Physical Activity and Cognition in Older Adults: The Potential of Tai Chi Chuan

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Chang, Y.K. Nien, Y.H., Tsai, C.L., & Etnier, J.L. (2010). Physical activity and cognition in older adults: The potential of Tai Chi Chuan. Journal of Aging and Physical Activity, 18(4), 451-472.

Abstract:

The purpose of this article is to review the potential of Tai Chi Chuan as a mode of physical activity that could have cognitive benefits for older adults and to provide potential directions for future research. A brief introduction to Tai Chi Chuan and its related physical benefits is provided. In addition, the empirical literature related to Tai Chi Chuan and cognition is reviewed. Potential mediators of the relationship between Tai Chi Chuan and cognition, including physical resources, disease status, and mental resources, are discussed. Based on the limitations of the extant literature, it is argued that future research in this area must provide more detailed descriptions of Tai Chi Chuan, particularly in terms of intensity and program progression. Consideration of the specific type of cognition that is expected to benefit is also encouraged, and approaches for further efforts to understand how Tai Chi Chuan affects cognition are recommended.

Keywords: aging | cognitive function | executive function | mind-body exercise

Article:

It is widely recognized that adults over age 65 make up one of the fastest growing segments of the population (Hutton, 2008). In 2006, older adults accounted for 12% of the overall population in the United States, and this group is expected to account for nearly 20% of the overall population by 2030 (Federal Interagency Forum on Aging-Related Statistics, 2008). This increasing demographic of the older population is a worldwide phenomenon (Gorman, 2002; Kalache & Kickbusch, 1997). With this increase in life expectancy, however, comes the expectation that more than half of all older adults will suffer from at least one age-related physical or mental ailment (Standage & Duda, 2004).

One age-related ailment that is experienced by many older adults is cognitive decline. Aging is generally accompanied by deterioration of brain structures, which is associated with decrements in cognitive performance (Coffey et al., 2001; Coffey et al., 1992). Older adults commonly experience cognitive decline in a number of areas including information-processing speed, reasoning, and memory (Salthouse, 2003) and are at increased risk of the onset of cognitive impairments such as dementia (Erickson & Kramer, 2009). Hebert, Scherr, Bienias, Bennett, and Evans (2003) indicated that 50% of adults over age 85 have dementia and noted that this has a dramatic impact on the individual, the family, and the economy. Fortunately, there is great individual variability in the experience of age-related cognitive decline and in clinical cognitive impairments (Erickson & Kramer, 2009), and several variables have been shown to be associated with a slower rate of cognitive decline in later life (Albert et al., 1995). Therefore, there is increasing interest in identifying factors that might maintain or prevent cognitive deterioration among the aging population.

The relationship between physical activity and cognition was first empirically examined in the 1970s (Spirduso, 1975). Over the past 4 decades, research on the benefits of physical activity for cognition has expanded, and this literature has been reviewed narratively (Brisswalter, Collardeau, & Rene, 2002; McMorris & Graydon, 2000; Tomporowski, 2003) and meta-analytically (Etnier, Nowell, Landers, & Sibley, 2006; Etnier et al., 1997; Sibley & Etnier, 2003) and from epidemiological (Kramer, Erickson, & Colcombe, 2006; Lautenschlager & Almeida, 2006) and neuroscience perspectives (Colcombe, Kramer, McAuley, Erickson, & Scalf, 2004; Cotman & Berchtold, 2002; Erickson & Kramer, 2009). The results of the meta-analytic reviews indicate that the cognitive performance of older adults benefits from physical activity participation, with one review reporting a moderate (Cohen, 1988) overall effect (ES = 0.48; Colcombe & Kramer, 2003) and another reporting a small to large effect (ES = 0.10–1.17; Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008). A moderate effect (ES = 0.57) has also been reported for studies focusing on the cognitive benefits for older adults with cognitive impairment and dementia (Heyn, Abreu, & Ottenbacher, 2004). After examining moderators, two of these reviews reported that the effects of physical activity on cognitive performance are task specific. Colcombe and Kramer indicated that larger effects were evident for executive function tasks (ES = 0.68) than speeded tasks, visuospatial-awareness tasks, and controlled cognitive tasks. On the other hand, Angevaren et al. found that the effects of physical activity were greatest for motor function (ES = 1.17) and auditory attention (ES = 0.50).

Although a generally positive effect of physical activity on cognitive performance has been demonstrated for older adults, one limitation of this literature is that it has largely focused on aerobic exercise (Brisswalter et al., 2002; Colcombe & Kramer, 2003; Erickson & Kramer, 2009; Tomporowski, 2003). The focus on aerobic forms of exercise was largely based on the presumed role of cardiovascular fitness as a potential mechanism of the relationship (Chodzko-Zajko, 1991; Colcombe et al., 2004). However, findings from meta-analytic reviews suggest that cardiovascular fitness is not the most likely mechanism of the effect (Angevaren et al., 2008; Colcombe & Kramer, 2003; Etnier et al., 2006). This then suggests that increases in cardiovascular fitness are not necessary for cognitive benefits, and, thus, other forms of physical activity that do not particularly emphasize improvements in cardiovascular fitness should be explored. Furthermore, given that the ACSM guidelines promote cardiorespiratory, resistance, and flexibility exercises for older adults (American College of Sports Medicine, 2010), examination of the potential benefits of other forms of exercise for cognitive performance is important.

Recently, a few researchers have shown that resistance exercise also has positive effects on cognition (Cassilhas et al., 2007; Chang & Etnier, 2009a, 2009b; Perrig-Chiello, Perrig, Ehrsam, Staehelin, & Krngs, 1998; Pontifex, Hillman, Fernhall, Thompson, & Valentini, 2009). However, to date, other types of exercise modalities such as flexibility or mind-body exercises have been largely ignored in the physical activity and cognition literature. Researchers have suggested that our understanding of the effect of different exercise modalities on cognition is still in its infancy; thus, it is important to further examine other modes of exercise as potentially benefiting cognitive performance (Erickson & Kramer, 2009; Kramer, Colcombe, McAuley, Scalf, & Erickson, 2005). Therefore, the purpose of this article is to provide an overview of the potential of a particular mind-body exercise, Tai Chi Chuan, to benefit cognitive function in older adults and to discuss future directions for research in this area. In particular, we will (a) briefly introduce Tai Chi Chuan, (b) review the literature discussing Tai Chi Chuan and cognition, (c) examine evidence related to the potential mediators of the relationship between Tai Chi Chuan and cognition, and (d) present possible implications and recommendations for future research in this area. We chose Tai Chi Chuan because this is a form of exercise that is well suited to older adults (Rogers, Larkey, & Keller, 2009), is increasing in popularity in Western countries (Yan & Downing, 1998), and has a relatively well-established empirical literature (Cheng, 2007; Yeh, Wang, Wayne, & Phillips, 2009). Although Tai Chi Chuan is considered a form of aerobic exercise (Lan, Chen, & Lai, 2004), its benefits for cognition have not been studied extensively, possibly because Tai Chi Chuan is not typically performed with a goal of increasing cardiovascular fitness.

Tai Chi Chuan and Its Relation Health Benefit

Tai Chi Chuan, also known as Tai Chi, Taijiquan, or Taiji, is a form of mindbody exercise originating from ancient China. Literally, Tai Chi Chuan can be distinguished into Tai Chi and Chuan. Tai Chi is translated as “supreme ultimate,” “Yin-Yang,” or “Yin and Yang” and is a concept of ancient Chinese philosophy that has been developed based on the oldest book of wisdom in China, the I-Ching or Book of Changes. Based on the Tai Chi philosophy, Yin and Yang are two ultimate, opposing, and interdependent forces (e.g., dark and light, female and male, low and high, slow and fast, inhale and exhale). The interactions between Yin and Yang are proposed to make the universe and humans function energetically. Chuan is literally translated as boxing or martial art. Although some might use the term Tai Chi (Hall, Miszko, & Wolf, 2009; Matthews & Williams, 2008; Nowalk, Prendergast, Bayles, D’Amico, & Colvin, 2001; Taylor-Piliae et al., 2010) rather than Tai Chi Chuan, the most appropriate term is Tai Chi Chuan, which is defined as a type of physical activity that incorporates movements that are characteristic of the martial arts and that are based on the ancient Chinese philosophy of Tai Chi (Li, Hong, & Chan, 2001; Yeh, Wang, et al., 2009).

History and Styles

The first written mention of Tai Chi Chuan can be found in a 17th-century text authored by the martial artist Wangting Chen, who described it as a new style of Chinese martial art. After Changxing Chen, the 14th generation of the Wangting Chen family taught Tai Chi Chuan to Luchan Yang, and Tai Chi Chuan began to be exported to other counties. Now, participation in Tai Chi Chuan has increased significantly in both Eastern and Western countries (Yan & Downing, 1998). As a result of developments through these years, at least five major styles of Tai Chi Chuan have been formally recognized: Chen, Yang, Wu, Hao, and Sun. Although these styles share a common idea and philosophy, each has its own movements and unique characteristics. For example, the Chen style emphasizes vigorous or exploding strikes with heavy breath, and its movements focus on internal and external rotation of the torso. The Yang style demands constant knee flexion, a wide stance, and a steady slow speed of movement (Wu, 2002). The Wu style is done with smaller stances than the Chen and Yang styles and includes a characteristic forward lean of the torso that is required in most of the movements. The Hao style has higher stances; a narrower stance width; compact, circular movements; and a slower pace than Chen, Yang, and Wu styles. The Sun style's postures are high and the footwork is agile; the body is centered and upright. Recently, a standard competition style was created by the Chinese Sports Commission for the purpose of tournaments, and this style consists of components from each of the styles and emphasizes fast, highly difficult, and complex movements. In addition to the general differences between movements, each style also has its own routines that include sequences of movements. For example, the Chen style has 83 movements, the Yang style has 108 movements, the Wu style has 84 movements, Hao has 96 movements, the Sun style has 97 movements, and the standard competition form can be 24 or 42 movements.

Tai Chu Chuan as a Multicomponent Intervention

In addition to the specific styles, which are defined by their movement characteristics, Tai Chi Chuan can also be described based on components that are similar among all styles (Larkey, Jahnke, Etnier, & Gonzalez, 2009; Wayne & Kaptchuk, 2008a). More specifically, Tai Chi Chuan can be described along physical, cognitive, social, and environmental domains.

The physical domain refers to the characteristics of the physical activity component of the Tai Chi Chuan program. In particular, Tai Chi Chuan has aerobic, muscular, and flexibility characteristics and can be described based on the intensity, duration, and frequency of the movements. The cognitive domain is involved because when practicing Tai Chi Chuan, participants are encouraged to focus on concentration, attention, mindfulness, imagery, visualization, and intention for specific purposes such as movement, energy management, or breathing control. The social domain is also a part of Tai Chi Chuan because it can be practiced with a partner using either static or dynamic methods. Finally, Tai Chi Chuan may be said to involve alternative health paradigms, philosophies, rituals, iconic meanings, and environmental influences. Given that each subdomain might exert an influence on cognitive outcomes either independently or in combination with the other components, researchers interested in Tai Chi Chuan must consider the potential influence of each component and should describe carefully the characteristics of a Tai Chi Chuan intervention with respect to all components.

Tai Chi Chuan and Health

Recently, Tai Chi Chuan has grown in popularity, and one of the main reasons for this is because it is believed to have health benefits (Chin A Paw, van Uffelen, Riphagen, & van Mechelen, 2008; Wayne & Kaptchuk, 2008b). Empirical evidence suggests that Tai Chi Chuan has a positive effect on cardiorespiratory function (Taylor-Piliae, 2008; Taylor-Piliae & Froelicher, 2004), muscle strength (Lan, Lai, Chen, & Wong, 2000), flexibility (Lan, Lai, Chen, & Wong, 1998), and balance and motor control (Wong & Lan, 2008). Older adults who practice Tai Chi Chuan regularly have also demonstrated improvements in blood lipid profiles (Tsai et al., 2003), hypertension (Ong, Cheung, Man, Lau, & Lam, 2007), immune function (Yeh, Chuang, et al., 2009), fall prevention (Gillespie et al., 2009), and pain management (Danusantoso & Heijnen, 2001).

In addition to the physical benefits, many researchers have examined Tai Chi Chuan’s effects on mental health. Research has shown that Tai Chi Chuan has a positive effect on quality of life (Deschamps, Onifade, Decamps, & BourdelMarchasson, 2009; Hill, Smith, Fearn, Rydberg, & Oliphant, 2007; Kjos & Etnier, 2006), depression (Cho, 2008), self-efficacy (Li, Fisher, Harmer, & McAuley, 2005; Taylor-Piliae, Haskell, Waters, & Froelicher, 2006), and anxiety-related stress (Rogers et al., 2009).

Tai Chi Chuan and Cognition

Computer searches of PubMed, PsycInfo, and Educational Research in Completion were conducted using the key terms Tai Chi, Tai Chi Chuan, Tai Ji, Taiji, mind-body exercise, cognition, cognitive performance, and executive function. Studies in the English language published before February 2010 were obtained for inclusion in this review, and six studies were identified that tested the effect of Tai Chi Chuan on cognitive performance (see Table 1).

Matthews and Williams (2008) evaluated the effects of a Tai Chi Chuan program (three sessions per week for 10 weeks) on cognitive performance in older adults (mean age 76.5 years). Cognitive performance was assessed using the Trail Making Test, a digit-symbol substitution test, and clock drawing. Results indicated that significant positive effects of the Tai Chi Chuan program were evident for Test B of the Trail Making Test (ES = 0.53) and for clock drawing (ES = 0.43). Given that benefits were not observed for the digit-symbol substitution task, these results suggest that Tai Chi Chuan might have benefits for executive function but not for general information-processing types of cognition. This is consistent with the report by Colcombe and Kramer (2003) that larger effects from physical activity are expected for executive-function tasks.

Similar results have been obtained recently by Taylor-Piliae et al. (2010) using an experimental design. They examined the effect of Tai Chi Chuan, a condition they call Western exercise, and an attention-control group on physical and cognitive function in healthy older adults. Both exercise groups completed sessions in classes and at their homes during an adoption phase (first 6 months) and a maintenance phase (next 6 months). The Tai Chi Chuan intervention involved the Yang 24-form performed for 60 min per session and at a lower than moderate intensity. The Western-exercise group performed aerobic, resistance, and flexibility exercises in 60-min sessions. In terms of cognitive measurement, semantic-fluency and digitspan tests were used. The results indicated that participants in the Tai Chi Chuan program experienced a significant improvement in digits-backward and semanticfluency performance from baseline to 12 months. Between-groups comparisons indicated that the Tai Chi Chuan group performed significantly better on digits backward than the other two groups at the end of both phases. Digits backward is considered modestly sensitive to executive control (Kaufman & Lichtenberger, 1999) and is related to other cognitive domains such as attention, concentration, mental tracking, and double tracking (Lezak, Howieson, Loring, Hannay, & Fischer, 2004). The authors concluded that because the practice of Tai Chi Chuan requires that participants pay attention and concentrate on their body and postures, this may explain the fact that Tai Chi Chuan benefited this specific type of cognitive performance more than did Western exercise.

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Hall et al. (2009), however, failed to support the positive effects of Tai Chi Chuan on cognitive tasks. Twenty-two older community-dwelling adults (62–85 years old) were randomly assigned to either a 12-week Tai Chi Chuan intervention or a control condition consisting of a course on healthy lifestyles. The Yang 24-style was taught, and participants were asked to attend twice a week for 1.5 hr per session. Cognitive performance was assessed by choice reaction-time tasks. Results showed that the control group improved in the ability to avoid obstacles under dual-task conditions, but no changes were observed for the Tai Chi Chuan group. Thus, the results of this study failed to support the claim for Tai Chi Chuan benefits specific to such task improvement.

Three studies examined the effects of long-term Tai Chi Chuan practice on cognition using the Mini Mental State Examination (MMSE), and the findings of these studies were not consistent (Burgener, Yang, Gilbert, & Marsh-Yant, 2008; Deschamps et al., 2009; Nowalk et al., 2001).

A repeated-measures randomized design was used by Burgener et al. (2008) to examine the effects of a multimodal intervention (including Tai Chi Chuan exercise, cognitive-behavioral therapies, and social-support treatments) on cognitive, physical, and behavioral outcomes in 43 older adults with early-stage dementia. The Tai Chi Chuan intervention was applied using the modified Chen style and was a 40-week program meeting three times a week for 1 hr per session. Participants were randomly assigned into the treatment group or an attentional-control group (education and delayed enrollment in the treatment). Cognitive function was assessed by the MMSE at 20 and 40 weeks. The treatment group showed improved cognitive performance on the MMSE from baseline to 20 weeks (ES = 0.48). However, there was no significant difference in MMSE performance from 20 to 40 weeks, which indicated that 20 weeks might be sufficient for cognitive gains as a result of this intervention.

Deschamps et al. (2009) compared the effects of an intervention called cognition-action (which consists of lower body muscle exercise, upper and core body exercises, and deep breathing and relaxation) with those of Tai Chi Chuan in 52 frail older adults age 65–94 years. The Tai Chi Chuan consisted of the Yang style for 24 weeks, four times a week, for 30 min per class. The intensity was light to moderate and was based on the participants' ability. Results demonstrated that after this 24-week intervention, both the cognition-action group and the Tai Chi Chuan group improved on a variety of mental and physical measures as reported on health-related quality of life (Short Form 12, SF-12), falls self-efficacy, and exercise self-efficacy; however, there was no significant change in performance on the MMSE as a function of the interventions.

Nowalk et al. (2001) used a randomized-trial design to explore the effects of three types of exercise intervention on cognitive performance. Participants were residents of two long-term care facilities. Facility employees were provided training in team management and in providing quality-of-life programming, and these programs were offered to all residents. Participants in the study were randomly assigned to resistance-exercise training, Tai Chi Chuan, or a control condition. These exercise programs were held three times a week for 2 years. Tai Chi Chuan was taught by a professional; however, no clear style or clear description was provided. Cognitive performance and physical functioning were measured over 2 years in 110 elders (mean age 84 years). The outcomes were evaluated at baseline and 6, 12, and 24 months. The authors indicated that although elders who fell during this time period had significantly lower MMSE scores, there were no differences on MMSE, time to first fall, time to death, and incidence of fall among the three programs.

To summarize, there has been only limited research addressing the effects of Tai Chi Chuan on cognition, and this literature has developed relatively recently, suggesting that examination of this research question is still in its infancy. Furthermore, the studies that have been done suffer from important methodological limitations. In particular, few of them address exercise intensity, duration, or frequency or describe the style and associated movements completely, which are recognized as important components of exercise prescription (American College of Sports Medicine, 2010). In addition, three of the five studies used the MMSE as the cognitive outcome. Although the MMSE is useful for testing for cognitive impairment, it might not be particularly sensitive to change as a result of an intervention (Salthouse, 2007) and might be influenced by personality factors (e.g., education; Roselli et al., 2009). Therefore, this has seriously limited the likelihood of observing significant results as a function of a Tai Chi Chuan intervention. Finally, a few of the studies administered Tai Chi Chuan as part of a combined treatment intervention (Deschamps et al., 2009; Nowalk et al., 2001), which makes the specific effects of Tai Chi Chuan on cognition indecipherable.

It is perhaps not surprising given these limitations that the findings of these studies have been mixed; however, there is some evidence that Tai Chi Chuan can benefit particular measures of cognition. In particular, significant effects were found when measures of executive function (Burgener et al., 2008; Matthews & Williams, 2008; Taylor-Piliae et al., 2010) were used, suggesting that the effects of Tai Chi Chuan on cognition might be task specific. Thus, the results from studies testing the effects of Tai Chi Chuan are consistent with the results of recent metaanalyses in showing that the effect of chronic exercise on cognition is task-specific (Angevaren et al., 2008; Colcombe & Kramer, 2003).

Potential Mediators Between Tai Chi Chuan and Cognition

Given the limited number of studies that have directly tested the effects of Tai Chi Chuan on cognitive outcomes, it is insightful to consider evidence regarding the effects of Tai Chi Chuan on variables identified as mediators of the relationship between physical activity and cognition. Spirduso, Poon, and Chodzko-Zajko (2008) proposed an exercise-cognition model to describe the relationship between exercise and cognition with emphasis on several potential mediators (see Figure 1). These mediators were categorized into physical resources (sleep effectiveness, energy/fatigue, appetite, pain, drug/medication usage), disease states (cardiovascular disease, hypertension, diabetes, and chronic obstructive pulmonary disease), and mental resources (depression, self-efficacy, chronic stress), and all were proposed to play indirect or direct roles in the relationship between physical activity and cognition. If Tai Chi Chuan affects these mediators, this would support its potential efficacy as an intervention to benefit cognitive performance. Given the large number of proposed mediators, it is not our goal to address all of them. Instead, sleep effectiveness, cardiovascular disease, hypertension, depression, and selfefficacy are specifically considered because these potential mediators have been examined as outcomes in previous research with Tai Chi Chuan. Therefore, in the following sections we describe research testing the effects of Tai Chi Chuan on potential mediators of the relationship between physical activity and cognition.

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Physical Resources

Sleep quality is a physical resource that was identified as potentially mediating the effects of physical activity on cognitive performance. The relationship between sleep quality and cognitive performance is reasonably well established. Older adults frequently experience poor sleep quality, which has been negatively associated with quality of life, an inability to perform daily tasks, and interpersonal difficulties (Lopez, 2008). In addition, poor sleep quality has been linked to diminished abilities in daytime cognitive performance, motor function, memory, and concentration (Lopez, 2008; Smith, 2001). Jones and Harrison (2001) indicated that sleep disturbances impaired the performance of frontal-lobe tasks and executive-function tasks such as verbal fluency, creativity, and planning skills. Evidence also supports the effects of exercise on sleep quality. Based on a comprehensive review conducted by Driver and Taylor (2000), both acute and chronic exercise have positive associations with sleep quality in elderly adults.

Research also demonstrates that Tai Chi Chuan has positive effects on sleep (Irwin, Olmstead, & Motivala, 2008; Li et al., 2004; Yeh et al., 2008). Li et al. (2004) used a randomized controlled trial to examine the effect of Tai Chi Chuan and a low-impact exercise program on self-rated quality of sleep and daytime sleepiness in 118 healthy elders (60–92 years). Participants participated in the eight-form easy Yang style of Tai Chi Chuan for 1 hr per session, three sessions per week, for 24 weeks. Relative to participants in the low-impact exercise condition, participants in the Tai Chi Chuan program showed a significant improvement in sleep quality, sleep-onset latency, sleep duration, and sleep efficiency.

Irwin et al. (2008) also used the eight-form easy Yang style of Tai Chi Chuan in a randomized controlled trial design. In their study, they looked at the effects of a 16-week instructor-led program and an additional 9 weeks of self-practice in 112 older adults. The Tai Chi Chuan program was performed for 25 weeks, three times a week, for 40 min per session, and the control group received a health education course. The results indicated that compared with the control group, older adults with both good sleep quality and poor sleep quality had significant improvement in their global sleep score, sleep quality, sleep duration, sleep disturbance, and habitual sleep efficiency after the Tai Chi Chuan sessions.

Yeh et al. (2008) applied five core Tai Chi Chuan movements from the Yang style through a 35-min home-based video instruction performed at least three times per week for 12 weeks. They measured sleep parameters (i.e., sleep stability) using a measure of cardiopulmonary coupling that was obtained before and after the intervention. Results showed that participation in Tai Chi Chuan positively affected sleep stability.

Given that sleep quality may mediate the relationship between physical activity and cognition and the evidence that Tai Chi Chuan benefits sleep quality, it is possible that Tai Chi Chuan may benefit cognition through positive effects on sleep.

Disease States

Cardiovascular disease (CVD) is one of the leading causes of immobility and mortality in older adults, and hypertension is a major risk factor for CVD (Ong et al., 2007). The prevalence of hypertension is particularly high in older adults (66.3%) and has not declined since 1999 (Ong et al., 2007). Of relevance to this review, Myers (2008) indicated that hypertension and cardiovascular risk factors are associated with deficits in cognitive performance, including working memory, attention, and executive function. The benefits of physical activity on cognition might be manifested through the mediators of CVD and hypertension. There is general consensus that both participation in physical activity and physical fitness, particular cardiorespiratory fitness, are linked to reduced CVD and hypertension (Blair, Cheng, & Holder, 2001; Pescatello et al., 2004). Furthermore, in a series of studies, Colcombe and colleagues found that older adults with high levels of cardiovascular fitness perform better on simple cognitive performance than older adults with lower fitness levels (Colcombe et al., 2004) and have greater gray- and white-matter cortical density, which is associated with executive function (Colcombe, et al., 2003). Recent research further indicates that cardiovascular fitness may serve a neuroprotective function for the older population (Kramer et al., 2005).

According to a systematic review of nine randomized controlled trials, Tai Chi Chuan can prevent or treat CVD and its risk factors (Lee, Pittler, Taylor-Piliae, & Ernst, 2007). The review also indicated that Tai Chi Chuan has been shown to significantly reduce blood pressure and has small beneficial effects on the incidence of stroke and chronic heart failure in patients with hypertension.

Participating in Tai Chi Chuan might also improve cardiovascular fitness, which is known to be related to the reduction of blood pressure and hypertension. Lan, Lai, Wong, and Yu (1996) conducted a series of studies related to physical fitness and Tai Chi Chuan. Using a cross-sectional design, they found that older adults with an average of 11 years of Tai Chi Chuan experience had significantly better oxygen uptake at the ventilatory threshold than did a sedentary group (Lan et al., 1996). After a 52-week class in Yang style (with 108 movements, 4.6 times a week, 24 min per session, and 52–63% heart-rate range), men showed a 16.1% improvement in aerobic fitness (VO_{2max}) and women showed a 21.3% increase (Lan et al., 1998). Using the same Tai Chi Chuan protocol, the benefit of Tai Chi Chuan on VO2max was also found in low-risk patients who had experienced coronary artery bypass surgery (Lan, Chen, Lai, & Wong, 1999). Recently, a meta-analysis indicated that Tai Chi Chuan has a moderate to large effect on aerobic capacity (ES = 0.83 for women and 0.65 for men) in people with an initially low level of physical activity (Taylor-Piliae & Froelicher, 2004). Thus, Tai Chi Chuan can benefit CVD and its related risk factors such as hypertension and cardiovascular fitness and may affect cognitive function indirectly through these mediators.

Mental Resources

According to the proposed model, cognition is also influenced by several mental resources such as depression (Thomas & O’Brien, 2008) and self-efficacy (Albert et al., 1995).

An epidemiological study demonstrated increases in depressive symptoms with age (Gallo & Lebowitz, 1999). Evidence also suggests that depression is associated with cognitive impairment (Thomas & O’Brien, 2008) and that depressive scores are predictive of cognitive decline in older adults over approximately 6 years (Carmelli, Swan, LaRue, & Eslinger, 1997). In addition, meta-analytic evidence supports a positive effect of physical activity on depression (Wipfli, Rethorst, & Landers, 2008).

Similar to physical activity in general, research has also demonstrated a positive effect of Tai Chi Chuan on depression. Cho (2008) randomly assigned 14 older adults with depression into Tai Chi Chuan or a control group for a 3-month intervention. After adjusting for age, gender, and education, results indicated that the Tai Chi Chuan group experienced significant improvements in depressive symptoms.

Self-efficacy, a major element of social cognitive theory, is a situation-specific form of self-confidence (Bandura, 1986). According to the results of the study by Albert et al. (1995), self-efficacy is one of the main endogenous factors by which to predict cognitive changes in an older population. A meta-analysis conducted by Netz, Wu, Becker, and Tenenbaum (2005) indicated that physical activity interventions have significant, positive effects on self-efficacy (ES = 0.38).

A few studies have examined the relationship between Tai Chi Chuan and self-efficacy. Taylor-Piliae et al. (2006) explored the possibility that Tai Chi Chuan programs would change adults' perceptions of their psychosocial status, including stress, mood, social support, and self-efficacy. Older adults (n = 39) attended a 12-week Tai Chi Chuan program applying the Yang 24 style, three times per week, for 60 min per session. The intensity of the Tai Chi Chuan was 4.0 metabolic equivalents (METs), which is similar to brisk walking and safe for older adults. Psychosocial outcomes were collected at baseline and 6 and 12 weeks. Perceived self-efficacy to overcome barriers (TCSE barriers) and to perform (TCSE perform) were included. The results indicated that the Tai Chi Chuan program significantly improved all areas of psychosocial status. In addition, participants reported moderate confidence at baseline and experienced a significant improvement in TCSE barriers and TCSE performance over time.

Li et al. (2001) examined the effects of Tai Chi Chuan on self-efficacy and physical function in older adults (average age 73.2 years). Participants (N = 98) were randomly assigned to either a 6-month Tai Chi Chuan program (Yang 24 style) that was conducted twice a week for 30 min or a wait-list control group (Li et al., 2001). Self-efficacy and physical function were assessed by self-report. The results indicated that the Tai Chi Chuan intervention led to improvements in selfefficacy and physical function and that increases in self-efficacy were related to improvements in perceived physical function.

In summary, evidence suggests that Tai Chi Chuan reduces depressive symptoms and improves self-efficacy. Based on the predictions of the model, it is possible that Tai Chi Chuan affects cognition through its benefits for depression and self-efficacy.

Summary

Overall, older adults commonly suffer from age-related decrements in mental and physical resources and from various age-related illnesses, and these decrements have been linked to poor cognitive performance. Although findings regarding the effects of Tai Chi Chuan on cognition are mixed, empirical support for its positive effects on these potential mediators is more consistent. Because these variables may mediate the relationship between Tai Chi Chuan and cognition, we believe that these findings are indirectly supportive of future research testing the effects of Tai Chi Chuan on cognition.

Directions for Future Research

As described, there is empirical evidence supporting myriad health benefits that result from older adults' participation in Tai Chi Chuan. In addition, evidence supporting the effects of Tai Chi Chuan on mediators that have been proposed to explain the effects of physical activity on cognitive performance suggests that Tai Chi Chuan might be beneficial for cognition. However, relatively few studies have examined the effects of Tai Chi Chuan on cognitive performance, and although there is evidence to support positive effects on measures of executive function, the literature is limited in scope and quality and results are mixed when cognition is defined more broadly. Given the prevalence of cognitive decline in the growing population of older adults and the personal, family, and social costs, more studies are needed to examine the potential cognitive benefits of Tai Chi Chuan. To advance our knowledge, we present several recommendations for future research.

First, given the differences between Tai Chi Chuan and Tai Chi, we recommend that future researchers use the term Tai Chi Chuan rather than Tai Chi. The second recommendation is that Tai Chi Chuan programs be described more completely with respect to their multiple components (Larkey et al., 2009; Wayne & Kaptchuk, 2008a). According to the ACSM's guidelines, the relevant components of exercise prescription include intensity, duration, frequency, and a description of the progression and mode of physical activity (American College of Sports Medicine, 2010). However, it is rare that studies on Tai Chi Chuan provide a complete description of all these components. More specifically, although some studies describe the frequency, duration, or intervention length, very few provide information about intensity or the progression of the program. Consideration of these aspects of a physical activity intervention is highly relevant for Tai Chi Chuan interventions. For example, different Tai Chi Chuan styles (such as Yang, Chen, Wu, and Sun styles), form lengths (8, 12, 24, or 108 movements), and movement complexity might dramatically influence the intensity of the Tai Chi Chuan program. In addition to fully describing the Tai Chi Chuan intervention with respect to these factors, we recommend that researchers use equipment (e.g., heart-rate monitors) and self-report (e.g., rating of perceived exertion) at regular intervals during the program to ascertain the intensity of the activity. Recently, Lan, Chen, and Lai (2008) used heart rate and blood lactate to reflect the intensity of classical Yang style Tai Chi Chuan and found that the style might be categorized as one of moderate intensity across different ages and genders. The status of exercise intensity can be used to determine and provide the appropriate progression of the Tai Chi Chuan program for each individual. Finally, researchers should provide details regarding the other relevant components of a Tai Chi Chuan intervention, including cognitive, social, and environmental influences (Larkey et al., 2009; Wayne & Kaptchuk, 2008a).

In addition, future research may benefit from exploring the potential effects of a single session of Tai Chi Chuan on cognitive performance. Research has shown that acute bouts of physical activity performed at moderate intensity benefit cognitive performance (Chang, Etnier, & Barella, 2009; Tomporowski, 2003). However, only a few studies have examined the acute effects of Tai Chi Chuan on either physiological or psychological outcomes. For example, Motivala, Sollers, Thayer, and Irwin (2006) examined 20 min of Tai Chi Chuan practice compared with a passive rest group and one using slow-moving physical activity. Results showed that the Tai Chi Chuan group experienced a significant decrease in sympathetic activity, which suggests that a single session of acute Tai Chi Chuan might benefit physiological status. To date, no study has examined the acute effects of Tai Chi Chuan on cognitive performance.

Also needed is further examination of the potential task specificity of the effects of Tai Chi Chuan on cognitive performance. Given the evidence that aerobic exercise has greater effects for measures of executive control (Colcombe & Kramer, 2003; Erickson & Kramer, 2009), it is possible that Tai Chi Chuan might also have task-specific effects. The extant research generally supports this because Tai Chi Chuan has been shown to have positive effects on executive-function tasks but not on information-processing tasks (Hall et al., 2009; Matthews & Williams, 2008). We encourage researchers to provide a clear definition of the cognitive task being used and apply multiple cognitive measures when exploring relationships between Tai Chi Chuan and cognitive performance (Etnier & Chang, 2009).

The issues of mediators and mechanisms underlying the effects of Tai Chi Chuan on cognitive function should also be considered because this is a current challenge for researchers working with physical activity and cognition more generally (Chodzko-Zajko, 1991; Kramer et al., 2005). We have provided a brief rationale for several potential mediators, concentrating on sleep effectiveness, cardiovascular disease, hypertension, depression, and self-efficacy. However, based on the physical activity–cognition model, there are several other potential mediators that might affect cognition directly or indirectly. For example, research applying Tai Chi Chuan has also shown positive effects for pain (Tsai et al., 2009; C. Wang, 2008), diabetes (Lee, Pittler, Kim, & Ernst, 2008; Tsang, Orr, Lam, Comino, & Singh, 2008; J.H. Wang, 2008), and stress (Jin, 1989, 1992), all of which might serve to mediate the effects on cognition. The underlying mechanism in these cases might include enhancing exercise-related changes in norepinephrine, epinephrine, dopamine, and cortisol (Jin, 1989, 1992).

Several neuroimaging techniques and electrophysiological measurements such as event-related potential, electroencephalogram, and structural and functional MRI have recently been applied to examine possible mechanisms underlying the effects of exercise on cognition (Hillman, Erickson, & Kramer, 2008). Through the use of these approaches, underlying information processing and mechanisms can be further examined (Colcombe et al., 2004; Hillman et al., 2008). Therefore, we encourage the use of these techniques to further advance our understanding of potential mechanisms underlying the relationship between Tai Chi Chuan and cognitive function.

Finally, also of interest and relevance is the research using animal models, which suggests that the combination of cognitive engagement with physical activity may provide greater benefits for cognitive performance than either activity alone (Black, Isaacs, Anderson, Alcantara, & Greenough, 1990; Kleim, Lussnig, Schwarz, Comery, & Greenough, 1996; Kleim, Vij, Ballard, & Greenough, 1997; Milgram et al., 2005). Given this evidence, Tai Chi Chuan exercise might be expected to have greater benefits on cognition than other forms of physical activity because it consists of multiple components including concentration, attention, mindfulness, imagery, philosophies, and psychosocial interactions. However, to date, no studies have been designed to systematically compare the effects of Tai Chi Chuan with less cognitively engaging forms of physical activity.

In conclusion, Tai Chi Chuan is an increasingly popular form of physical activity for older adults who may be at risk for age-related cognitive decline. The literature examining the effects of Tai Chi Chuan on cognitive performance is extremely sparse and is limited by a general failure to use cognitive outcomes expected to be particularly sensitive to the effects of Tai Chi Chuan. That being said, there is some evidence that Tai Chi Chuan is beneficial for executive function, has positive effects on general measures of cognition, and is positively associated with health benefits, which are important in their own right but which might also be important for mediating the effects of Tai Chi Chuan on cognition. There is also evidence showing that physical activity combined with cognitive engagement results in changes in the cerebral structure and better cognitive performance in animal models. Given that Tai Chi Chuan is likely to be more engaging than other forms of exercise, it is possible that it might actually have larger cognitive benefits than other, less engaging activities. Future research is clearly necessary to advance our understanding of the potential benefits of Tai Chi Chuan for cognitive performance.

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