



Tai Chi Improves Brain Metabolism and Muscle Energetics in Older Adults

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Scholarly Report submitted in partial fulfillment of the MD Degree at Harvard Medical School

Date: 04 April 2018

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Scholarly Report Title: Tai Chi Improves Brain Metabolism and Muscle Energetics in Older Adults

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Abstract:**Background and Purpose:**

Tai Chi is a mind-body exercise that has been shown to improve both mental and physical health. As a result, recent literature suggests the use of Tai Chi to treat both physical and psychological disorders. However, the underlying physiological changes have not been characterized. The aim of this pilot study is to assess the changes in brain metabolites and muscle energetics after Tai Chi training in an aging population using a combined brain-muscle magnetic resonance spectroscopy (MRS) examination.

Methods:

Six healthy older adults were prospectively recruited and enrolled into a 12-week Tai Chi program. A brain ¹H MRS and a muscle ³¹P MRS were scanned before and after the training, and post-processed to measure N-acetylaspartate to Creatine (NAA/Cr) ratios and Phosphocreatine (PCr) recovery time. Wilcoxon signed rank tests were utilized to assess the differences between pre- and post-Tai Chi training.

Results:

A significant within-subject increase in both the NAA/Cr ratios ($p = 0.046$) and the PCr recovery time ($p = 0.046$) was observed between the baseline and the post-training scans. The median percentage changes were 5.38% and 16.51% for NAA/Cr and PCr recovery time, respectively.

Conclusions:

Our pilot study demonstrates significant increase of NAA/Cr ratios in posterior cingulate gyrus and significantly improved PCr recovery rates in leg muscles in older adults following short-term Tai Chi training, and thus provides insight into the beneficial mechanisms.

My intellectual contribution to the project:

The study design and grant submission were developed prior to my involvement in the study. I participated early in the study by contacting local Tai Chi instructors to identify possible participants in the study. I participated in Tai Chi classes to identify possible locations of training. In addition to recruiting study participants I worked with the lab to help refine the study protocol. This included testing the magnetic resonance (MR) safe exercise equipment which included determining the appropriate percentage of maximum weight to be used for the exercise

portion of the protocol, positioning of the ^{31}P coil, and instructions for the participants. For the manuscript preparation I conducted a literature search to identify the reproducibility of NAA measurements in gray matter using ^1H MRS, and the reproducibility of time constant measurements using ^{31}P MRS which was added to the manuscript. In addition I did an analysis of our own measurements to determine internal validity of the study. Finally, I reviewed the manuscript as a whole prior to submission.

Contributions from Other Authors:

Min Zhou: Recruitment and Scanning of patients, primary data analysis, manuscript preparation

Huijun Liao: Recruitment and Scanning of patients, manuscript preparation

Lasya P. Sreepada: Post-processing of MRS data

James A. Balschi: Study design, MR expertise

Alexander P. Lin: Principal Investigator for the Center for Clinical Spectroscopy and this study.

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Authors: Min Zhou; Huijun Liao; Lasya P. Sreepada; Joshua R. Ladner; James A. Balschi;

Alexander P. Lin

How your work fits into the field: Provide a more detailed introduction, rationale, and background than is typically found in a published paper.

Introduction and Background:

Tai Chi is a form of exercise that focuses on physical and psychological conditioning. This mind-body exercise is unique from other forms of physical conditioning as it also emphasizes strong concentration, improved alertness, and breathing control. [1-4] Numerous studies have shown that Tai Chi can strengthen the muscles of the lower extremities, and improve cognition. Supporting these conclusions is a growing body of morphological MRI and functional MRI studies which suggest Tai Chi can improve neuroplasticity.[5-11] However studies to date have not been able to mechanistically describe the improvements in physical and psychological conditioning or their relationship to one another. Magnetic resonance spectroscopy (MRS) is an important method for elucidating mechanistic information about regional physiology. It is able to accomplish this by non-invasively measuring the endogenous chemicals of body tissues. ^1H

MRS is frequently used to study biochemical process in the brain. Specifically N-acetyl aspartate (NAA) is a marker of neuronal health and is reduced in processes that destroy neurons. For example, after head trauma, NAA can be used to predict patient outcomes and is an especially useful measure of diffuse axonal injury. [12-17] Utilizing the same technology ^{31}P MRS is able to measure phosphorus containing molecules within tissue and is commonly used to track adenosine diphosphate (ADP) and phosphocreatine (PCr) in tissue. These can be used as surrogate markers to quantify mitochondrial function by measuring the rate of recovery of phosphocreatine (PCr) following exercise.[18] This study intended to apply these unique MRS methods to participants undergoing Tai Chi training to better characterize the mind and body effects of Tai Chi training in an aging population.

Describe gaps that your paper helps to fill as well as the clinical and research implications of your work.

Our study found significantly increased NAA/Cr ratios in posterior cingulate gyrus and significantly improved PCr recovery time in leg muscles in older adults after 12-weeks of Tai Chi training. This reinforces previous findings that Tai Chi may promote neuroplasticity and increase lower extremity muscle oxidative capacity in older adults. However this study also quantifies the improvement in both neuronal density and improved oxidative capacity associated with 12-weeks of training.

NAA is a metabolite found almost exclusively within cell bodies of neurons, and directly reflecting neuron cell number.[22] A decrease of NAA level is an indication of neuronal loss, and can be seen following trauma, as well as in healthy aging, Alzheimer's disease, stroke, multiple sclerosis, schizophrenia, epilepsy, and bipolar disorder.[17, 23-25] Just as NAA can indicate neuronal loss it can also indicate increased neuronal density. In addition a growing body of research indicates that aerobic fitness promotes neuronal integrity and viability. A study of 137 healthy older adults demonstrated that higher aerobic fitness level correlated with increased NAA levels in the frontal cortex.[15] Another study compared neurochemical concentrations between sedentary and endurance-trained middle-aged adults, and found that endurance-trained adults had significantly higher NAA/Cr in the frontal grey matter.[16] Our results demonstrated significantly increased NAA/Cr in healthy older adults after 12-weeks of Tai Chi training, suggesting either increased neuroplasticity, or potentially, a protective effect of Tai Chi on neurons.

While this study elucidates increased neuronal density associated with Tai Chi, it was not able to distinguish the cause of the increased NAA. Tai Chi is a moderate-intensity aerobic exercise that utilizes 50-58% of heart rate reserve, and it also requires strong concentration with breathing control when performed properly [1]. This aerobic conditioning has an expected increase in NAA, but unlike other forms of aerobic exercise Tai Chi has added focus on psychological benefits of improved attentiveness and reduced stress and anxiety.[1, 4] Further research is needed to fully characterize the contribution of each aspect of Tai Chi training to the observed increase in neuroplasticity.

Of note, different from the prior studies, we acquired the MRS data in posterior cingulate gyrus which has been shown to be more sensitive to global changes in the brain.[19] Furthermore, the PCG plays an important role in cognitive processes such as attention [26] which has been shown to be enhanced by Tai Chi.[8] Finally the PCG was also selected because it is highly reproducible with a covariance of 2-2.5%.[27]

Our results also showed a significant increase in the PCr recovery of the vastus medialis after 12 weeks of Tai Chi training. PCr recovery time, measured by ³¹P MRS, is a reliable indicator of skeletal muscle mitochondrial metabolism.[18, 28] It is very reproducible with a covariance of 8%.[29] It reflects the mitochondrial ATP synthesis during recovery from exercise, which is driven by oxidative metabolism.[30, 31] Our findings of decreased PCr recovery time indicate that Tai Chi training improves muscle mitochondrial function in older adults. Other studies have characterized the benefits of improvements in PCr recovery rate. Choi et al assessed the muscle bioenergetics by post-exercise PCr recovery rate in a study with 126 participants and showed that muscle bioenergetics were highly correlated with walking speed.[32] Furthermore, a study by Zane et al with 326 participants demonstrated that impaired muscle mitochondrial energetics, assessed by PCr resynthesis rate, affected muscle strength and had a negative effect on walking performance.[33] Thus, our results provide an insight into the physiological mechanisms of the increased lower extremity muscular strength and improved motor control following Tai Chi exercise.

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Appendix 1: Journal of Neuroimaging Submission