later, I began studying Tai Chi and Qigong with a series of Chinese teachers in Seattle and San Francisco. I became passionate about it and eventually started

leading my own classes. I also spent several weeks taking care of my wife's grandfather as he deteriorated with colon cancer.

These experiences eventually led me to a job as an activities director—basically an unofficial recreational therapist—in an assisted-living facility. I became fascinated by the impact of lifestyle behaviours that eventually led to chronic disease and then death. Even everyday things we take for granted, like leg strength and range of motion, quickly grabbed my attention. I saw how they became major determinants in the length and quality of one's life.

It was in this period that I used Qigong exercises as an activity in the dementia unit, and I began to notice that this exercise had some positive effects on patient behaviour. During our patient care-plan meetings I mentioned this to the consulting geriatric psychologist. She said, "It sounds like a research project to me." I got excited at the prospect of doing a study, and soon returned to school. Little did I know that these years later I would be doing a systematic review to understand Tai Chi's role in cardiovascular prevention.

1: INTRODUCTION AND RATIONALE

1.1 The Public Health Issue

Cardiovascular disease (CVD) is the leading cause of death in the world, accounting for 29% of all deaths (WHO, 2009). Low- and middle-income countries currently contribute about 80% of global CVD-related deaths (Reddy, 2004). The World Health Organization (WHO) predicts that the South-East Asian region will carry the largest burden of CVD (WHO, 2009). The prevalence of CVD in China and India is higher than in high-income nations combined (American Heart Association, 2010a). In Canada, chronic disease is expected to make up 89% of total mortality, and 34% of that burden is attributable to CVD (WHO 2005). In the United States, CVD accounted for 34.3% of all deaths in 2006 (American Heart Association, 2010b).

1.2 Cardiovascular Disease and the Western Healthcare System

Clearly, determinants of CVD are a high worldwide health risk, including in the United States and Canada. The WHO states, "At least 80% of premature heart disease, stroke and type 2 diabetes, and 40% of cancer could be prevented through healthy diet, regular physical activity and avoidance of tobacco products" (2005), supporting that primary prevention is undoubtedly the best approach to address CVD risk. However, the Western system of healthcare places a strong emphasis on secondary and tertiary care rather than primary prevention (Frownfelter and Dean, 2006; Holman and Lorig, 2004). If a health system focuses on biotechnology and surgery, there tend to be more of those

interventions used instead of primary prevention, the prevention of the risk factors in the first place (Bodenheimer, 2005).

With a biotech emphasis, healthcare becomes a profit-making venture, and the costs become high, leading to inequitable distribution of healthcare services (Bodenheimer, 2005). Often people of low socioeconomic status are left out of the system. The poor can no longer afford the high costs of secondary and tertiary care and sometimes forego prevention all together, until an extreme event occurs and the emergency room becomes their primary care (Hendrick, 2010; Lasser et al., 2006).

The Center for Disease Control in the United States calls for the creation of new "conceptual models and community interventions that include race/ethnicity, social class, and gender in social and historical context…to eliminate the disparities in chronic disease incidence and prevalence in communities of color" (Liburd et al., 2005, p. 18). Thus, there is a need for low-cost, high-yield exercise health promotion at the community level, not only in the US and Canada but worldwide.

1.3 The Epidemiology of Cardiovascular Disease

Cardiovascular disease (CVD) is often thought of as a ''sneaky, silent disease'' (Angus et al., 2005) because the biomarkers for the disease lipid levels, blood pressure, cardiorespiratory function including aerobic capacity, and body-mass slowly develop over time. These biomarkers often go unnoticed until the heart or vascular system reaches a critical level of stress, and then an infarct occurs, seemingly out of nowhere. However, the numbers that epidemiologists compile tell a different story: 600 million people with high blood pressure, 1 billion overweight adults, 300 million obese people worldwide

(American Heart Association, 2010), and 26.2% of US citizens and 56% of Canadians who do not meet the recommended levels of physical activity (Brownson et al., 2005; CFLRI, 2002).

Another aspect of CVD that adds to its "sneaky" image is how it manifests itself in a population. Most countries start off in the first stage of the epidemiologic transition, dealing with a high mortality rate, usually from infectious disease and high birth rate. Then, as a country starts to make headway both economically and in disease control, chronic diseases, and CVD in particular, become more prevalent until they slowly become the leading causes of death (Yusuf, et al., 2001).

1.4 Physical Activity

The association between physical inactivity and cardiovascular disease has been explored since the 1950's, and knowledge about the relationship has been steadily increasing (Rose, 1969). The words "overwhelming" and "incontrovertible" have been used to describe the preponderance of evidence that as physical activity increases, risk for CVD decreases (Warburton et al., 2006a; Warburton et al., 2007). Many studies have shown that physical activity can play a role in preventing atherosclerotic coronary artery disease (CAD), decreasing blood pressure, increasing HDL, decreasing BMI, and possibly reducing cigarette usage (Thompson et al., 2003; Warburton et al., 2006b).

Physical activity is defined as "any bodily movement produced by skeletal muscles that result in energy expenditure" (Caspersen et al., 1985, p.126). Physical activity and exercise are often undifferentiated in common vernacular. Although the two terms share many common fundamentals, they are not synonyms. Physical activity is a

broad term that explains all human activities. Exercise is one aspect within the broader scope of physical activity and is a structured physical activity with the specific objective of improving health or performance (Caspersen et al., 1985). Health scientists over the past 50 years have tried to categorize and identify human activity by energy expenditure, or how many kcals are burned by a particular activity. This categorization was developed because of its convenience and cost-effectiveness for large epidemiologic studies.

In population-based studies, participants self-report their physical activities and their levels. Where 1 MET or 3.5 ml O_2/kg of body weight/minute is equivalent to resting oxygen metabolic demand, those levels are then coded by a research assistant and categorized as either high-intensity activity (at least 6-8 metabolic equivalents, or METs), moderate-intensity (4–6 METs) or low-intensity (2-4 METs), and some studies include total energy expenditure measured in kilocalories per day (Warburton et al., 2006a). Typically, jogging, stair climbing, and aerobic exercise classes are associated with vigorous levels of activity. Walking is considered moderate, and light intensity includes activities such as golf and activities of daily living (ADLs). There is also another informal category called "light-to-moderate," into which Tai Chi falls.

Self-reporting of activity levels is problematic to such studies because the data rely on a person's ability to accurately remember, thus is subject to recall bias. Another obstacle in correctly quantifying physical activity is the challenge of defining the most valid and reliable measure (Blair and Jackson, 2001; LaPorte et al., 1979). Measures that are currently used include self-reporting, room calorimetry, CO_2 and VO_2 measurement (such as VO_2max), indirect calorimetry or conversion of energy expenditure equivalents,

heart rate monitoring, and accelerometry (Ekeland). There is no consensus on the best measure of physical activity (Blair and Jackson, 2001; Troiano, 2009).

Although there is disagreement within the exercise physiology field on how to measure cardiorespiratory function (CRF), VO_2max has been used consistently with strong evidence as one of the best objective measures of CRF and as a valid and reliable predictor of CVD mortality (Mancini, 2000; Warburton et al., 2006a). In fact, many researchers are suggesting its inclusion as its own risk factor category for CVD (Laukkanen, 2002; Mancini et al., 2000).

VO_2 is oxygen consumption, which is calculated by measuring oxygen content in the arteries, minus oxygen content in the veins, and then multiplying by cardiac output (Frownfelter and Dean, 2006). VO_2max means the aerobic capacity, or the maximum amount of oxygen delivered by the lungs and heart to the large muscle groups during physical activity (Warburton et al., 2006a).

There are two main ways of assessing VO_2max. There are direct treadmill tests in which the person being tested wears a special type of mask that collects the expelled gases. There are also complex algorithms that estimate VO_2max by taking into account heart rate, age, gender, BMI or weight, and distance walked by time. The direct treadmill tests are generally more accurate and are often used for studies with smaller sample sizes. However, they are more costly and inconvenient for population-level studies, so METs or energy expenditure is estimated in most studies, and there is debate about the reliability of this estimation process (Blair and Jackson, 2001; Kwan et al., 2004; Sergi et al., 2010).

It is also noteworthy that musculoskeletal fitness, separate from aerobic capacity, should be considered when evaluating risk reduction. Warburton et al. recently

acknowledged a growing body of literature that shows when musculoskeletal fitness is improved, there is an overall boost in the reduction of risk of chronic disease (2006b). Many activities of daily living are not high-intensity activities and yet they help maintain independence and thus increase longevity. For this reason, musculoskeletal and cardiorespiratory fitness appear to be dependent upon one another.

1.5 Current Recommendations

In the United States, the American College of Sports Medicine (ACSM) and American Heart Association (AHA) worked together to update recommendations for physical activity, with the primary recommendation being, "To promote and maintain health, all healthy adults need to engage in moderate-intensity aerobic physical activity for a minimum of 30 $min \cdot day^{-1}$ on 5 $d \cdot wk^{-1}$ or vigorous-intensity aerobic activity for a minimum of 20 $min \cdot day^{-1}$ on 3 $d \cdot wk^{-1}$" (Haskell et al., 2007, p. 1090). The United States Department of Health and Human Services based its recommendations for physical activity on the same report by Haskell et al. (2007).

In Canada, the Public Health Agency of Canada (PHAC) and the Canadian Society of Exercise Physiology (CSEP) also worked together and recently updated their

recommendations. Figure 1, below, is from Canada's Physical Activity Guide to Healthy Active Living (Adults 20-55) (CSEP, 2008).

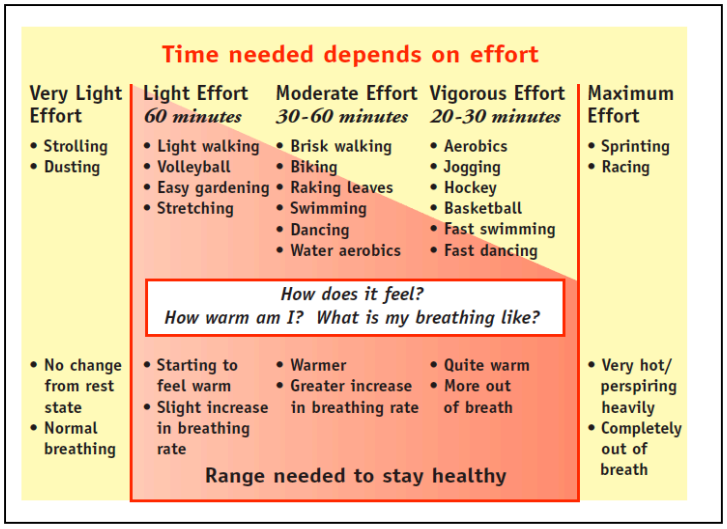

Figure 1. CSEP physical activity guidelines for adults age 20-55

1.6 The Complementary and Alternative Medicine Holistic Approach and Traditional Chinese Medicine

Complementary and alternative medicine (CAM) is considered a supplement or an alternative to allopathic medicine, taking a holistic approach to treating a patient. The National Center for Complementary and Alternative Medicine (NCCAM), a part of the National Institutes of Health in the United States, defines it as “a group of diverse medical and health care systems, practices, and products that are not generally considered part of conventional medicine” (NCCAM, 2010).

Because the holistic approach is rooted in a time when doctors did not have today’s powerful medical and technological tools at their disposal, physicians tended to treat the whole person and the environment around them (Cohen, 1997; Kaptchuk, 2000).

Traditional Chinese Medicine (TCM), born thousands of years ago, epitomizes this approach (Hong, 2004; Kaptchuk, 2000). Health systems of that era were radically different from today, with no medical technology to speak of; secondary and tertiary prevention was not as efficient or effective. Consequently, people who lived prior to the advent of modern medicine had to be resourceful and devise systems of primary prevention, which were essential for survival.

At the basis of the TCM system stands *Qi*, which is often translated as a fundamental form of vital energy that animates all living things (Yang, 2009). Some scholars explain *Qi*'s place in Chinese thought as "a formless 'reality,' which, though not graspable by the senses, is immanent in all things" (Xu, 2010, p. 967). This belief in *Qi* is also essential to Tai Chi, which shares many principles with TCM and has been integrated into the TCM system.

1.7 The Roots of Tai Chi

Both Tai Chi and TCM are rooted in the Chinese philosophy called Taoism, which is based on intense observations of patterns in nature, such as the movement of water, wind, and rocks. Early Taoists developed treatises on longevity, hygiene, and immortality, and these ideas fuel much of Chinese culture. Feng Shui, dietetics, martial arts, painting, and TCM all use the same paradigm or explanatory model of how the universe works (Kaptchuk, 2000; Kohn, 1993; March, 1968). The individual is but a microcosm of the universe, and to achieve harmony or happiness, one should align himself or herself with *Qi* to stay in harmony with the melding of energy and matter (Kaptchuk, 2000). If an individual becomes un-aligned or a blockage occurs, then disharmony can fester and "dis-ease" or disease will result (Yang, 2009).

Taoism is represented graphically by the icon known in the west as the "yin-yang" symbol, which illustrates a balanced interrelationship of opposites—for example, night and day, and hot and cold, etc. (Frank, 2003; Kaptchuk, 2000). Embedded in its Taoist roots, Tai Chi literally means "grand ultimate point," (Yang, 2008) the point of balance in the yin-yang. The oldest known writing that discusses yin-yang theory is the "I Ching," or "The Book of Changes," which describes the natural ebb and flow of energy in the universe and how that effects change, written during the Bronze Age, 1100 B.C. (Hong, 2004) (Yang, 2010). Tai Chi's main aim, to harmonize or align oneself with *Qi*, was summed up by the Taoist sage Chuang Tzu in the 4th century B.C.: "Set your body straight, see everything as one, and natural harmony will be with you" (Lan, 2002, p.217).

The origins of Tai Chi are rooted in mythical Chinese culture. The Chinese credit the celebrated hero Zhang San Feng with the creation of Tai Chi. Legend has it that he observed a hawk attacking a snake. As the battle between the two animals ensued, the snake repeatedly used relaxed evasive movements to elude the aggressive attacks of the hawk. Finally, the exhausted and frustrated hawk flew away. There are several versions, using different birds, but this is the basic myth (Frank, 2003). However, the true origins of Tai Chi are in dispute. The first historical record shows Tai Chi was developed in the 17th century in Chen Village (Yang, 2010). Later, Tai Chi was passed on to Yang Lu Chan, who developed the Yang style, which is now the most popular and most researched.

Yang Lu Chan's grandson Yang Cheng Fu became the inheritor of the Yang tradition. He defined Tai Chi as "the art of concealing hardness within softness, like a

needle in cotton" and asserted that "its technique, physiology, and mechanics all involve considerable philosophic principles" (Wile, 1983, p.3). He popularized Tai Chi for the masses and distinguished two levels, the civil and the martial (Wile, 1983). The civil is the "essence" and can be used for development of health, which is referred to as a type of *gong,* or practice or skill. In this way it falls under the umbrella of *Qigong*, a type of *Qi*-based exercise that literally means the practice (*gong*) of moving life's vital energy (*Qi*) (Cohen, 1997). The martial is the "function," which has the civil in mind but can be used for self-defence (Wile, 1983). Traditionally, Tai Chi is often taught in this martial manner, in which learning the form is not an end unto itself but a first step in which the basics are internalized. Then, after a year or so, the student learns push hands and sword practice.

As Tai Chi has developed through the centuries and through various schools of practice, it has become not one specific set of movements but can be practiced in different forms. The so-called empty hand forms are the subject of all Tai Chi research. "Long forms" contain many more movements than "short forms," which are not traditional but are modified to ease the learning curve. Different traditional styles are descended from the Chen but have evolved as various families transformed them, including the Yang, Wu, Sun, and Li styles. The variability of forms and intensities of physical activity among them is one of the challenges in conducting research on Tai Chi, an issue that will be discussed further below.

1.8 Tai Chi's Proven Health Benefits

When Mao Zedong took power of China in 1949, he outlawed all traditional practices, including TCM, Tai Chi, and Qigong, and viewed them as superstitious (Chen,

2004). However, during health reforms Mao and his advisors began to see Traditional Chinese Medicine, including Tai Chi and Qigong, as an opportunity to aid in primary healthcare (Xu, 2010). Mao saw individual physical fitness as a sign of a strong nation. Qigong and Tai Chi fit into his vision of active masses, and his efforts in primary care inspired much of the Alma Ata conference in 1978 (Janes, 1999; Xu, 2010). Because Mao was a modernist who believed in science, a tremendous research effort began to explore Tai Chi and Qigong. Thus, Tai Chi and Qigong had to prove not to be merely a mystical superstition through using tools of scientific observation, which at that time were mainly large case studies (Kaptchuk, 2000; Xu, 2010).

Today in North America, Tai Chi has a variable and intense research history. It has been used and studied as an intervention on AIDS patients, haemophiliacs, and just about every type of disease imaginable. One search on Google Scholar using the search term "Tai Chi" yielded 24,700 hits, and a search of the Cochrane Library website brought up reviews on Tai Chi and hypertension, headaches, depression, rheumatoid arthritis, fall reduction, and dementia. Such associations have led it to be falsely perceived by some as a panacea.

One of the first influential studies on Tai Chi in the US was in 1996, when a team of researchers received funding from the National Institutes of Health to study Tai Chi and fall reduction (Wolf et al., 1996). There have been many studies replicating its efficacy in fall reduction, and it is included in many recommended guidelines for that purpose, including those issued by the Canadian Society of Exercise Physiology (CSEP, 2008), the US Department of Health and Human Services (US DHHS, 2008) and the American Physical Therapy Association (APTA, 1999) (Appendix D).

Table 1. Health Benefits of Tai Chi Practice

The Health Benefits of Tai Chi Practice
Has low impact on joints*
Develops leg strength*
Increases range of motion/flexibility*
Increases balance and motor control*
Increases psychosocial function*
Prevents falls in the elderly*
Is proven to be at least a low- to moderate-intensity exercise
Uses mind to focus on developing coordinated movement
Is easily modified according to physical abilities
Doesn't require any special equipment
Can be performed indoors or outdoors
***Lan et al., 2002**

In 1973 in Hunan Province, an archaeologist unearthed a silk scroll dating back to c. 168 B.C. that depicted exercise postures. Below each embroidered pictograph was a written "exercise prescription" for different types of diseases, many of which were chronic conditions (Cohen, 1997). This evidence suggests that long before this recent surge in research, early Taoists had devised a method of self-care in the form of exercise to manage chronic conditions. Today, a growing body of evidence suggests that Tai Chi may be an efficacious intervention for the primary, secondary and tertiary prevention of CVD, diabetes, and the determinants of those diseases (Kaptchuk, 2000; Taylor-Piliae and Froelicher, 2004; Thornton, 2008; Yeh et al., 2008). However, of all the studies conducted on a broad variety of diseases, the literature on Tai Chi for the primary prevention of CVD is one of the least explored.

1.9 Rationale: Tai Chi and Chronic Disease

The current view of Tai Chi in Western popular culture is that it is primarily a Chinese exercise for elderly people, and not one particularly ideal for cardiorespiratory fitness. Some people who are interested in martial arts see Tai Chi as a viable form of

martial arts training. The definition used commonly by both Western and Eastern researchers is that "Tai Chi is a low impact, low to moderate intensity exercise incorporating elements of balance, strength, flexibility, relaxation, and body alignment" (Taylor-Piliae and Froelicher, 2004, p.49).

A broader view, however, is presented in a 2002 demographic survey done in the United States, which found that more than 2.5 million people practiced Tai Chi and 500,000 practiced Qigong (Birdee et al., 2009). The age range was evenly split throughout all age groups, countering the stereotype that Tai Chi is primarily for older adults. Birdee et al. posit that because Tai Chi has roots in martial arts, it increasingly may be viewed as masculine and attractive to younger people (2009). The majority of the Tai Chi and Qigong users was Caucasian, but proportionately there was no difference in race or ethnicity; most had a healthy BMI and self-reported good health. The authors also found that 11.4% of the users practiced Tai Chi for a cardiovascular workout. From this study, it would appear that a large number of people perceive Tai Chi as a cardiovascular workout and good for health maintenance. The findings in this study provide ample justification for evaluating Tai Chi's efficacy as a cardiovascular exercise.

Yang Cheng Fu describes a curriculum of Tai Chi that starts with the empty hand forms. He continues to describe four varieties of push hands, two-person sparring and free sparring, and three or more weapons forms, each with its own choreographed movements for two people who alternately role play as attacker and defender (Wile, 1983). Wayne and Kaptchuk's definition comes close to a unifying description of Tai Chi as

> an exercise based on slow intentional movements, often coordinated with breathing and imagery, which aims to strengthen and relax the physical body and mind, enhance the natural flow of what the Chinese call *qi* (a non-translatable word that describes the interpretation and connection of phenomenon, or life energy), and improve health, personal development, and self-defence (2008a, p. 96).

Still missing from their description, however, is the elaborate curriculum that many Tai Chi practitioners follow.

Many health benefits have been demonstrated in scientific studies (Jones et al., 2005), suggesting that Tai Chi has the potential for a large-scale community intervention. While Tai Chi might provide cardiovascular disease prevention at every level of society, including low-income communities, further rigorous study is needed. The implications for public health are outlined in Table 2.

Table 2. Potential Advantages and Benefits of Tai Chi for Public Health

Potential Advantages and Benefits of Tai Chi For Public Health
Inexpensive to implement, no special clothes or machines needed A Tai Chi class is an effective venue to deliver health education There are a multitude of health benefits Primary and secondary prevention can be taught at same time, thus potentially more motivating Great for social capital Appeals to certain Asian populations and increasingly to non Asian populations An alternative for people who do not prefer a gym atmosphere or Western exercise Can be performed indoors or outdoors Intellectually stimulating because of its philosophical roots

1.10 Literature Review

To date, there have been two systematic reviews/meta-analyses on Tai Chi and aerobic capacity and one review on Tai Chi and cardiorespiratory capacity. The two measuring VO_2max and/or VO_2peak were by Taylor-Piliae and Froelicher (2004) and

Lee et al. (2009). Thornton's review analyzed the cardiorespiratory capacity in Tai Chi (2008).

In a meta-analysis reported by Taylor-Piliae and Froelicher (2004) on the effectiveness of Tai Chi exercise in improving aerobic capacity, the data involved a total of seven studies (n=344). Three of those studies had other exercises as the sole controls. Consequently, the authors divided the analysis in parts. The Tai Chi vs. sedentary analysis included four studies (n=253), which found the Tai Chi group was significantly different from the control with a significant effect size of .80. The Tai Chi vs. other exercise analysis, which included three studies (n=91), had no significant difference between groups, with an effect size of .22.

The standout finding from this analysis is that the authors seized an opportunity of finding a dose-response. Within studies on Tai Chi, many differing types of practices are used. Some researchers use the Yang long form for their intervention, and some use a modified shorter version of Tai Chi. Subsequently, they analyzed those factors and found that practicing the Yang style long form of Tai Chi had a greater effect on the aerobic capacity than practicing a modified version of Tai Chi, with a significant effect size of 1.10; CI =+.82, +1.38. Overall, Taylor-Piliae and Froelicher's meta-analysis concluded that there is potential benefit in aerobic capacity when performing Tai Chi (2004).

The review by Lee et al. (2009) included six studies broken into three separate analyses: Tai Chi vs. sedentary (n=71); Tai Chi vs. physical exercise (n=78); and Tai Chi vs. walking (n=47). Many of the studies were used in the meta-analysis reported by Taylor-Piliae and Froelicher (2004). The studies that did not overlap were on patients with chronic heart failure, breast cancer, or hypertension. Only two studies were on

healthy subjects. The authors reported that when Tai Chi was compared with physical activity that consisted of either low-to-moderate intensity or aerobic exercise, there was no difference (p = .44).

In the Tai Chi vs. sedentary comparison, again no difference was found (p = .49). There are two possible explanations for not finding a difference. One, four of the studies used were on patients with a chronic disease, and, two, the Brown et al. (1995), study used a "Tai Chi-like" treatment. The author was contacted to explain exactly what made up the treatment because the study looked at mindfulness aspects for psychological improvements. The author provided contact information for the Tai Chi instructor to give more details, but the instructor did not reply to contact attempts. Hence, it is very likely that a traditional Tai Chi form was not used.

Similarly, in the study by Lee et al. (2009), no difference was found between Tai Chi and the walking comparison group. The authors do not discuss this finding specifically, perhaps because the only difference in the Tai Chi vs. physical exercise analysis and the Tai Chi vs. walking exercise analysis is that Young et al. (1999) is included in the physical exercise group. Thus, the two categories differed only by one study.

The critical review by Thornton (2008) looked at a number of indicators for cardiovascular disease, including heart rate, blood pressure, Lipid levels, VO_2max, METs, and psychosocial factors. Thornton reported that after an intervention period of one year several studies report increases of 16-20% in VO_2max. The author states that "while there is selection bias in many studies and RCTs, the evidence does indicate that Tai Chi provides aerobic/cardiorespiratory benefit" (Thornton, 2008, p. 58).

Thornton raises good questions about how the frequency, duration, and style of Tai Chi practiced might affect cardiorespiratory capacity. He also raises the issue of how much aerobic exercise is too much or too little. Of particular interest is Thornton's assertion that low-intensity exercise has higher levels of adherence than vigorous exercise. Although this is a compelling point, there is no citation. A plausible explanation is that there are injuries associated with vigorous activity, which could lead people to discontinue or lose interest in the routine.

In short, two of the reviews supported Tai Chi for the improvement of aerobic capacity, while one found that the results were insufficient to support any improvement. The included studies in both meta-analyses are problematic, using many different measures, styles of Tai Chi, and populations. This leads to difficulty in interpreting the results. This does not mean that there is nothing to gain by these studies, but the knowledge is largely useful to improve further studies.

1.11 The Purpose of this Paper

Today**,** many health agencies have recommendations that classify certain types of exercise to perform different functions. The classification process itself can be limiting and present certain biases without proper testing of all types of exercise. Western science has been slow in researching Asian healing modalities/exercises such as Tai Chi. In spite of these obstacles in studying Tai Chi, there is a small but growing body of literature that has been attempting to ascertain if Tai Chi is an efficacious practice for primary prevention of CVD (Lee et al., 2009; Taylor-Piliae and Froelicher, 2004; Thornton, 2008).

Tai Chi can be an alternative to western-style exercise, which may improve adherence to exercise prescriptions by populations who do not enjoy western-style exercise as well as by Pacific Asians at home or abroad who want to prevent CVD. The purpose of this paper is to evaluate the evidence and make a recommendation as to whether Tai Chi can be labelled an effective exercise in improving aerobic capacity in healthy populations.

2: METHODS

2.1 Data Collection

Data collection began first with broad electronic searches using the terms "CVD and Tai Chi," and "blood pressure and Tai Chi." The next search was on measurable indicators of CVD, lipid levels, BMI, cardiorespiratory fitness, and aerobic fitness with "Tai Chi" included in the search terms. Then it became clear that a good indicator for primary prevention of CVD was VO_2max. The search eventually focused on "VO_2max and Tai Chi," "cardiorespiratory function and Tai Chi," and "aerobic capacity and Tai Chi." A total of five databases were used: Google Scholar, Cochrane CENTRAL, PubMed, Science Direct, and EBSCO HOST. The searches were supplemented by looking at three reviews of cardiorespiratory function and Tai Chi to find missed studies: Taylor-Piliae and Froelicher (2004), Lee et al. (2009), and Thornton (2008).

2.2 Criteria for Inclusion

The inclusion criteria were that a study must be written in or translated into English, outcome measures were either in VO_2max, VO_2peak, or METs, and the exercise had to be specifically Tai Chi rather than any other Eastern form of martial art or exercise. The primary prevention study population were not to include people with CVD, diabetes, cancer, or any other major chronic disease. There had to be a sedentary control and/or a brisk walking group. Additionally, the full text had to be available, excluding poster sessions or summaries in peer-reviewed journals.

2.3 Criteria for Exclusion

Studies were excluded if they were not written in or translated into English or if the full text was unavailable. Thus, poster sessions and summaries were excluded. Additionally, studies were excluded if the study population was previously diagnosed with a major chronic disease such as diabetes or cancer. Although there are studies using comparisons including other Asian martial arts or exercises, such as qi gong, they were excluded in favour of studies using specifically Tai Chi.

2.4 Assessment of Methodological Quality

In determining the studies' methodological quality, study design, sample selection, sample size, randomization occurrence, types of controls, discrepancies in reporting results, description of Tai Chi intervention, and measurement tools were assessed. These factors were discussed and used in the comparison of the evidence between studies in the analysis.

2.5 Systematic Review of Tai Chi Studies

A systematic review was chosen because of the low quality and variability of treatment intensities of included studies. The only two meta-analyses on this topic found contradictory results mainly because of rigid inclusion criteria necessary to use the meta-analysis methodology. A systematic review allowed for more flexibility in comparing studies. Additionally, leading researchers in complementary and alternative medicine argue that "an objective evaluation demands to consider the totality of the available, rigorous evidence. Such an aim is best achieved by systematic reviews" (Ernst, 2007, p. 314).

The focus of this analysis is the comparisons of Tai Chi and walking, traditional long form vs. modified short forms of Tai Chi, and a summary analysis of the studies that measured outcomes in METs.

3: RESULTS

3.1 Study Characteristics

Three hundred and sixty-one studies were evaluated initially, with a final thirty-nine studies assessed further (Appendix A). Of those, eighteen fit the inclusion criteria, including eight observational studies, five random controlled trials, and five non-random samples with controls. Two separate analyses were conducted: Tai Chi vs. walking (3 studies, Table 5 in Appendix B), and traditional long form vs. modified version of Tai Chi (18 studies, Table 6 in Appendix C). The analysis focused on Tai Chi's effect on VO_2max and METs.

3.2 Tai Chi vs. Walking

In 2006, Audette et al. conducted an RCT comparing Tai Chi and walking. Nineteen previously sedentary, elderly female participants were assigned in either a modified 10-posture Yang style Tai Chi group (TCG) or a brisk walking group (BWG) for 8 weeks. The authors found the within-person change in VO_2max to be TCC 4.2 ±3.03 ml VO_2/kg/min and BWG .2 ± 2.63 ml VO_2/kg/min. They reported a positive effect for Tai Chi in personal gain from baseline, over walking and sedentary. However the between group results show no significant difference at $p = .08$.

Brown et al. (1995) also conducted an RCT comparing Tai Chi and walking for a 16-week period. Forty-two previously sedentary participants included healthy men with a mean age of 50.6±8.0 and healthy women with a mean age of 54.8±8.3 who were

randomly assigned to either a modified Tai Chi form (TCG) or a moderate-intensity walking group (WG). The authors reported that the VO_2peak (ml VO_2/kg/min) in the Tai Chi group (-.09pre-post) was not significantly higher than that for those in the walking group for men (2.8 pre-post), nor in the women's TCG (-1.2pre-post) over the MWG (1.8 pre-post). The moderate intensity walking had the highest gains in VO_2max.

Most recently, in 2009, Hui et al. conducted an RCT comparing a modified version of Yang style Tai Chi with brisk walking. Two hundred and twenty-five sedentary participants were assigned to either a walking group or a Tai Chi group for a period of 12 weeks. The Tai Chi group reported a mean change in VO_2max of 7.82 for men and 4.48 for women. The men in the walking group had a mean change of 7.56 ml VO_2/kg/min, and the women had 6.50 ml VO_2/kg/min. The authors report that there was no significant difference between Tai Chi and the walking control group. They recommended that Tai Chi is a safe alternative to brisk walking for cardiorespiratory fitness.

3.3 Modified Tai Chi Against Sedentary Controls vs. Traditional Tai Chi Against Sedentary Controls

3.3.1 Modified Tai Chi Against Sedentary Controls

In a different arm of the same 2006 study discussed above, Audette et al. found that when the TCG's estimated VO_2max was compared with the sedentary control group (SCG) there was a significant difference at $p = .003$. The within-group change was also significant (TCG 4.2 ±3.03 and SCG -4.4 ± 3.01). Both groups were previously sedentary. There was a consistent positive effect for Tai Chi in both the between-group and within-group difference, over sedentary for VO_2max (2006).

Brown et al. (1995) conducted an RCT on Tai Chi vs. sedentary controls with 49 previously sedentary participants using a modified Tai Chi form. The authors found that the male Tai Chi group's VO_2max actually decreased and reported a negative pre-post difference (-.09), which was significantly lower than the moderate-intensity walking group (2.8). Women in the Tai Chi group had a pre-post difference (-1.2) compared with the moderate-intensity walking group in women (1.8). The results were significant, but no p-value was reported.

In 2002, Chao et al. conducted an observational study on experienced Tai Chi Qigong practitioners. The style was a non-traditional, Tai Chi-type style more akin to Qigong. VO_2max was not measured, but they reported the METs of this exercise, which ranged from 3.0 in women to 3.7 in men.

In 2000, Fontana conducted an observational study on 26 experienced Tai Chi Chih practitioners and novices "unfamiliar with exercise" (Fontana, 2000, p. 3). Tai Chi Chih is closer to Qigong than to traditional Tai Chi. The author mentioned that VO_2max was measured, but there was no reporting of it. However, METs reported ranged from 1.5 during slow exercises to 3.6 in faster exercises with a breathing focus.

Hui et al. (2009) conducted an RCT on Tai Chi vs. sedentary controls with an intervention period of 12 weeks. Two hundred and twenty-five sedentary participants were evaluated, and the result was a positive effect for a mean change in VO_2max in Tai Chi over sedentary (p = .001). The METs for Tai Chi group were reported at 3.3. The authors concluded that Tai Chi is more appealing than walking because it requires lower demands but "yields similar levels of health benefits" (Hui et al., 2009, p. 7). They recommend studies with longer intervention periods.

Song et al. (2003) conducted an RCT with a modified 12-posture Sun style Tai Chi form developed for arthritic patients. The study included 43 women diagnosed with osteoarthritis but who were otherwise healthy and had been sedentary for at least a year; they were allocated to either a Tai Chi or sedentary control group for 12 weeks. The Tai Chi group's pre and post difference was 1.64(6.0) ml/kg/min vs. the control group .091(4.2) ml/kg/min, with $p = .653$. The results show no significant difference in VO_2max between Tai Chi and sedentary controls after the 12-week intervention. There was an overall 43% dropout rate due to personal and family problems.

The Young et al. (1999) study was one of the early RCTs on Tai Chi. Although it did not use sedentary controls, it compared a 13-posture modified version of Yang style Tai Chi with aerobic exercise in 62 previously sedentary adults between the ages of 60 and 80, with stage 1 hypertension, for a period of 12 weeks. Inclusion criteria defined "sedentary" as less than 10 minutes of vigorous exercise per week. The mean change in the aerobic exercise group was 1.64 ± .86 (SE), compared to .97 ± .81(SE) in the Tai Chi group. The between-group difference was not statistically significant at $p = .57$.

3.3.2 Traditional Tai Chi Against Sedentary Controls

In 1989, Brown et al. conducted an observational study on six experienced practitioners of the long form Yang style Tai Chi, with a mean age of 35 and a mean practice time of eight years. One episode of 24.9 minutes of Tai Chi practice yielded a mean VO_2 of 1.07ℓ min-1. The mean energy expenditure of Tai Chi during the study was 4.04 METs. The authors state that because the energy expenditure of TCC is at 4 METs, it might not be appropriate for improving CRF, according to the ACSM's 1986 recommendations.

Chen et al. (2008) conducted a non-random controlled study with 24 participants, comparing Tai Chi against sedentary controls. The style used was unspecified but was 108 postures long. Selection criteria required that the Tai Chi group had to have practiced for three times per week for more than three years. The Tai Chi group's VO_2peak (27.9) was not significantly different than the sedentary control group's (25.2) $p > .05$. Also, reported were the pre and post measures of VO_2peak only in Tai Chi group 23.15 (pre) and 47.17 (post), which shows a large change before and after practice. The METs reported for the Tai Chi group were 1.4 (pre) and 3.9 (post). The authors use these statistics as strong evidence for Tai Chi as moderate intensity exercise.

Lai et al. (1995) conducted a non-random study comparing 45 experienced Tai Chi practitioners of the 108 Yang style long form, with a mean practice time of 6.7 years, against 39 sedentary controls during a two-year period. The Tai Chi group's VO_2max was 31.6± 7.6 (pre) and 30.7 ±7.1 (post) in males compared with 24.4±4.4 (pre) and 22.8±4.4 (post) in controls. Tai Chi group females reported 20.7±2.3 (pre) and 20.1±2.5 (post) compared with 16.2±2.3 (pre) and 15.0± (post) in female controls. Both results showed Tai Chi significantly improved VO_2max over sedentary controls at the .05 level.

Lai et al. (1993) gathered 90 participants for an observational study comparing experienced Tai Chi practitioners of the108 Yang style, with a mean practice time of 6.3 years, to sedentary controls. The Tai Chi group's reported VO_2max was 33.9± 6.3 in males and 21.8 ±2.2 in the females, compared with 26.3±4.4 in the male controls and 19.0±3.6 in females controls ($p < .01$ and $p < .05$). The authors recommended using the long form rather than the short for researching VO_2max. Their findings support Tai Chi as an aerobic exercise for the elderly.

Lan et al. (2008) conducted a non-random sample of 69 participants over a period of five years. VO_2peak was measured in the male Tai Chi group (experienced Tai Chi practitioners) at 31.4± 7.0 (pre) and 29.8 ±6.8 (post) compared with 25.2±4.5 (pre) and 22.7±4.4 (post) in male sedentary controls. VO_2peak in the Tai Chi group was significantly higher than controls at $p = .04$. Females in the Tai Chi group (experienced Tai Chi practitioners) reported 21.9±3.6 (pre) and 20.8±3.1(post) compared with 16.9±2.3(pre) and 15.1±2.2(post) in females sedentary controls, which was significantly different with $p = .03$. Both results support Tai Chi significantly improving VO_2peak over sedentary controls at the .05 level. The authors state that Tai Chi decreases the rate of decline of VO_2peak more than controls, and they assert that "this long term study substantiates that TCC is beneficial to aerobic capacity, body composition and flexibility in elder adults" (Lan, 2008, p. 1049).

Lan et al. (2004b) conducted an observational study on 36 male participants: 12 classical experienced Tai Chi practitioners, 12 experienced Qigong practitioners, and 12 sedentary controls. The Tai Chi group's VO_2peak was 32.5 ±4.9, while the control group's was 24.3 ±3.6. The Tai Chi group differed significantly from the control at $p < .05$. The Tai Chi group's VO_2peak was slightly higher than the Qigong group (29.3±4.7).

Lan et al. (1998) conducted a non-random study that compared VO_2max in 20 experienced Tai Chi practitioners of the Yang style long form with 18 sedentary controls over a period of one year. The male Tai Chi group (24.2±5.2pre - 28.1 ±5.4post) had an improvement statistically significant compared with the sedentary controls (24.0±4.8pre - 23.6 ±5.0post) with $p = .001$. The female Tai Chi group (16.0±2.5pre - 19.4 ±2.8post)

had an improvement statistically significant compared with the sedentary controls (15.8±2.5pre - 15.6 ±2.6post) with p = .002.

Lan et al. (1996) conducted a non-random study on 41 Tai Chi practitioners experienced with the 108 Yang style form against 35 sedentary controls. The Tai Chi group's VO_2peak was 26.9 ± 4.7 for males, compared with the control's 21.8 ±3.1. The Tai Chi group's women had VO_2peak of 20.1 ± 2.9, compared with the control group's 16.5 ± 2.0. Both results were statistically significance at .05. The authors state that Tai Chi "is beneficial to maximum cardiorespiratory function in the elderly" (Lan et al., 1996, p. 615.)

Wang et al. (2001) conducted an observational study on experienced Tai Chi practitioners who have been practicing the Yang style long form for a mean of 11.2 years and compared their VO_2peak against sedentary controls. The Tai Chi group's VO_2peak was 23.4 ±.7, while the control group's was 17.4 ±.9. TCC significantly differed from controls at p <.05.

Zhou et al. (1986) conducted an observational study on 11 Tai Chi practitioners, ages 24 to 35, with an average of 5 years experience in the long form 108 Yang style. VO_2max was measured by collected gases. The authors make a distinction between long form Tai Chi and short or modified versions. They report the long form as expending "no more than 4.1 METs, corresponding to a mean oxygen intake value of 1.03 $\ell \cdot min^{-1}$ (Zhou et al., 1986, p. 9)." They state that the metabolic intensity of Tai Chi "seems insufficient to generate improvements of cardiorespiratory fitness in healthy young adults" (Zhou et al., 1986, p. 10).

Schneider and Leung (1991) conducted an observational study on 10 male participants with a mean age of 35.5 and a mean practice time of 6.7 years of an unspecified style of Tai Chi. The authors found that the mean VO_2max in the Tai Chi group was 16.00 ± 3.90 with %VO_2max at 36.4 ± 6.50.

The summary of effects of Tai Chi in Tab1e 3 demonstrates why a meta-analysis using the current body of inconsistent literature would limit any findings.

Table 3: Summary of Effects for Tai Chi vs. Being Sedentary for VO_2max

Summary of Effects for Tai Chi vs. Sedentary for VO_2max		
	Positive Finding	Non-significant
Modified Tai Chi	2	3
Traditional Tai Chi	6	1
Totals	**8**	**4**
RCTs	2	4
Non-experimental	6	1
Totals	**8**	**5**

4: DISCUSSION

The bulk of the research showing support for Tai Chi as improving VO_2max is observational or of a non-random design, which weakens the strength of the evidence. This analysis demonstrates that Tai Chi is a variable intensity exercise. The short form has been determined to be a low to moderate intensity exercise (Thornton, 2008) (Taylor-Piliae and Froelicher, 2004). The research reviewed above indicates that the long form is of a higher intensity (Brown et al., 1989) (Lai et al., 1993) (Lai et al., 1995) (Lan et al., 1996) (Lan et al., 1998) (Lan et al., 2004b) (Lan et al., 2008) (Zhou et al., 1986). However, the problems with the research mean that the designation of high intensity is not definitive. Additionally, there are many other aspects of the Tai Chi curriculum that have not been tested, including sword forms, push hands, and two-person choreographed forms. These activities would be likely to register a higher level of intensity and could bias the conclusion that practicing long form rather than short form is the reason for VO_2max gains.

4.1 Tai Chi vs. Walking

Overall, there were three random control trials that compared walking and Tai Chi. They all used a modified version of Tai Chi, and all found non-significance between group differences in $V0_2$max. Audette et al. (2006) and Brown et al. (1995) had stronger study designs and clearer displays of data but used shorter versions of Tai Chi. Hui et al. (2009) used a 32-posture form, but the study had some flaws. The author's description of

the randomization process by geographical location is confusing, and standard deviations were missing from a table. Further, it is unclear how many groups were included in the study, as a supplemental walking group was added after the others and didn't include the control for comparison, nor did it use VO_2max. However, the study had a large population that was randomized, which is unusual with Tai Chi studies and is important for statistical power.

Because of the inconsistencies in treatment intensities, any meta-analysis conducted would show non-significant results, as seen in the Tai Chi meta-analysis by Lee et al (2009). However, the fact that all RCTs found no difference between Tai Chi and walking—a proven VO_2max-improving exercise (Suter et al., 1994)— suggests that Tai Chi's capacity for improving cardiorespiratory capacity could be under-rated. Because Tai Chi demonstrates the same results as walking, it would follow that Tai Chi could be recommend to the same groups as walking for cardiovascular health.

4.2 Traditional vs. Modified Tai Chi

Lai and Lan describe non-random controlled and observational studies including detailed case studies of experienced Tai Chi practitioners. Because these studies were performed on subjects in Taiwan, where Tai Chi is ubiquitous, and no randomization was used, they offer only limited information about Tai Chi and its potential benefits for people from other cultures. There could be cultural contextual elements that affected the results. The authors used matched controls, which improves the statistical power of the results but did not overcome small sample sizes, nor did it exclude genetics as a factor for improved aerobic capacity. In addition, because the Yang style long form is more challenging to learn and is part of a more traditional curriculum, it is possible that the Tai

Chi groups also engaged in push hands, sword, and san sou, which are more vigorous aspects of Tai Chi. It doesn't appear that the authors addressed this issue.

In the five RCTs conducted by Audette et al. (2006), Brown et al. (1995), Hui et al. (2009), Song et al. (2003), and Young et al. (1999), random assignment reduced the chance of the results being confounded by genetic factors in cardiorespiratory fitness. However, even with stronger design, there were small sample sizes in all studies except in the study by Hui et al. (2009). Additionally, all five RCT studies used a modified short version of Tai Chi, which has been shown to be less efficacious in improving aerobic capacity (Table 3). The problems in researching Tai Chi that are created by the huge variability of treatment intensities is an issue discussed further in the Limitations section.

4.3 Metabolic Equivalents (METs)

Six studies measured the METs of traditional and modified versions of Tai Chi (Appendix E). The findings range from 1.5 to 4.6 (Brown et al., 1989) (Chao et al., 2002) (Chen et al., 2008) (Fontana, 2000) (Schneider and Leung, 1991) (Zhou et al., 1986). According to recommendations for physical activity (Warburton, 2006a) this places Tai Chi in its own category of an activity that is generally low- to moderate-intensity.

When considering METs for fitness improvement, it is important to consider both absolute intensity and relative intensity. For example, Tai Chi should be considered to have less intensity than running a 5-minute mile. However, a relatively lower MET level, such as 4, could be peak intensity for some, such as older people.

5: Limitations

Three main issues arise when conducting or reviewing research about Tai Chi: lack of uniformity in Tai Chi forms and curricula, the problem of choosing the appropriate measures, and cultural bias and the CAM paradox (Janes, 1999).

5.1 Lack of Uniformity

Because Tai Chi is an exercise with many forms—traditional long forms; modified, short forms; and supplemental practices such as push hands that are taught in most traditional curricula—one of the largest challenges with Tai Chi research is in standardization of practices studied. In Taylor-Piliae and Froelicher's 2004 meta-analysis of classical Yang style vs. modified Tai Chi, the authors found significant differences between the two types of practices. Any analysis is potentially biased by this lack of standardization, as is this analysis in particular, critiquing studies with modified Tai Chi Qigong, modified Tai Chi Chih, modified 32-posture Yang style Tai Chi, modified 12-posture Sun style Tai Chi designed for arthritic patients, modified 13-movement Yang style, traditional long form Yang style, a style labelled as an unspecific "traditional" form, and one described as a "Tai Chi-type" exercise.

Furthermore, many of the RCTs use modified Tai Chi styles due to the convenience of lessening the learning curve. When designing studies of Tai Chi, researchers are faced with the issue of getting enough funding to secure a sample willing to invest a considerable length of time to learn the long form of Tai Chi and other aspects

of the curriculum. However, while modified, short forms are more convenient, they are less vigorous and demonstrate less significant outcomes.

Such challenges to having standardized practice makes it difficult to truly assess a dose-response of intensity and, therefore, problematic to classify Tai Chi's efficacy as a cardiovascular workout without reservations.

5.2 Appropriate Measures

The most appropriate measure for assessing cardiovascular fitness is a matter of dispute. The clinical research of exercise science uses VO_2max and other sophisticated measures, CVD epidemiologists use physical activity questionnaires (PAQs), and the recommendations of public health agencies are based on METs (Swain and Franklin, 2006). Although clinical researchers and epidemiologists come together to make these public health recommendations accessible to the public who need a simple regime to follow, it does confuse the measure.

Furthermore, a problem with studies in which the researchers estimated VO_2max is that there has been research showing an inconsistency between measuring expired gases and using the algorithm for predicting VO_2max in elderly populations (Kwan et al., 2004) (Sergi et al., 2010). This could account for some of the inconsistent results and emphasizes credit due to the findings reported by Lai and Lan (1995) because of the consistent use of expired gas measurement.

Another important debate is on how little physical activity is too little and how much it takes to reach the ceiling effect. This quandary is pointed out by Warburton et al. (2006b) regarding how much exercise is actually needed to benefit cardiovascular fitness:

> Recently, investigators have postulated that even lower levels of weekly energy expenditure may be associated with health benefits (Paffenbarger et al., 1993) (Kushi et al., 1997) (Leon et al., 1987). A volume of exercise that is about half of what is currently recommended may be sufficient, particularly for people who are extremely deconditioned or are frail and elderly. (p. 805)

There is also some indication that musculoskeletal fitness contributes to the reduction of risk of chronic disease (Warburton et al., 2006b) and helps maintain physical independence. Vigorous exercise comes with risks such as injury from falling, over-stretching, sprained ankles, and sudden cardiac failure (Myers, 2003) (Nicholl et al, 1995) (Thompson et al, 2007) and may not be appropriate for many people, particularly those who are older, have injuries, or are starting from a sedentary lifestyle. To date there hasn't been an evaluation of any risks of Tai Chi practice, but it appears to be very safe.

Additionally, the reductionist method of breaking elements into to their smallest parts has potentially negative consequences for Tai Chi research. In exercise physiology research, when Tai Chi is measured for a specific element, such as VO_2max, reach, gait, or balance, what can result is a very narrow view of Tai Chi's potential. Thus, it risks being pigeonholed into the view of being labelled, for example, as a "balance" exercise. Instead, Tai Chi has traditionally been a holistic activity developed to be an efficient singular practice for health, quality of life, and martial skills. Furthermore, when science does find some efficacy, the efficacious practice may be removed from the integrated whole. Reductionism may push an intervention to be used out of context, risking that it loses effectiveness that might occur if it remained a holistic practice. These issues with western scientific research risk missing some of the other benefits that Tai Chi might provide, such as cardiovascular disease prevention or psychosocial wellbeing.

5.3 Cultural Bias and the CAM Paradox

> With its practitioners' emphasis on *qi* and its association in the United States and Europe with other ostensibly "Eastern esoteric practices" (hatha yoga, transcendental meditation, Zen Buddhism, etc.) that have become part and parcel of a global New Age marketplace (Barmé 1994; Dutton 1998), taijiquan has taken a specific path in that process. (Frank, 2003, p. 263)

Such reductionism discussed above creates a heavy burden for Tai Chi research and other interventions that come under the umbrella of Complementary and Alternative Medicine (CAM), which often derive from a holistic, pre-science philosophy. As such, Tai Chi suffers from the "CAM paradox."

CAM, therefore Tai Chi, is subject to the notions of scientific coherence and plausibility (Hill, 1965). In that, they do not fit in with a specific type of evidence that is considered coherent and plausible within the Western scientific framework—that which gets funding, governmental approval, and esteem in the scientific community (Janes, 1999). This creates a theory-ladenness type of bias (Brewer and Lambert, 2001), making it difficult for new information that might support the efficacy of Tai Chi (or other CAM interventions) to come into the scientific fold (Brewer and Lambert, 2001). Thus, funding agencies are reluctant to fund research on Tai Chi, and researchers are reluctant or unable to proceed with studies. This situation creates a cycle that does a disservice to scientific discovery.

This barrier to Tai Chi's acceptance in the scientific community also feeds the existing Western cultural bias and expectations of what Tai Chi is and who practices it. There is a stereotype in Western culture that Tai Chi is for elderly Chinese people who practice in the park (Frank, 2007). This stereotype can lead to incorrect assumptions on

the part of the public, researchers, funders, and public health agencies about the appropriateness or effectiveness of Tai Chi in preventative health.

6: RECOMMENDATIONS

Tai Chi is already integrated into health systems for some health conditions. It is taught at the Mayo Clinic in their cardiac rehabilitation department (Mayo Clinic, 2010) and is recommended in other areas of the health system (APTA, 1999). Tai Chi's effectiveness in preventing cardiovascular disease makes it rife with potential as a health promotion in many parts of the world. Because Tai Chi has low impact on joints—and in fact has benefits for joint health (Song et. al, 2003)—and is less exhausting than an exercise such as jogging, more people may choose it as an exercise regimen if they know its benefits for cardiovascular health. Its low cost delivery also makes it ideal for implementation in community programs that serve low-income people.

There does, however, need to be more research on its efficacy in the primary prevention of CVD. The following recommendations are aimed at researchers, recommending agencies, and Tai Chi instructors and current practitioners.

6.1 Dose-Response Relationship

First and foremost, research with strong design needs to establish a dose-response relationship between a particular style of Tai Chi—such as Yang long form—and energy expenditure with VO_2max. Research also needs to establish a dose-response relationship between different aspects of the traditional Tai Chi curriculum—such as sword forms and push hands—and VO_2max.

This would standardize Tai Chi into categories so that researchers could further understand Tai Chi's capacity and so that people could choose more accurately which type of exercise is appropriate for their desired outcome.

6.2 Physical Activity Measures and Guidelines

The optimum level and lower threshold for effectiveness of physical activity to reduce risk of CVD is still unclear (Warburton, 2006b). This lack of clarity is an obstacle in determining where Tai Chi fits in the range of exercise intensities recommended for CVD prevention. Further research is needed in order to determine that threshold with more confidence.

In addition, more studies need to evaluate VO_2max to determine if it should become a universally recognized predictor of CVD mortality, particularly in public health. This research should also address risks and effects of injuries that occur during exercise vigorous enough for VO_2max gain. Although VO_2max might be desirable for cardiovascular fitness, recommendations should consider its impact on musculoskeletal health.

Once those issues are addressed, physical activity guidelines and public health agencies need to address them accurately and consistently in their recommendations.

6.3 Recommendations to Tai Chi Researchers

This analysis offers the following recommendations to researchers studying Tai Chi and its health benefits:

1. Tai Chi researchers need to stay current on findings of the research issues discussed above and be vigilant in addressing them in study designs. Refer to other studies and use similar measures, such as VO_2max, so that findings can be compared directly and can provide a solid foundation of evidence for practical recommendations and subsequent studies.

2. When conducting a study collecting information about experienced Tai Chi practitioners, they should inquire about the participants' other types of physical activities, such as push hands, sword forms, walking, jogging, etc. Had Lan et al. and Lai et al. addressed this in their numerous studies on experienced practitioners, there would be a more precise understanding of the role of possible confounders.

3. Address the dose-response relationship discussed in section 6.1. Researchers should continue to study the Yang style Tai Chi curriculum, which is the most studied. The practice type, frequency, and duration should be addressed directly and consistently. Sword forms and push hands should be addressed explicitly, and observational studies should be employed to determine whether or not those adjunctive practices introduce variability.

4. Design studies that recruit and train participants in an RCT for a time period sufficient enough to learn the Yang style 108-posture long form, such as a minimum of one hour, three times per week, for six months.

5. Be more vigorous in assuring good study design by limiting the amount of outcome variables in order to focus the study and have findings appropriately address the hypothesis. Specifically, when assessing potential effect on cardiorespiratory fitness,

measure VO_2max, lipid levels, BMI, and other indicators that previous researchers have measured, so that a consistent body of evidence can be established.

6.4 Recommendations to the Tai Chi Community

It is important that Tai Chi instructors and practitioners avoid thinking that Tai Chi is a panacea for every illness. As demonstrated in this review, the findings on Tai Chi's exercise intensity and efficacy in increasing cardiovascular fitness are inconsistent. Thus, until the issues regarding standardization of research are addressed, it is recommended that a modified, short-form Tai Chi practice be supplemented with brisk walking or some other moderate to vigorous activity if there is no other physical limitation such as arthritis. That said, it is important to take care not to cause injury that might interrupt or end the exercise regimen.

7: CONCLUSION

Given the inconsistency of the studies reviewed and the difficult task of reducing Tai Chi to one indicator, results are not straightforward. However, it is safe to say that the traditional long form of Yang style Tai Chi is a moderate intensity exercise and that practicing that version would probably lead to improvements in aerobic capacity for people with previously sedentary lifestyle or low intensity workouts. Such gains would be especially beneficial with good adherence to the practice, with less chance of injury, thus interruption. Practitioners of modified shorter versions might consider augmenting their Tai Chi practice with a brisk walk a few times per week.

Tai Chi can be compared favourably to walking, as neither requires a group or a class. Indeed, Tai Chi is arguably more accessible than walking because as an indoor activity it can elicit an exercise response more easily for most people. This is especially the case in a climate like winter in Canada, when outdoor activities can be unsafe. Tai Chi is also adaptable to either a standing or sitting position, which makes it versatile and accessible for those who cannot walk or who can walk with difficulty.

By integrating Tai Chi into the public health system, where specific public health programs are developed around Tai Chi, there would be more access for at-risk Asian immigrant communities, elderly populations, and people who find recommended forms of Western-style exercise unappealing or daunting. Often the best exercise is that which is most enjoyable and therefore sustainable, and Tai Chi can be an option for people who find it appealing over other types of exercise. Thus, Tai Chi can be used to increase

physical activity, disease prevention, and quality of life for groups who are historically marginalized in the health care system. Finally, health by definition extends beyond physical health; thus, the psychosocial benefits of Tai Chi warrant further study.

8: CRITICAL REFLECTIONS

Coming back to school late in life after a spiritual, new-agey childhood without any early science background really opened my eyes to the difference between the traditional knowledge (i.e., pre-science, indigenous) and science-based knowledge, as well as how one's philosophical position has a great impact on life choices.

The pre-science mind has to rely on strong faith in things that can never be proven wrong. Then, when things go wrong, it is explained as one's faith not being strong enough or as God's will/fate. On the other hand, while science is far from perfect, it does provide a system of evaluating "reality" and empowers through knowledge of cause and effect.

Also, due to my deeper knowledge of the inconsistencies of the evidence surrounding Tai Chi for improving aerobic capacity, I am seriously considering supplementing my Tai Chi practice with more established aerobic activity. This is a continuation of how my life has been since I entered the public health program in 2008: a constant re-evaluation of my beliefs and actions regarding my personal health, as well as the information I pass on to others in my life.

Appendices

Appendix A

Summary of Studies Considered after Major Exclusions

Author, Title	*Tai Chi style, sample size, measurement*	*Final inclusion or exclusion*
Audette, J.S., Jin, Y.S., Newcomer, R., Stein, L., Duncan, G., Frontera, W. R. (2006). Tai Chi versus brisk walking in elderly women. Age and Ageing, 35:388-393.	Modified 10 posture Yang style Tai Chi for 8 weeks, estimated VO_2max, 27 participants	Included
Barrow, D., Bedford, A., Ives, G. O'Toole, L., Channer, K.S. (1996). An evaluation of the effects of Tai Chi Chuan and Chi Kung training in patients with symptomatic heart failure: a randomized controlled pilot study. Postgraduate Medicine, 83(985):717-21.	Secondary prevention	Excluded
Bashore, J.E., Watson, C.E., (1999) effects of Tai Chi, treadmill walking and reading on indices of stress. POSTER	No style reported, 19 college-age participants, VO_2max was not an outcome measure	Excluded
Brown, D.D., Mucci, W.G., Hetzler, R.K., Knowlton, R.G. (1989). Cardiovacular and ventilatory responses during formalized Tai Chi Chuan exercise. Research Quartely for Exercise & Sport, 60:246-250.	Long form Yang style (8years exprience), 6 participants mean age of 35, VO_2max measured expired gases by Hans Rudolph Manual Cardiac output CO2 rebreathing value and expired gas concentrations by Beckman OM-11 oxygen analyzer and a Godart Capnograph.	Included
Brown, D.R., Wang, Y., Ebbeling, C.B., Fortlage, L., Puleo, E., Benson, H., Rippe, J.M. (1995). Chronic psychological effects of exercise and exercise plus cognitive strategies. Medicine and Science In Sports and Exercise.	Modified Tai Chi (unknown) for 16 weeks, expired gases VO_2peak, 135 participants (Tai Chi instructor was contacted but no reply)	Included
Channer, K.S., Barrow, D., Barrow, R., Osbornes, W., Ives, G. (1996). Changes in Haemodynamic parameters following Tai Chi Chuan and aerobic exercise in patients recovering from acute myocardial infarction. Postgraduate Medicine, 72:349-351.	Secondary prevention	Excluded
Chao, Y.F.C., Chen, S.Y., Lan, C., Lai, J.S. (2002). The cardiorespiratory response and energy expenditure of Tai-Chi-Qui-Gong. The American Journal of Chinese Medicine, 30(4):451-461.	Tai Chi-type style not traditional Tai Chi but more of a Qigong style, No VO_2max	Included

Chen, Y.Y., Chiang, J., Chen, Y.J., Yang, R.S., Lin, J.G. (2008). Cycling and Tai Chi Chuan exercises exert greater immunodulatory effect on surface antigen expression of human hepatitis B virus. Chinese Medicine Journal, 121(21):2172-2179.	Style not mentioned but 108 postures(Tai Chi group had to practice for 3 times per week for over 3 years, 24 participants, Corival ergometer estimated VO_2peak	Included
Fontana, J. (2000). The costs of a modified form of Tai Chi exercise. Nursing Research, 49(2):91-96.	Tai Chi Chih (Not Tai Chi but an American modified Tai Chi-type style not traditional Tai Chi Closer to Qigong,), 26 participants, VO_2max was measured by expired air using Quinton Q-plex metabolic cart, no VO_2max measures were reported	Included
Hong, Y., Jing, X.L., Robinson, P.D.(2000). Balance control, flexibility, and cardiorespiratory fitness among older Tai Chi practitioners. British Journal of Sports Medicine, 34:29-34.	Classical Yang style (long or short not specified), 78 participants, HRV	Excluded
Hsu, M.D., Ho, J.M., Fang, C.L., Chen, Y.Y. (2001). The effects of Tai Chi Chuan practice on VO_2max and immune functions. ABSTRACT	Tai Chi style unknown, 30 participants, estimated VO_2max	Excluded
Hui, S.S.C., Woo, J., Kwok, T. (2009). Evaluation of energy expenditure and cardiovascular health effects from Tai Chi and walking exercise. Hong Kong Medicine Journal, 15(1S2).	32 posture Yang style for 12 weeks, 374 participants, estimated VO_2	Included
Jones, A.Y., Dean, E., Scudds, R.J. (2005). Effectiveness of a community-based Tai Chi program and implications for public health initiatives. Archives of Physical Medicine and Rehabilitation, 86:619-625.	No VO_2max	Excluded
Lai, J.S., Lan, C., Wong, M.K., Teng, S.H. (1995). Two-year trends in Cardiorespiratory function among older Tai Chi Chuan practitioners and sedentary subject. Journal of American Geriatrics Society, 43:1222-1227.	108 Yang style with a mean practice time of 6.7 years (intervention period 2 yrs), 84 participants, expired air VO_2max medical graphics corp, system 2000.	Included
Lai, J.S., Wong, M.K., Lan, C., Chong, C.K., Lien, I.N. (1993). Cardiorespiratory responses of Tai Chi Chuan practitioners and sedentary subjects during cycle ergometry. J Formos Med Assoc, 92:894-9.	108 Yang style with a mean practice time of 6.3 years, 90 participants, expired air VO_2max medical graphics corp, system 2000.	Included
Lam P., Dennis, S.M., Diamond, T.H., Zwar, N. (2008). Improving glycaemic and BP control in type 2 diabetes the effectivenss of Tai Chi. Austrailian Family Physician, 37(10):884-887.	Secondary prevention	Excluded
Lan, C., Chen, S.Y., Lai, J.S. (2008). Changes of aerobic capacity, fat ratio and flexibility in older TCC practitioners: a five-year follow-up. The American Journal of Chinese Medicine, 36(6):1041-1050.	Classical Yang style 108 posture Tai Chi (intervention period 5 years), 69 participants, expired air VO_2peak medical graphics corp, system 2000.	Included

Lan, C., Chou, S.W., Chen, S.Y., Lai, J.S. (2004). Relative exercise intensity of Tai Chi Chuan is similar in different ages and gender. The American Journal of Chinese Medicine, 32(1):151-160.	Classical Yang style Tai Chi, 100 experienced Tai Chi practititioners of different age groups VO_2max was measured by expired air VO_2max medical graphics corp, system 2000.	Excluded
Lan, C., Chou, S.W., Chen, S.Y., Lai, J.S., Wong, M.K. (2004). The aerobic capacity and ventilatory efficiency during exercise in Qigong and Tai Chi Chuan practitioners. The American Journal of Chinese Medicine, 35(1):141-150.	Classical Yang style with a mean practice time of 4.7 years, 24 participants (all men), expired air VO_2peak medical graphics corp, system 2000.	Included
Lan, C., Lai, J.S., Chen, S.Y., Wong, M.K. (1998). 12-month Tai Chi training in the elderly: its effect on health fitness. Medicine and Science in Sports and Exercise 30:345-351.	108 Yang style for at least 5 years, (intervention period 12 months)60 participants, expired air VO_2max medical graphics corp, system 2000.	Included
Lan, C., Lai, J.S., Wong, M.K., Yu, M.L. (1996). Cardiorespiratory function, flexibility and body composition among geriatric Tai Chi Chuan practitioners. Archives of Physical Medicine and Rehabilitation, 77(6):612-616.	108 Yang style with a mean practice time of 11.8 years, 76 participants, expired air VO_2max	Included
Lan, C., Su, T.C., Chen, S.Y., Lai, J.S. (2008). Effect of Tai Chi Chuan training on cardiovascular risk factors in dylipidemic patients. The Journal of Alternative and Complementary Medicine, 14(7):813-819.	Secondary prevention	Excluded
Lee, E.N. (2004). The effects of Tai Chi exercise program on blood pressure, total cholesterol and cortisol level in patients with essential hypertension. Journal of Korean Academic Nursing, 34(5):829-837.	In Korean	Excluded
Liu, X., Miller, Y.D., Burton, N.W., Brown, W.J. (2009). Preliminary study of Tai Chi and Qigong medical exercise on indicators of metabolic syndrome and glyaemic control in adults with raised blood glucose levels. British Journal of Sports Medicine, 43:840-844.	Secondary prevention	Excluded
Lu, W.A., Kuo, C.D. (1972). The effect of Tai Chi Chuan on the autonomic nervous modulations in older persons. Medicine and Science In Sports and Exercise	No VO_2max	Excluded
Lu, W.A., Kuo, C.D.(2006). Comparison of the effects of Tai Chi Chuan and Wai Tan Kung exercises on autonomic nervous system modulation and the hemodynamics in elder adults. The American Journal of Chinese Medicine, 34(6):959-968.	No VO_2max	Excluded
Park, I.S., Song, R.S., Oh, K.O., So, H.Y., Kim, D.S., Kim, J.I., Kim, T.S., Kim, H. L., Ahn, S.H. (2009). Journal of Advanced Nursing, 66(2):282-292.	Secondary prevention	Excluded

Schneider, D., Leung, R. (1991). Metabolic and Cardiorespiratory responses to the performance of Wing Chun and Tai Chi Chuan exercise. International journal of sports medicine, 12:319323.	Style not mentioned, 20 participants, VO_2max was measured using a modified Bruce protocol, expired gases were measured by a SensorMedics Horizon 4400 metabolic cart.	Included
Song, R., Ahn, S.H., So, H.Y., Park, I.S., Kim, H.L., OK, L.K., Sung, K.J. (2009). Effects of Taichi exercise on cardiovascular risk factors and quality of life in post-menopasual women. Journal of Korean Academic Nursing, 39(1):136-144.	6 Month Tai Chi intervention, 60 Participants (female) in KOREAN	Excluded
Song, R., Lee, E.O., Lam, P., Bae, S.C. (2003). Effects of Tai Chi exercise on pain, balance, muscle strength, and perceived difficulties in physical functioning in older women with osteoarthritis: a randomized clinical trial. The Journal of Rheumatology, 20(9):2039-2044.	Modified 12 posture Sun style Tai Chi for arthritic patients (intervention period 12 weeks) , 43 participants (female only), Calculated VO_2max	Included
Takeshima, N., Rogers, N.L., Rogers, M., Islam, M.M., Koizumi, D., Lee, S. (2007). Functional fitness gain vaires in older adults depending on exercise mode. Medicine and Science In Sports and Exercise.	Yang style 24 posture form of Tai chi (intervention period 12 weeks),113 participants, VO_2max	Excluded
Taylor-Piliae, R., Haskell, W.L., Froelicher, E.S. (2006). Hemodynamic responses to a community-based Tai Chi exercise intervention in ethnic Chinese adults with cardiovascular disease risk factors. European Journal of Cardiovascular Nursing, 5:165-174.	Secondary prevention	Excluded
Thomas, N.G., Hong, A.W.L., Tomilson, B., Lau, E., Lam, C.W.K., Sanderson, J.E. (2005). Effects of Tai Chi and resistance training on cardiovascular risk factors in elderly Chinese subjects: a 12 month longitudinal randomized controlled intervention study. Clinical Endocrinology, 63:663-669.	Yang style 24 posture Tai Chi (intervention period 12 months), 207 participants (males), No VO2max.	Excluded
Thornton, E.W., Sykes, K.S., Tang, W.K. (2004). Health benefits of Tai Chi exercise: improved balance and blood pressure in middle-aged women. Health Promotion International, 19(1):33-38.	No VO_2max	Excluded
Tsai, J.C., Wang, W.H., Chan, P., Lin, L.J., Wang, C.H., Tomilson, B., Hsieh, M.H., Yang, H.Y., Liu, J.C.(2008). The beneficial effects of tai chi chuan on blood pressure and lipid profile and anxiety status in a randomized controled trial. The Journal of Alternative and Complementary Medicine, 14(7):	No VO_2max	Excluded
Wang, J.S., Lan, C., Wong, M.K. (2001). Tai Chi Chuan training to enhance microcirculatory function in healthy elderly men. Archives of Physical Medicine and Rehabilitation, 82:1176-1180.	108 Yang style with a mean practice time of 11.2 years, 20 participants, expired air VO_2peak	Included
Young Rohm, D., Appel, L.J., SunHa, J. (1999). The effect of aerobic exercise and Tai Chi on blood pressure in older people: the results of a randomized trial. American Geriatrics Society, 47:277-284.	Modifed 13 movement Yang style (intervention period 12 weeks), 62 participants with stage 1 hypertension, estimated VO_2max.	Included

Zhou, D., Shepard, R.J., Plyey, M.J., Davis, G.M. (1986). Cardiorespiratory and metabolic responses during Tai Chi Chuan Exercises. Canadian Journal of Sports Sciences,9(1):7-10.	Long form 108 Yang style, 11 Participants 24-35 years of age with an average Tai Chi experience of 5 years, VO_2max was measured by collected gases Jaegar Ergo-Oxyscreen	Included

Appendix B

Summary of Tai Chi vs. Walking Studies

Authors	*Audette et al. (2006)*	*Brown et al. (1995)*	*Hui et al. (2009)*
Tai Chi Style	Modified 10 posture Yang style	Modified Tai Chi (unknown style)	Modified 32 posture Yang style Tai Chi
Duration, frequency, intervention period	1 hour, 3 days per week, for 12 weeks	30-45 minutes, 3 days per week, for 16 weeks	30 minutes, 5 days per week, for 12 weeks
Measurement	Estimated VO_2max	Expired gases VO_2peak	Estimated VO_2max
Sample population	19 healthy women ≥ 65	135 healthy, sedentary men and women from 40 to 69 years of age	374 sedentary, middle-aged participants (men and women)
Study design	RCT (Tai Chi vs walking)	RCT (Tai Chi vs walking)	RCT Tai chi vs brisk walking vs heartrate controlled walking
Results	No significant effect was found for Tai Chi in VO_2max over walking	The moderate intensity walking had the highest gains in VO_2max	Brisk walking had higher gains in VO_2, no significant difference between Tai Chi and the light walking control group was found

Limitations	Small sample size, estimated VO_2max (not expired air), a modified Tai Chi form, Non-generalizable populations	Small sample size, Modified Tai Chi-type	Authors seems reluctant to admit non-efficacy for Tai Chi. Modified Tai Chi, estimated VO_2max, confusing organization
Strengths	Strong study design, randomization, reported attrition rates	Strong study design, randomization, many arms to allow for a good solid comparison with walking, reported attrition rates	Large sample size, Random assignment, sedentary controls
Times Cited	25	137	2

Legend
RCT – randomized clinical trial

Appendix C

Studies of Traditional Tai Chi Against Sedentary Controls vs. Modified Tai Chi Against Sedentary Controls

Author, Title	*Tai Chi Style*	*Duration, frequency, intervention period*	*Measure-ment and sample*	*Study design*	*Results*	*Limitations*	*Strengths*
Audette, J.S., Jin, Y.S., Newcomer, R., Stein, L., Duncan, G., Frontera, W. R. (2006). Tai Chi versus brisk walking in elderly women. Age and Ageing, 35:388-393.	Modified 10 posture Yang style	1 hour, 3 days per week, for 12 weeks	Estimated VO_2max, 19 healthy women ≥ 65	RCT (Tai Chi vs sedentary)	Positive effect for Tai Chi in personal gain from baseline, and between group difference over sedentary for VO_2max p = .003.	Small sample size, estimated VO_2max not expired air, a modified Tai Chi form, Non-generaliz-able populations	Strong study design, randomiz-ation, Attrition rate reported
Brown, D.R., Wang, Y., Ebbeling, C.B., Fortlage, L., Puleo, E., Benson, H., Rippe, J.M. (1995). Chronic psychological effects of exercise and exercise plus cognitive strategies. Medicine and Science In Sports and Exercise.	Modified Tai Chi (unknown style)	30-45 minutes, 3 days per week, for 16 weeks	Expired gases VO_2peak, 135 healthy sedentary men and women from 40 to 69 years of age	RCT (Tai Chi vs sedentary)	No effect between Tai Chi and sedentary control for VO_2max.	Small sample size, Modified Tai Chi-type	Strong study design, randomiz-ation, valid and reliable measure-ment tools, Attrition rate reported, generaliz-able populations
Chao, Y.F.C., Chen, S.Y., Lan, C., Lai, J.S. (2002). The cardiorespiratory response and energy expenditure of Tai-Chi-Qui-Gong. The American Journal of Chinese Medicine, 30(4):451-461.	Modified Tai Chi Qi gong	Cross-sectional	no VO_2max. 47 partici-pants with a mean age of 60.7 with a practice time of at least 5 days/ week for over 6 mo	Observa-tional study of experi-enced Tai Chi Qigong practi-tioners	METs ranged from 2.8 in women to 3.7 in men	Selection bias, small sample size, Non-random design, no pre and post measures, some unhealthy subjects	Exploratory assessment of METs for Qigong

Fontana, J. (2000). The costs of a modified form of Tai Chi exercise. Nursing Research, 49(2):91-96.	Modified Tai Chi Chih	Cross-sectional	VO_2max was measured by expired air using Quinton Q-plex metabolic cart, 26 health partici-pants, men ages 21-40 and women ages 21-50	Observa-tional study with experi-enced Tai Chi practi-tioners and novices	METs ranged from 1.5 in slow exercises to 3.6 in faster exercises with breathing focus.	Selection bias, small sample size, non-random design, article says it measured VO_2max but no VO_2max measures were reported, no pre and post measures, subjects were compen-sated for their partici-pation, study used self reported exercise behaviours	Exploratory assessment of METs for a modified version of Tai Chi on a generaliz-able population, reported non-compliance
Hui, S.S.C., Woo, J., Kwok, T. (2009). Evaluation of energy expenditure and cardiovascular health effects from Tai Chi and walking exercise. Hong Kong Medicine Journal, 15(1S2).	Modified 32 posture Yang style Tai Chi	30 minutes, 5 days per week, for 12 weeks	Estimated VO_2max, 374 sedentary, middle-aged partici-pants (men and women)	RCT Tai chi vs walking vs sedentary controls	Positive effect for a mean change in VO_2max in Tai Chi over sedentary $p = .001$	Authors seems reluctant to admit non-efficacy for Tai Chi. Modified Tai Chi, estimated VO_2max, confusing addition of later group	Large sample size, Random assignment
Song, R., Lee, E.O., Lam, P., Bae, S.C. (2003). Effects of Tai Chi exercise on pain, balance, muscle strength, and perceived difficulties in physical functioning in older women with osteoarthritis: a randomized clinical trial. The Journal of Rheumatology,	Modified 12 posture Sun style Tai Chi for arthritic patients	Minimum 20 minutes per session, 3 times per week, for 12 weeks	Estimated VO_2max, 43 partici-pants, healthy females 55 or older with evidence of osteo-arthritis	RCT Tai Chi vs sedentary controls	No effect between Tai Chi and sedentary control for VO_2max.	There was a 43% drop out rate, small sample sizes, modified Tai Chi, estimated VO_2max not expired air, non-generaliz-able population	Strong study design, randomi-zation

20(9):2039-2044.							
Young Rohm, D., Appel, L.J., SunHa, J. (1999). The effect of aerobic exercise and Tai Chi on blood pressure in older people: the results of a randomized trial. American Geriatrics Society, 47:277-284.	Modifed 13 movement Yang style	1 hour group exercise 2 times per week, supple-mented by home practice with the goal of 30 to 45 minutes per session, 4 to 5 days per week, for 12 weeks	Estimated VO_2max, 62 partici-pants between the ages of 60 and 80 with stage 1 hyper-tension	RCT Tai Chi vs Aerobic Exercise (no sedentary controls)	No effect between Tai Chi and aerobic exercise group for VO_2max p = .57.	Used a modified version of Tai Chi , estimated VO_2max, non-generaliz-able population	Strong study design, randomi-zation
Brown, D.D., Mucci, W.G., Hetzler, R.K., Knowlton, R.G. (1989). Cardiovacular and ventilatory responses during formalized Tai Chi Chuan exercise. Research Quarterly for Exercise & Sport, 60:246-250.	Tradi-tional long form Yang style	Cross-sectional	VO_2max measured expired gases, Hans Rudolph Manual Cardiac output CO_2 re-breathing value and expired gas concen-trations, Beckman OM-11 oxygen analyzer and a Godart Capno-graph, 6 male partici-pants, mean age of 35 with 8 years Tai Chi experience	Observa-tional study of experi-enced Tai Chi practi-tioners	The mean energy expenditure of Tai Chi during the study was 4.04 METs	Small sample size, non-random design, no pre and post measures	Exploratory assessment of the long form of Tai Chi's exercise output on a general-izable population
Chen, Y.Y., Chiang, J., Chen, Y.J., Yang, R.S., Lin, J.G. (2008). Cycling and Tai Chi Chuan exercises exert greater immunodulatory	Tradi-tional style not mentioned but 108 postures	Cross-sectional	Corival-ergometer estimated VO_2peak, 24 partici-pants men and women with a	Non-random control-led Tai Chi vs sedentary controls	The METs were also reported 1.4(pre) and 3.9(post). No effect between Tai Chi and sedentary	Small sample size, non-random design, estimated VO_2max not expired air, no pre	Compared pre and post exercise VO_2peak and METs in Tai Chi group

effect on surface antigen expression of human hepatitis B virus. Chinese Medicine Journal, 121(21):2172-2179.			mean age of 55.3, 12 of whom had a practice time for at least 3 times per week for over 3 years		control for VO_2peak but reported 23.15 pre exercise and 47.17 post exercise VO_2peak	and post measures in both groups	
Lai, J.S., Lan, C., Wong, M.K., Teng, S.H. (1995). Two-year trends in Cardio-respiratory function among older Tai Chi Chuan practitioners and sedentary subject. Journal of American Geriatrics Society, 43:1222-1227.	Tradi-tional 108 Yang style	54 minutes, 5 times per week, over 2 years	Expired air VO_2max medical graphics corp. system 2000, 84 partici-pants 50-78 years old, with a mean practice time of 6.7 years, some healthy and some not	Non-random Tai chi vs sedentary	Positive effect for Tai Chi in personal gain from baseline, over sedentary for VO_2max.	Small sample size, non-random design, mix of unhealthy and healthy	Compared pre and post VO_2peak after two years of long form Tai Chi training against sedentary
Lai, J.S., Wong, M.K., Lan, C., Chong, C.K., Lien, I.N. (1993). Cardio-respiratory responses of Tai Chi Chuan practitioners and sedentary subjects during cycle ergometry. J Formos Med Assoc, 92:894-9.	Tradi-tional 108 Yang style	Cross-sectional	Expired air VO_2max medical graphics corp. system 2000, 90 healthy partici-pants between 50 and 64 years of age with a mean practice time of 6.3 years	Observa-tional Tai chi vs sedentary	Positive effect for Tai Chi over sedentary for VO_2max.	Small sample size, non-random design, no pre and post measures	Compared pre and post VO_2peak of long form Tai Chi training against sedentary, reported attrition rates
Lan, C., Chen, S.Y., Lai, J.S. (2008). Changes of aerobic capacity, fat ratio and flexibility in older TCC practitioners: a five-year follow-up. The	Tradi-tional 108 Yang style	54 minutes per day, 7 days per week, over 5 years	Expired air VO_2peak medical graphics corp. system 2000, 69 healthy participant s with a	Non-random Tai chi vs sedentary	Positive effect for Tai Chi over sedentary for VO_2max.	Small sample size, non-random design, attrition rate not reported	Compared pre and post VO_2peak of long form Tai Chi training for 5 years against sedentary The length

American Journal of Chinese Medicine, 36(6):1041-1050.			mean age of 64.7 at baseline				of interven-tion is definitely an achieve-ment, generaliz-able population
Lan, C., Chou, S.W., Chen, S.Y., Lai, J.S., Wong, M.K. (2004). The aerobic capacity and ventilatory efficiency during exercise in Qigong and Tai Chi Chuan practitioners. The American Journal of Chinese Medicine, 35(1):141-150.	Tradi-tional 108 Yang style	Cross-sectional	Expired air VO_2peak medical graphics corp. system 2000, 24 healthy partici-pants, all men, with average age of 58.6, with a mean practice time of 4.7 years	Observat ional Tai Chi vs Qigong vs sedentary	The Tai chi group's VO_2peak was 32.5 ±4.7 vs controls 24.3 ±3.6. TCC significantly differed from controls at $P < .05$, VO_2max for Qigong was 29.3 ±4.7.	Small sample size, non-random design, no pre and post measures	Using Qigong in this study allows for a dose response of VO_2peak again subjects were similar on baseline anthro-pomoetric measures
Lan, C., Lai, J.S., Chen, S.Y., Wong, M.K. (1998). 12-month Tai Chi training in the elderly: its effect on health fitness. Medicine and Science in Sports and Exercise 30:345-351.	Traditiona l 108 Yang style	1 hour per session, avg 4.6 times per week, over 12 months	Expired air VO_2max medical graphics corp. system 2000, 38 healthy partici-pants between the ages of 58 and 70 with a mean practice time of 11.2 years	Non-random Tai chi vs sedentary	Positive effect for Tai Chi over sedentary for VO_2max	Small sample size, non-random design	Evaluated Tai Chi and VO_2max over a one year period, reported attrition rates

Lan, C., Lai, J.S., Wong, M.K., Yu, M.L. (1996). Cardio-respiratory function, flexibility, and body composition among geriatric Tai Chi Chuan practitioners. Archives of Physical Medicine and Rehabilitation, 77(6):612-616.	Tradi-tional 108 Yang style	Cross-sectional	Expired air VO_2max, 76 healthy and unhealthy partici-pants over 60 years of age, with a mean practice time of 11.8 years	Non-random Tai chi vs sedentary	Positive effect for Tai Chi over sedentary for VO_2max	Small sample size, non-random design, no pre and post measures	Evaluated Tai Chi and VO_2max in a elderly population with 11.8 years of long form Tai Chi training
Wang, J.S., Lan, C., Wong, M.K. (2001). Tai Chi Chuan training to enhance microcirculatory function in healthy elderly men. Archives of Physical Medicine and Rehabilitation, 82:1176-1180.	Tradi-tional 108 Yang style	Cross-sectional	Expired air VO_2peak, 20 healthy partici-pants over 60 years of age with a mean practice time of 11.2 years	Observa-tional Tai Chi vs sedentary	Positive effect for Tai Chi over sedentary for VO_2max (P <.05)	Selection bias, small sample size, non-random design, no pre and post measures	Evaluated Tai Chi and VO_2peak in a elderly population with 11.2 years of long form Tai Chi training
Zhou, D., Shepard, R.J., Plyey, M.J., Davis, G.M. (1986). Cardio-respiratory and metabolic responses during Tai Chi Chuan Exercises. Canadian Journal of Sports Sciences,9(1):7-10.	Tradi-tional 108 Yang style	Cross-sectional	VO_2max was measured by collected gases Jaegar Ergo-Oxy-screen, 11 partici-pants 24-35 years of age with a mean practice time of 5 years	Observa-tional study with experi-enced Tai Chi practi-tioners	"no more than 4.1 METs, correspond-ing to a mean oxygen intake value of 1.03 l-min-1."	Small sample size, non-random design, no pre and post measures	Exploratory assessment of METs and VO_2max for Tai Chi in healthy adults with an average age of 28.4, generaliz-able population
Schneider, D., Leung, R. (1991). Metabolic and Cardiorespirator y responses to the performance of Wing Chun and Tai Chi Chuan exercise. International journal of sports medicine,	Unknown style not mentioned	Cross-sectional	VO_2max was measured using a modified Bruce protocol, expired gases were measured by a Sensor-Medics	Observa-tional study Tai chi vs Wing Chun (no sedentary controls)	METs 4.6, mean VO_2max in the Tai Chi group was 16.00 ± 3.90 with %VO2max at 36.4 ± 6.50	Small sample size, non-random design, no pre and post measures	Exploratory assessment of METs and VO_2max for Tai Chi in healthy male adults, generaliz-able population, reported

12:319323.			Horizon 4400 metabolic cart, 20 partici-pants (male with a mean age of 35.5) with a mean practice time of 6.7 years				attrition rates

Legend: RCT – randomized clinical trial

Appendix D

Fortunately, physical therapy can help you learn to cultivate and maintain higher levels of strength, flexibility, and endurance in a way that still feels safe and secure. Research indicates that the risk of falling in older adults can be reduced *dramatically* when specific exercises, activities, and interventions are prescribed by physical therapists. There are instances, however, in which physical therapy alone may not be appropriate. If you have an inner ear disorder, for example, you will need to consult a physician.

Tai Chi

The ancient martial art of tai chi has become very popular in the West in recent years, and classes are often available through community colleges, local recreation centers, YMCAs, community centers, etc. Research has shown that people of all ages—including older adults—often find it to be helpful in promoting balance and preventing falls. An added bonus is that tai chi may add to your sense of emotional well-being.

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How Physical Therapy Can Help

If you consult a physical therapist about falls and balance, he or she will likely review your medical history and determine your general physical condition, as well as conduct an inventory of tests specifically designed to measure balance and gait (your individual style of walking). If you have fallen before, your physical therapist will ask you to describe the accident in some detail to find out what caused the fall. (Just as important as actual falls are "near-falls"—instances in which you were on your way down but managed to "hang on.")

After your physical therapist has determined what is impairing your balance, he or she will design a program of exercises and activities just for you, with an emphasis on strength, flexibility, and proper gait. All exercises would be planned for maximum safety and security. Your physical therapist may also perform specific interventions to increase your range of motion and musculoskeletal flexibility. These may include electrical stimulation, massage, hydrotherapy, heat, cold, and ultrasound. If you have balance problems related to the inner ear, your physical thera-

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Figure 2: Tai Chi page of APTA brochure (APTA, 1999)

Appendix E

Comparison of Studies Measuring METs

Study	Style	METs
Fontana 2000	Tai Chi Chih	1.4-3.6
Brown et al, 1989	Traditional Yang Long	4.04
Chao et al, 2002	Tai-Chi-Qui-Gong	3.1
Zhuo et al, 1986	Traditional Yang Long	4.1
Schneider and Leung, 1991	Not specified	4.6
Chen et al 2008	Traditional Yang Long	3.9

Reference List

References marked with an asterisk indicate studies included in the systematic analysis.

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