

The Effect of Tai Chi Exercises on the Cognitive Function in Older Adults: an Examination of P300

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Abstract

The purpose of this study is to examine how Tai Chi exercise will affect older adults' cognitive information processing. The participants involved in this study are 30 who have very low physical activity level (below 3200kcal/a week) among older adults 150 (aged 65-70, male and female) of the Y senior citizen center in D city. They were divided in two groups; the experimental group in which they performed Tai Chi exercise and the control group in which they didn't use a table of random number assigned wirelessly. Cognitive function was assessed by neuroelectrical response, and Event-Related Potential (ERP) at Fz, Cz, and Pz during an oddball task. In the results, The Tai Chi exercise group exhibited larger P300 amplitude than the control group. The Tai Chi exercise group exhibited shorter P300 latency than the control group. The results of the analysis revealed that Tai Chi exercise may be beneficial aspects of cognition, particularly among older adults. It was concluded that long-term aerobic exercise like Tai Chi is associated with attenuation of cognitive decline in older adults

Keywords: Aging, Cognitive Function, Older Adult, P300, Tai Chi

1. Introduction

In recent years, the many researchers^{1,2} indicated that the preservation of mental and psychological health of older adults was directly related to successful old age and observed that the most of older adults showed a decline in their physical and cognitive function with increasing age. Therefore, it is essential for older adults to engage in active and positive physical activity and then lead to a positive life in order to delay the decline in physical and cognitive function³. Many researchers have therefore emphasized physical activity in older adult and asserted cognitive ability would increase in proportion to more physical activity³⁻⁸. Furthermore, the other researchers also emphasized that participation in aerobic exercise may ameliorate or protect against declines in the brain^{9,10} and cognitive function¹¹⁻¹⁴ associated with aging.

Cognitive function includes learning, perception, reasoning, problem-solving and memory, which are impaired when growing older. In addition, when the function of the central nervous system doesn't work actively, this leads to problems in daily life or severe psychological disorders in older adults, and they also tend to be isolated^{3,15}. However, whether physical activity in older adults has an impact on cognitive function in a real life has not enough proved yet. Recently, it has been suggested that Tai chi exercise, which older adults can easily perform whenever, wherever has a good influence on the entire body for older adults¹⁶⁻¹⁸. Tai chi is recommended as an appropriate activity for older adults due to its low or moderate intensity, its health benefits, its calm and non-competitive character, the fact that it does not require specific equipment and its enormous flexibility with regard to the time devoted to practice and the place where it can be performed^{19,20}.

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Wang, Liu, Mimura, & Fujimoto²¹ also stated that Tai chi consists of graceful and slow movement as the traditional martial arts in China. It is a low intensity exercise focusing on promotion of health. It is not only interesting due to pursuing a variety of modified movement, but also doesn't need any specific facility or apparatus. Some studies^{22,23} have reported that Tai chi had beneficial effects on psychological as well as on physiological function. Jin²⁴ reported that the practice of Tai chi was helpful in decreasing tension, depression, anger, fatigue, confusion, anxiety. Brown et al²⁵ have also concluded that Tai chi exercise was effective in promoting psychological benefits such as decreasing mood disturbance and improving general mood. Furthermore, other researchers^{22,26} suggested it can be very helpful to raise up the physical and mental stability and lower tension, stress, depression, anger, fatigue, disorder and the anxiety level. However, in spite of this the majority of studies on Tai chi exercise have focused on the physical benefits for the health of practitioners, devoting less attention to the psychological aspects²⁷. Of all the studies carried out on Tai chi exercise to analyze its psychological effects, the number devoted to cognitive variables is extremely small²⁸. Recently, Kim, Choi, & Kim⁵ have argued that Tai chi exercise has a positive impact on cognitive and physical function for older adults. However, there is no sufficient research that emphasizes the importance of exercise related to the improvement and maintenance of cognitive function for older adults. Especially, there is very rare research that investigates the practical possibility of reducing a decrease in older adults' cognitive function through brain psychophysiological/psychophysiological approach. And it has not yet been proven enough on effect of Tai Chi exercise. Therefore, it is necessary to verify the effect of Tai Chi exercise that can be helpful to reduce the decrease in their cognitive function for older adults when they grow older. Recently psychologists have tried to study the change of cognitive function in human or mechanism related to it. They assume that engagement in exercise is related to older adults' brain information processing or cognitive function introducing scientific and objective measurement tools such as EEG, ERP, fMRI, MEG that can sense undetected change in self reported questionnaire or behavior observation^{11,29,30}. ERPs as a measure of neural activity appear to be a sensitive index of changes in cognition associated with aging^{31,32}. proven to be a useful tool in characterizing age-related changes

in cognition exhibiting robust age-related reductions in amplitude and slowing of latency across multiple tasks and populations^{33,34}. These P300 age-related changes may reflect deficits in the underlying processes such as degeneration of the functional cortical interconnection that occur with age^{35,36}, resulting in a reduced ability to orient attention and suppress extraneous neuronal operations to facilitate attentional processing. The P300 amplitude is sensitive to the allocation of attentional resources during task processing since P300 amplitude is larger when subjects devote more effort to a task leading to the proposal³⁷. The P300 latency indexes stimulus classification speed, with longer latencies reflecting increased processing time³⁸⁻⁴⁰. Previous studies using neuroelectric measures have begun to elucidate the mechanisms engaged by the beneficial relationship between physical activity and cognitive health during aging⁴¹⁻⁴⁴. Sedentary individuals demonstrated slower P300 latencies and smaller amplitude at central and parietal scalp than highly active participants⁴⁵. Hillman et al⁴² observed that older sedentary individuals exhibited the longest latency relative to older-fit. Hillman, Kramer, Belopolsky, & Smith⁴³ conducted a survey how physical activity will affect P300 component when older adults performed executive function task. As a result, the group doing physical activity is higher amplitude than the group not doing in p300 and faster latency. More specifically, greater P300 amplitude^{43,45-47} and faster P300 latency^{42,43,45,48} were observed for high active older adults compared to low active older adults both during executive function task and non-executive functions. Similar findings have suggested a positive association between physical activity or aerobic fitness and cognitive aging^{42,43,45}. That is active old adults seem to be able to compensate age-related deficit, but low active old adults could not utilize compensatory mechanism. Reduced amplitude and slower latency in sedentary individuals may be related to age-related degeneration in brain structures. Given a neural inhibition genesis for P300, it is reasonable to suppose that aerobic fitness promotes an increased ability to inhibit neuronal activity unrelated to task performance, which would facilitate the stimulus evaluation to increase P300 amplitude and decrease its latency. Although P300 can be a very important indicator whether older adults have a cognitive disorder with aging, these studies are not enough to state the connection with physical activity and the decrease in cognitive function⁴. Therefore, it is very critical to see whether Tai Chi exercise

can increase in p300 amplitude and can make faster in p300 latency and the speed of the specific information processing. It means the effect of exercise as a strategy for arbitration with aging can be measured more scientifically and objectively in terms of brain psychophysiological approach. Previous studies showed the effect of exercise on older adults' cognitive function based on behavior observation and self reported questionnaire, but this study has supplemented the limitation through brain psychophysiological approach. It was hypothesized that age would be associated with reduced amplitude and longer latency for the P300 components as found previously. Therefore, the purpose of this study was to examine how Tai Chi exercise will affect older adults' cognitive information processing.

2. Method

2.1 Participants

The participants involved in this study are 30 who have very low physical activity level (below 3200 kcal/a week) among older adults 150 (aged 65-70, male and female) of the Y senior citizen center in D city. All participants provided written informed consent, in accordance with the institutional review board at University of K. Participants were free of neurological disorder, cardiovascular disease, any medications that influence central nervous system function. That they have over 24 points in MMSEK means they don't have any disorder in cognitive function. They had never experienced psychological and physiological test and experiments in the brainwaves. They had no hearing problems and were all right-handed. They were divided in two groups; the experimental group in which they performed Tai Chi exercise and the control group in which they using a table of random number assigned wirelessly. Table 1 below shows the general traits of subjects engaging in this study.

2.2 Device and Assignment

2.2.1 The Measurement of Physical Activity Level

We used YPAS (Yale Physical Activity Survey) that is widely used to research a variety of activities such as housework, leisure and workout⁴⁹. That is, it can calculate calories from the energy consumption during a variety of activities. It can be divided into 3 parts; Energy consumption index,

Total activity time index, Summary scores by sorts of activity. It was proved to very reliable and valid in one study on older adults by Young, Jee & Appel⁴⁹.

2.2.2 The Measurement of Physical Activity Level

Participants engaged in a type of binaural auditory tasks: an Oddball task, which has been used to elicit the ERP components. In Oddball task, participants subjected to three blocks of 100 tonnes (80 common, 20 rare in each block). In oddball task, participants were asked to press a button when they heard the rare (target) tones and to count the number of rare tonnes they heard in each of the trials. Common tones were 1000Hz and rare tones were 2000Hz. Intensity of tones employed in both tasks was 80db. Tones were presented in the ear canal via a soft earplug insert. The inter-stimulus interval was set a 2.00 seconds.

2.2.3 The Measurement of EEG

EEG was recorded from three sites of the scalp corresponding to Fz, Cz, and Pz of the International 10-20 electrode placement system⁵⁰, which were referenced to the right mastoid (A2) while Fpz served as the ground. All electrode impedances were below 5 k Ω . EEG was acquired at a sampling rate of 512 Hz and amplified 20,000 times, while the eye channels was amplified 5,000 times using Grass model 12A5 Neurodata Acquisition amplifiers with band-pass filter setting of 0.1-100 Hz (96-db/octave). Continuous data were collected with QEEG-8 (Laxtha Inc) software. Stimuli were generated using Telescan 2.9 (Laxtha Inc) software, which sent a trigger indicating the condition of each trial for offline sorting, reduction and analysis of EEG and behavioral data. EEG signal processing was conducted off-line with Telescan 2.9 software. EEG was referenced by linear derivation to average mastoids. Ocular correction was performed and eye blinks were correction algorithm⁵¹. The time series data were epoched into 1000 msec segments, and baseline corrected based on a 100 msec pre stimulus interval. Any epoch containing amplitude greater than $\pm 75\mu\text{V}$ was removed with artifact rejection procedures. To exclude trials that are contaminated by artifact, each epoch was visually inspected and removed manually. The rare epoch for the oddball task was sorted according to trial type. The oddball rare trial was then averaged in the time domain to yield two averaged time series

Table 1. Mean and standard deviations for age, height, weight, and physical activity level of participants

Group	Age (years)	Height (cm)	Weight (kg)	Physical activity level (kcal/a week)
	M±SD	M±SD	M±SD	M±SD
The experimental group	65.37±1.42	167.81±1.28	66.89±3.44	3027.14±2.51
The control group	66.05±1.22	167.69±2.04	67.02±1.53	3060.56±1.79

with event-related potentials and then filtered with low-pass filter setting of 10 Hz (24-db/octave). Waveforms were analyzed by peak picking with a latency window of 200-450 ms then the P300 amplitude and latency were saved as a data file for further statistical analysis.

2.3 Experiment Procedure

Upon arriving at the testing room, participants were briefed on the main objectives of the experiment. After hearing for the purpose of study, participants completed an informed consent, health history and demographics questionnaire⁵² to screen for any previous health issues that might be exacerbated by exercise. Then they also did Yale examines physical activity. After providing a brief overview of the testing procedures, participants were seated in a comfortable chair in front of a computer screen. The participants were then prepared for electrocortical measurement in accordance with the Society for Psychophysiological Research Guidelines⁵³. A lycra electrode cap (Electro-Cap International, Eaton, OH) was fitted to the participant's head and 3 electrode sites were prepared using Omni-prep and electrode gel. The EEG data collection was asked to open eye and inhibit vertical and horizontal eye movement by focusing fixation point (black cross with white background). After an acceptable EEG signal was observed, the participant was given the task instructions and a baseline EEG during eye open and eye close was recorded each for 2 minutes. Participants were given the opportunity to ask questions and 10 practice trials were provided to ensure that the subject understands the task requirements. Each oddball task was administered in three blocks each with a brief rest period between blocks. Total three blocks were counterbalanced. After completion of EEG data collection, they performed

Tai Chi exercise each 50 minutes three days a week for 12 weeks. The detailed workout of Tai chi is firstly to do warm-up for 10 minutes; Twirling wrist, Body stretch, Neck exercise, Both shoulder exercises, Waist exercise, Lateral exercise, Squat thrust, Turning ankles and Muscle relaxation exercise. Then they did Tai Chi exercise for 35 minutes. Finally, they took cool-down exercise for 5 minutes; vertical movement, muscle relaxation exercise.

2.4 Statistical Analysis

The experimental design in this study used two-way ANOVAs with repeated measures of 2 (group) and 2 (pre and post). There are two dependent variables; reaction time and accuracy rate when doing oddball. In ERP analysis, this study also used three-way ANOVAs with repeated measures of 2 (group) and 3 (region) and 2 (pre and post). There are two dependent variables; latency period and amplitude of P300. The level of statistical significance was at $\alpha=.05$ and Turkey's HSD was used for post-experimental verification. All statistical analysis was performed by using SPSS 18.0 program.

3. Results

3.1 ERP Analysis

3.1.1 Behavioral Measures

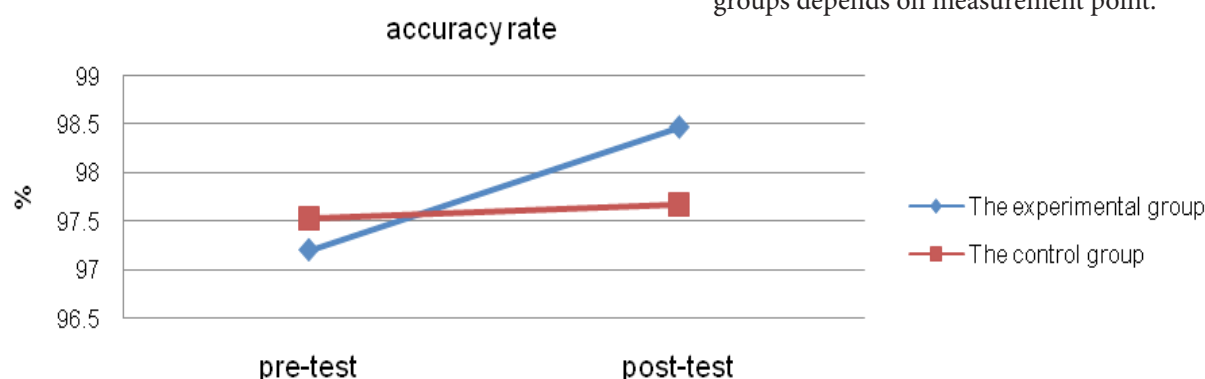
Behavioral performance is analyzed by dividing response to stimulation into accuracy rate and reaction time. The accuracy rate is calculated by forward reaction/number of stimulation. Individual's reaction time takes an average of only forward reaction. Table 2 shows accuracy rate and reaction time to each condition.

Table 2. Mean and standard deviations for accuracy rate and reaction time by groups

group	factor	pre-test	post-test
		M±SD	M±SD
The experimental group	accuracy rate (%)	97.20±.68	98.47±.74
The control group		97.53±.52	97.67±.90
The experimental group	reaction time (msec)	958.51±160.07	639.85±89.09
The control group		962.53±225.15	930.23±209.36

3.1.1.1 Accuracy Rate

There is no significant difference in group [$F(1, 22)=1.39$, $p>.05$] but pre-post test [$F(1, 22)=9.33$, $p<.01$] and there is a significant difference in groups and interaction effect between the pre and post test [$F(1, 22)=7.14$, $p<.05$]. Figure 1 below shows that difference between measurement points depends on the groups or difference between groups depends on measurement point.

**Figure 1.** Interaction effect of accuracy rate depending on the groups.

As a result of the post test on difference between groups depending on measurement point, there is no significant difference ($p>.05$) in the accuracy rate between the two groups, but the experimental group is higher than the control group ($p<.05$) in the post test. As a result of the post test on difference between measurement points depending on groups, there is a significant difference ($p<.05$) in the post test compared to the pre test in the experimental group whereas there is no significant difference in the pre and post test in the control group.

3.1.1.2 Reaction Time

As a result of reaction time, there is a significant difference between groups [$F(1, 28)=7.08$, $p<.05$] and the pre-post test [$F(1, 28)=25.43$, $p<.001$]. Also, there is a significant difference in groups and interaction effect between the pre and post test [$F(1, 28)=16.93$, $p<.001$]. Figure 2 indicates the difference between measurement points depends on the groups or difference between groups depends on measurement point.

As a result of the post test on difference between groups depending on measurement point, there is no significant difference ($p>.05$) in reaction time between two groups in the pre test, but the experimental group is faster than the control group in reaction time ($p<.001$). As a result of the post test on difference between measurement points depending on groups, reaction time in the post test is faster than that in the pre test ($p<.001$) whereas there is no significant difference between the pre and the post test in the control group.

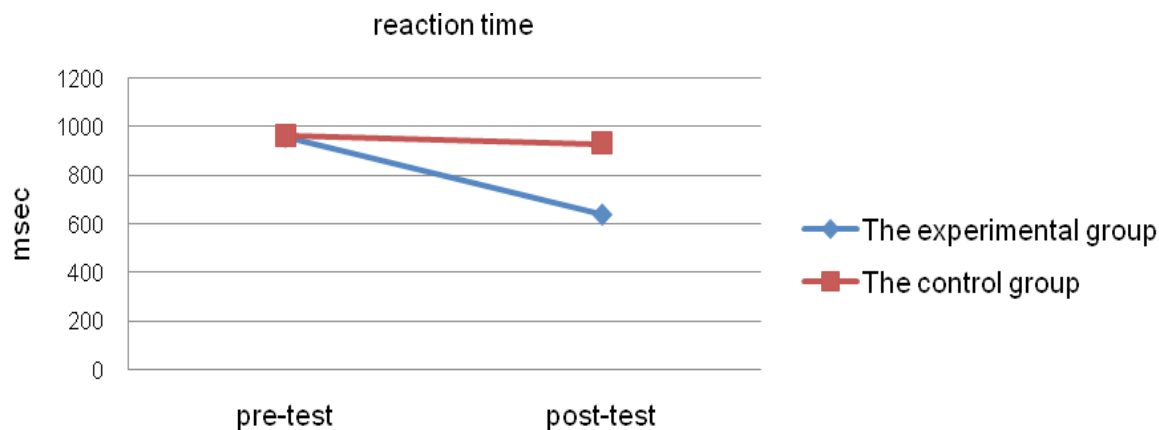


Figure 2. Interaction effect of reaction time depending on the groups.

3.2 ERP Component Analysis

group	type	region	pre-test	post-test
			M±SD	M±SD
The experimental group	amplitude	Fz	6.83±1.20	12.07±1.98
		Cz	6.96±1.91	10.32±3.66
		Pz	7.14±3.38	8.49±3.27
Fz		8.61±3.48	8.37±2.39	
Cz		6.52±2.07	6.51±1.89	
Pz		6.90±3.05	6.96±2.22	
The control group	latency	Fz	353.54±30.23	311.96±8.76
		Cz	348.28±33.16	309.44±8.92
		Pz	341.56±34.76	330.85±27.86
Fz		332.09±26.74	337.55±25.93	
Cz		336.64±35.35	339.69±25.21	
Pz		338.34±33.13	352.89±31.39	

3.2.1 P300 Amplitude

As a result of analyzing the amplitude to P300, there is no main effect in group and region [$F(2, 84) = .90, p > .05$] but there is a main effect in group [$F(1, 84) = 9.74, p < .01$], region [$F(2, 84) = 5.61, p < .01$], and between the pre and the post and groups [$F(1, 84) = 21.97, p < .001$] they interacted with each other. It was indicated that the difference between the measurement points can be changed by kinds of group or the difference

between groups by the measurement point (Figure 3). As a result of the post test on difference in groups depending on measurement point, there is no significant difference between two groups in the pre test, whereas the experimental group is higher than the control group ($p < .05$) in amplitude in the post test. As a result of the post test on difference between measurement points depending on the groups, the post test is faster than the pre test in the experimental group, whereas there is no significant difference between the pre test and

the post test in the control group. And there is no significant difference between region and interaction effect between the pre and post test [$F(2, 84)=2.08, p<.05$].

difference between the pre and the post test in the control group.

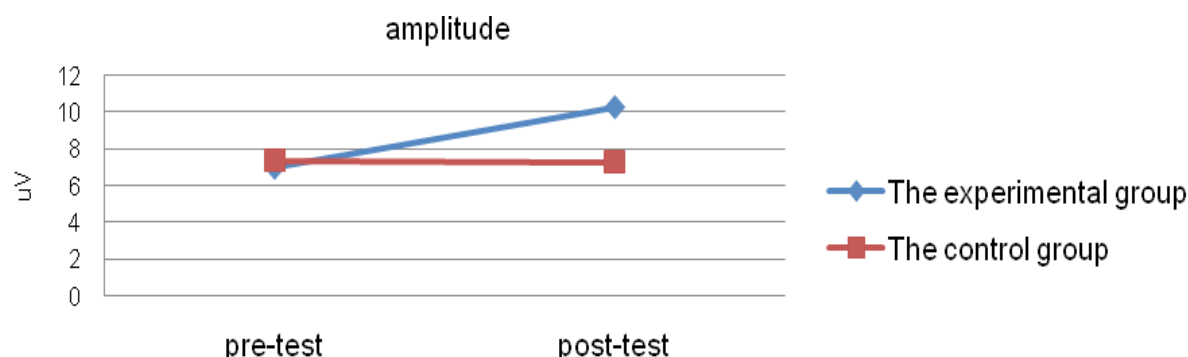


Figure 3. Interaction effect of amplitude depending on the groups.

3.2.2 P300 Latency

As a result of analyzing latency period to P300, there is no interaction effect on group [$F(1, 84)=2.09, p>.05$], region [$F(2, 84)=.26, p>.05$], between region and the pre, post test [$F(2, 84)=2.70, p>.05$], among group, region and the pre, post test [$F(2, 84)=.66, p>.05$]. But there is an interaction effect on among region [$F(2, 84)=7.89, p<.01$], group and the pre, post test [$F(1, 84)=22.21, p<.001$]. It was suggested that the difference between the measurement points can be changed by kinds of group or the difference between groups by the measurement point (Figure 4).

4. Discussion

The purpose of this study was to investigate how Tai Chi exercise will affect older adults' cognitive information processing. As a result of reaction time while performing an assignment, there is a significant difference between two groups. It reveals that the experimental group (doing Tai Chi exercise) is significantly faster than the control group (not doing Tai Chi exercise).

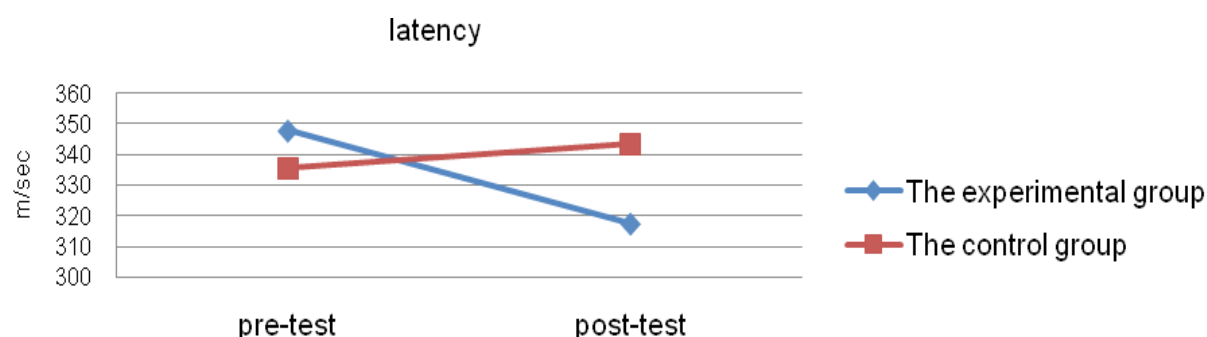


Figure 4. Interaction effect of latency depending on the group.

As shown in the Figure 4 below, as a result of the post test between two groups depending on measurement point there is no significant difference ($p>.05$) in latency period and the post test is shorter than the pre test ($p<.001$) in latency period. As a result of the post test on difference between measurement points depending on the groups in latency, the post is shorter than the pre test ($p<.001$) in the experimental group, whereas there is no significant

As a result of accuracy rate, the experimental group is higher than the control group. The results are consistent with that of Hillman et al⁴⁵ arguing that the experimental group doing aerobic exercise is significantly faster than the control group in reaction time. It is also consistent with the earlier studies^{43,54,55} that increased physical activity improved accuracy rate. Hence it shows that improvement of cardiopulmonary function by

doing Tai Chi exercise can delay the decrease in cognitive function with aging though they are 60-80 aged. The result of analyzing P300 amplitude in ERP, the Tai Chi exercise group is significantly higher than the control group. It means doing Tai Chi exercise can affect older adults' cognitive ability. Amplitude in p300 reflects nervous change to information related to assignment. When they paid attention more in proportion to the amount of attention resource, amplitude in p300 increased⁵⁶. Bashore⁴⁶ supported it by arguing that older adults with a high physical strength level have higher amplitude than those with a low physical strength level. Hillman et al⁴² also supported it that reported older adults with a high aerobic capacity showed higher amplitude in p300 than those with a lower aerobic capacity. It is also consistent with the result of the study conducted by Hillman et al⁴³. They stated that the physical exercise group had higher amplitude in p300 than the group that didn't any physical exercise. As a result of the latency period in P300, Tai Chi exercise group showed a significantly shorter latency period than the control group. The latency period indicates time for information processing when performing the assignment. So it means participants in the Tai Chi exercise group have the ability to process information more quickly^{57,58}. The results in this study supported Bashore⁴⁶ that older adults with a high strength level shower latency period shorter than those with a low period level just as a Tai Chi exercise group showed the latency period shorter than the control group. It is consistent with the result from Hillman et al⁴³ asserting that a physical activity group showed a latency period more quickly than a non-physical activity group. Hillman et al⁴² backed up the result of this study arguing that a group with a high aerobic ability showed a latency period in p300 more quickly than one with a low aerobic ability. These results showed the importance of aerobic exercise in terms of the brain information processing. Especially they supported argument by Cotman & Berchtold⁵⁹ and Swain et al⁶⁰ that aerobic exercise can help the impaired cognitive function related to aging protect and improve the integration of the central nervous system and cognitive function. It can be verified that the improvement of aerobic ability by regular exercise can prevent cognitive and brain function for older adults from decreasing. After considering all the results, the steady aerobic exercise such as Tai Chi has a positive impact on older adults' cognitive ability. Especially when doing Tai Chi, they keep the lower

center of gravity making up a centripetal tendency and efferent contraction on the upper and lower limb muscle from various angles. These successive movements can enhance respiratory activity. This supported argument by Hall, Smith & Keels⁶¹ that aerobic exercise can derive improvement of cardiovascular function and increase blood flow rate in the brain leading to prevention for the decrease in cognitive function. It also backed up the earlier studies^{48,62,63} revealing that proper physical activity can cause changes of brain function related to aging. It is very helpful for older adults to do Tai Chi exercise regularly for the sake of improving physical fitness for health and leading an independent life in an old age as aging can cause the decrease in stamina and physical function in particular in a daily life. For the further study, we can study how long-term aerobic exercise will affect mental health for older adults especially in terms of emotional aspect.

5. References

1. Kim WC, Choi SL, Kim SW. The effects of tai chi exercise on skill related fitness and mental health in elderly adult. *The Korea Journal of Sports Science*. 2012; 21(4):437-55.
2. Shin MK. Effects of an exercise program on frontal lobe cognitive function in elders. *Journal of Korean Academy of Nursing*. 2009; 39(1):107-15.
3. Kim YS. The effect of cognitive ability and self-esteem on regular exercise in the elderly. *The Korean Journal of Physical Education*. 2001; 40(4):181-93.
4. Kim SW, Lee GY, Yoo HS. Effect of aging and physical activity on cognitive function: an examination of P300. *International Journal of Digital Content Technology and its Applications*. 2013; 7(12):261-80.
5. Kim WC, Choi SL, Kim SW. The effect of Tai Chi exercise on the cognitive and physical function in older adults. *International Journal of Digital Content Technology and its Applications*. 2013; 7(12):239-55.
6. Kim HJ, Choi JH, Lee KM. Effects of combination training of resistance and walking exercise on psychomotor performance in the elderly. *Journal of Physical Growth and Motor Development*. 2004; 12(2):97-105.
7. Lee YJ, Kim SM. The effect of physical activity program on cognition and ADL of demented elderly. *Journal of the Korea Gerontological Society*. 2003; 23(4):17-31.
8. Jung YJ, Min S. The effects of singing program combined with physical exercise on physiologic changes, perception function and degree of depression in the elderly women. *Journal of Korean Biological Nursing*. 2001; 3(2):35-50.
9. Colcombe SJ, Kramer AF, McAuley E, Erickson K, Scalf P. Cardiovascular fitness training and changes in brain volume as measured by voxel based morphometry. *Psychophysiology*. 2004; 41:S19.

10. Cotman CW, Engesser-Cesar C. Exercise enhances and protects brain function. *Exerc Sport Sci Rev*. 2002; 30(2):75–9.
11. Colcombe SJ, Kramer AF. Fitness effects on the cognitive function of older adults: a meta-analytic study. *Psychol Sci*. 2003; 14(2):125–30.
12. Hillman CH, Erickson KI, Kramer AF. Be smart, exercise your heart: exercise effects on brain and cognition. *Nat Rev Neurosci*. 2008; 9(1):58–65.
13. Hillman CH, Kramer AF, Belopolsky AV, Smith DP. A cross-sectional examination of age and physical activity on performance and event-related brain potentials in a task switching paradigm. *Int J Psychophysiol*. 2006; 59:30–9.
14. Kramer AF, Erickson KI. Capitalizing on cortical plasticity: influence of physical activity on cognition and brain function. *Trends Cognit Sci*. 2007; 11(8):342–8.
15. Hogan BA. Physical and cognitive activity and exercise for older adults: review. *Journal of Aging and Human Development*. 2005; 60:95–126.
16. Abbott R, Lavretsky H. Tai Chi and Qigong for the treatment and prevention of mental disorders. *Psychiatr Clin*. 2013; 36(1):109–19.
17. Kim HN. The definition and meanings of slow exercise. *Journal of Leisure and Recreation Studies*. 2005; 29:23–34.
18. Liu Y, Mimura K, Wang L, Ikuta K. Psychological and physiological effects of 24-style Taijiquan. *Neuropsychobiology*. 2005; 52:212–8.
19. Jimenez PJ, Melendez A, Albers U. Psychological effects of Tai Chi Chuan. *Arch Gerontol Geriatr*. 2012; 55(2):460–7.
20. Li F, Fisher KJ, Harmer P, Irbe D, Tarse RG, Weimer C. Tai Chi and self-rated quality of sleep and daytime sleepiness in older adults: a randomized controlled trial. *J Am Geriatr Soc*. 2004; 52(6):892–900.
21. Wang L, Liu Y, Mimura K, Fujimoto S. The psychophysiological effects of Taiji sense in Taijiquan exercise. *Jpn J Phys Fitness Sports Med*. 2007; 56(1):131–40.
22. Taylor-Piliae RE, Haskell WL, Stotts NA, Froelicher ES. Improvement in balance, strength, and flexibility after 12 weeks of Tai Chi exercise in ethnic Chinese adults with cardiovascular disease risk factors. *Alternative Ther Health Med*. 2006; 12:50–8.
23. Wang YT, Taylor L, Pearl M, Chang L. Effects of Tai Chi exercise on physical and mental health of college students. *Am J Chin Med*. 2004; 32(3):453–9.
24. Jin P. Efficacy of Tai Chi, brisk walking, meditation, and reading in reducing mental and emotional stress. *J Psychosom Res*. 1992; 36(4):361–70.
25. Brown DR, Wang Y, Ward A, Ebbeling CB, Fortlage L, Puleo E, Benson H, Rippe JM. Chronic psychological effects of exercise and exercise plus cognitive strategies. *Med Sci Sports Exerc*. 1995; 27(5):765–75.
26. Wang YT, Taylor L, Pearl M, Chang LS. Effects of Tai Chi exercise on physical and mental health of college students. *Am J Chin Med*. 2004; 32(3):453–9.
27. Wang C, Schmid CH, Hibberd PL, Kalish R, Roubenoff R, Ronen R, McAlindon T. Tai Chi is effective in treating knee osteoarthritis: a randomized controlled trial. *Arthritis Care Res*. 2009; 61(11):1545–3.
28. Chang CY, Hung CK, Chang YY, Tai CM, Lin JT, Wang JD. Health-related quality of life in adult patients with morbid obesity coming for bariatric surgery. *Obes Surg*. 2010; 20(8):1121–7.
29. Frodl T, Meisenzahl EM, Zetzsche T, Born C, Groll C, Jager M. Hippocampal changes in patients with a first episode of major depression. *Am J Psychiatr*. 2002; 159:1112–8.
30. Fushimi M, Matsubuchi N, Sekine A. Progression of P300 in a patient with bilateral hippocampal lesions. *Clin Neurophysiol*. 2005; 116:625–31.
31. Goodin DS, Squires KC, Henderson BH, Starr A. Age-related variations in evoked potentials to auditory stimuli in normal human subjects. *Electroencephalogr Clin Neurophysiol*. 1978; 44(4):447–58.
32. Polich J, Lardon MT. P300 and long-term physical exercise. *Electroencephalogr Clin Neurophysiol*. 1997; 103(4):493–8.
33. Anderer P, Semlitsch HV, Saletu B. Multichannel auditory event-related brain potentials: effects of normal aging on the scalp distribution of N1, P2, N2 and P300 latencies and amplitudes. *Electroencephalogr Clin Neurophysiol*. 1996; 99(5):458–72.
34. Fjell AM, Walhovd KB. P300 and neuropsychological tests as measures of aging: scalp topography and cognitive changes. *Brain Topogr*. 2001; 14(1):25–40.
35. Bashore TR, Ridderinkhof KR. Older age, traumatic brain injury, and cognitive slowing: Some convergent and divergent findings. *Psychol Bull*. 2002; 128(1):151.
36. Reuter-Lorenz PA. New visions of the aging mind and brain. *Trends Cognit Sci*. 2002; 6(9):394–400.
37. Wickens C, Kramer A, Vanasse L, Donchin E. Performance of concurrent tasks: a psychophysiological analysis of the reciprocity of information-processing resources. *Science*. 1983; 221(4615):1080–2.
38. Duncan-Johnson CC. P300 latency: a new metric of information processing. *Psychophysiology*. 1981; 18:207–15.
39. Kutas M, McCarthy G, Donchin E. Augmenting mental chronometry: the P300 as a measure of stimulus evaluation time. *Science*. 1977; 197(4305):792–5.
40. McCarthy G, Donchin E. A metric for thought: a comparison of P300 latency and reaction time. *Science*. 1981; 211(4477):77–80.
41. Kramer AF, Hillman CH. Aging, physical activity, and neurocognitive function. *Psychobiology of exercise and sport*. 2006; 45–59.
42. Hillman CH, Weiss EP, Hagberg JM, Hatfield BD. The relationship to age and cardiovascular fitness to cognitive and motor processes. *Psychophysiology*. 2002; 39:1–10.
43. Hillman CH, Kramer AF, Belopolsky AV, Smith DP. A cross-sectional examination of age and physical activity on performance and event-related brain potentials in a task switching paradigm. *Int J Psychophysiol*. 2006; 59:30–9.

44. Hillman CH, Erickson KI, Kramer AF. Be smart, exercise your heart: exercise effects on brain and cognition. *Nature Reviews Neuroscience*. 2008; 9(1):58–65.
45. Hillman CH, Belopolsky AV, Snook EM, Kramer AF, McAuley E. Physical activity and executive control: Implications for increased cognitive health during older adulthood. *Res Q Exerc Sport*. 2004; 75:176–85.
46. Bashore TR. Age, physical fitness and mental processing speed. *Annu Rev Gerontol Geriatr*. 1989; 9:120–44.
47. McDowell K, Kerick SE, Santa Maria DL, Hatfield BD. Aging, physical activity and cognitive processing: an examination of P300. *Neurobiol Aging*. 2003; 24:597–06.
48. Dustman RE, Emmerson RY, Ruhling RO, Shearer DE, Steinhaus LA, Johnson SC. Age and fitness effects on EEG, ERPs, visual sensitivity, and cognition. *Neurobiol Aging*. 1990; 11:193–200.
49. Young DR, Jee SH, Appel LJ. A comparison of the Yale physical activity 84 survey with other physical activity measures. *Med Sci Sports Exerc*. 2001; 33:955–61.
50. Jasper HH. The 10-20 electrode system of the international federation. *Electroencephalogr Clin Neurophysiol*. 1958; 10:371–5.
51. Semlitsch HV, Anderer P, Schuster P, Presslich O. A solution for reliable and valid reduction of ocular artifacts, applied to the P300 ERP. *Psychophysiology*. 1986; 23(6):695–703.
52. Thomas S, Reading J, Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). *Can J Appl Sport Sci*. 1992; 17(4):338–45.
53. Putnam LE, Johnson R, Roth WT. Guidelines for reducing the risk of disease transmission in the psychophysiology laboratory. *Psychophysiology*. 1992; 29(2):127–41.
54. Colcombe SJ, Kramer AF, McAuley E, Erickson KI, Scalf P. Neurocognitive aging and cardiovascular fitness. *J Mol Neurosci*. 2004; 24(1):9–14.
55. Kramer AF, Hahn S, Gopher D. Task coordination and aging: Explorations of executive control processes in the task switching paradigm. *Acta psychologica*. 1999; 101(2):339–78.
56. Polich J, Heine MR. P300 topography and modality effects from a single-stimulus paradigm. *Psychophysiology*. 1996; 33(6):747–52.
57. Kim SW, Kim JS, Park HJ, Moon DW, Kim JG. P300 responses evoked by auditory stimuli: effects of task difficulty. *Korean Journal of Sport Psychology*. 2008; 19(2):17–28.
58. Woo MJ. The influence of aerobic capacity on frontally-mediated executive function: an ERP study. *The Korean Journal of Physical Education*. 2009; 48(3):167–77.
59. Cotman CW, Berchtold NC. Exercise: a behavioral intervention to enhance brain health and plasticity. *Trends Neurosci*. 2002; 25(6):295–301.
60. Swain RA, Harris AB, Wiener EC, Dutka MV, Morris HD, Theien BE, Greenough WT. Prolonged exercise induces angiogenesis and increases cerebral blood volume in primary motor cortex of the rat. *Neuroscience*. 2003; 117(4):1037–46.
61. Hall CD, Smith AL, Keele SW. The impact of aerobic activity on cognitive function in older adults: a new synthesis based on the concept of executive control. *Eur J Cognit Psychol*. 2001; 13:279–300.
62. Blair SN, Kohl HW3rd, Barlow CE, Paffenbarger RS, Jr, Gibbons LW, Macera CA. Changes in physical fitness and all-cause mortality: a prospective study of healthy and unhealthy men. *JAMA*. 1995; 273:1093–8.
63. Chodzko-Zajko WJ, Moore KA. Physical fitness and cognitive functioning in aging. *Exerc Sport Sci Rev*. 1994; 22:195–220.