The effects of proprioception and tactile sensation on visuospatial ability in the upper limb perturbation state of long-term Tai Chi practitioners

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Abstract: Purpose: Falls are closely related to visuospatial ability in older adults. Visuospatial ability is the ability to process visual information and feed it back into motion, and it is also one of the basic abilities of People's Daily life. When older adults perform some targeted upper limb disturbance movements in daily life, their visuospatial ability is usually assessed by object localization difference (the distance difference between the location located by the subject's memory and the original target location). Smaller object localization difference represents better visuospatial ability. As a traditional Chinese multi-genre fitness exercise, Tai Chi might be an option for improving visuospatial ability. Tai Chi encompasses motor (a series of body movements) and mental (mind concentration) elements, and has been proven to improve motor and cognitive functions among older adults. Further, practicing Tai Chi improved the sensitivity of proprioception and tactile sensation, which were positively related to visuospatial ability. Therefore, the purpose of this study was to investigate the benefits of Tai Chi practice for visuospatial ability during upper limb perturbation state and their relationship to practitioners' visuospatial ability was related to their proprioception and tactile sensations. Materials and methods: An a priori power analysis (G*Power Version 3.1) indicated that a minimum of 15 participants was needed in each group to obtain an alpha level of 0.05 and a beta level of 0.80 based on a previous report, in which the TTS was compared after the matched bias (2.75 ± 0.85) or unmatched bias (3.76 ± 1.01) exercises.18 older adults aged 65~77 with more than 5 years of experience in Tai Chi practice and 19 older adults in the control group with irregular physical exercise experience were recruited. The inclusion criteria were as follows: age ≥ 65 years, long-term Tai Chi practice experience (at least four times per week, 1 h each time, for more than 5 years) for the Tai Chi group, and absence of regular exercise (total exercise time less than 1 h per week in the past 3 years) for the control group. The exclusion criteria were movement disorders or

nervous system diseases, recent lower extremity and dominant arm surgery, cardiovascular pathologies, diabetes or hepatorenal syndrome, coordination function disorders, peripheral neuritis, Parkinson’s disease, Alzheimer’s disease, and Mini-Mental State Examination (MMSE) scores < 24. All participants were right arm dominant, defined by the outstretched hand to reach an object. The target positioning error (TPE), ankle proprioception, tactile sensation of the two groups were compared. Target Positioning Error Test: Each participant wore experimental shoes provided by the laboratory (Flattie, Qingdao Luzhong Co. Ltd., Qingdao, China). A reflective marker (Marker-1) was attached to a metal bar (height = 2 m, diameter = 1.5 cm) with a solid base; another reflective marker (Marker-2) was attached to the tip of the index finger of a participant’s dominant arm. The metal bar was removable, and the height of Maker-1 was adjustable. A force plate (AMTI 600* 900, AMTI Inc., Watertown, MA, United States) was used to collect force data at 1,000 Hz. A 12-camera motion analysis system (Vicon, Oxford Metrics, Yarnton, England) was used to collect the markers’ three dimensional data at 100 Hz. The force plate and motion analysis system were collected via the Vicon system with internal synchronization.The location of the marker-1 is adjustable. The horizontal location could be adjusted by moving the bar forward or backward, the vertical location could be adjusted by attaching the marker to the high or low part of the bar. The height of Marker-1 was adjusted to the participant’s shoulder joint height with 1.3 times the dominant arm length to the shoulder joint horizontally. The metal bar location was adjusted to allow participants to stand on the center of the force plate. The participants raised their dominant arms and used Marker-2 to point to the remembered position of Marker-1, and then return to a stable standing position as soon as possible. Five trials were performed. Proprioception test: The proprioception threshold at the ankle joint of the dominant leg was assessed using a proprioception test device (AP-II, Sunny Co. Ltd., Jinan, China). Good test-retest reliability (ICC value, 0.74~0.94) for the device has been reported previously. The dominant leg was defined as the preferred leg for kicking a football in the lab. The minimum angular motion that the patient can detect during ankle dorsiflexion/plantarflexion was collected by using the proprioception test device. The device consists of a box and a platform that can rotate within the frontal and sagittal planes. Two electric motors drive the platform at an angular velocity of 0.4◦ /s. The movement of the platform can be stopped at any time by a hand switch controlled by the participants. An electronic goniometer in the device recorded the angular displacement of the platform. Each participant was seated on a height-adjustable chair with the foot placed on the platform. During the ankle proprioception test, the knee and hip joints were flexed at 90◦, and the leg was perpendicular to the surface of the platform when the platform was placed in a horizontal position. Approximately 50% of the participant's lower extremity weight was rested on the platform using the thigh cuff suspension system to control unwanted sensory cues from the contact between the platform and the plantar surface of the foot. The participant sat with their eyes closed and wore headphones with light music playing to eliminate potential environmental visual and auditory stimulation. The participant was instructed to concentrate on their foot and press the hand switch to stop the movement of the platform when they could sense motion, followed by identification of the rotation direction. The motor was operated to rotate with a random time interval ranging from 2 to 10 s after an indication to start a trial. At least five trials were performed for each direction to reduce random measurement errors. Tactile sensation test: The dominant foot's tactile sensation was tested with the participants while lying supine on the treatment table with a set of Semmes-Weinstein monofilaments (six piece foot kit, North Coast Medical, Inc., Morgan Hill, CA, United States), which showed good test-retest reliability (ICC value, 0.83~0.86). Monofilaments of 6 different sizes used in this study were 2.83, 3.61, 4.31, 4.56, 5.07, and 6.65 that applies 0.07, 0.4, 2, 4, 10, and 300 grams of force when being pressed into a C-shape (bent 90◦). The filament size was log10 (10 × force in milligrams). The filaments were applied to the skin on the bases of the great toe, 1st and 5th metatarsals, arch, and heel in random order. These touches were performed for 1 s and with two repetitions. Randomized null-stimuli were added to ensure that the participants could not anticipate the application of the filaments. Plantar sensitivity was determined by the initial application of the thin filaments, progressing to the thicker filaments until the participants were able to detect the tactile sensation. The participants were asked to provide a verbal response about the localization of the area tested when they perceived the stimulation. The sensitivity threshold was determined by the minimum monofilament gauge detected correctly. A less sensitivity threshold indicates better plantar tactile sensation. The relationships of visuospatial ability to proprioception and tactile sensation were investigated. Data reduction: The hand movement onset was taken as the moment when hand velocity exceeds 5% of the maximal hand speed at the beginning of the movement. The hand movement offset was calculated when the hand velocity fell below 5% of the maximal hand speed (the maximum speed of the Marker M2) at the end of the movement. Marker-2 position data were filtered with a 5 Hz fourthorder lowpass Butterworth filter and used in calculating TPE in the AP, ML, and vertical directions and three-dimensional space.Results: Of the 37 participants, 18 were included in the Tai Chi group (female = 4, male = 14, age = 69.7 ± 3.9 years, weight = 70.6 ± 11.0 kg, height = 1.68 ± 0.08 m, BMI = 24.8 ± 2.9 kg/m2 , MMSE scores = 28.83 ± 1.01, Tai Chi experience = 10.6 ± 5.6 years), and 19 were included in the control group (female = 5, male = 14, age = 68.2 ± 3.3 years, weight = 71.4 ± 12.4 kg, height = 1.65 ± 0.08 m, BMI = 26.2 ± 3.1 kg/m2 , MMSE scores = 27.11 ± 2.38). Independent t-tests showed no significant differences in age, weight, height, and BMI between the groups. The Shapiro-Wilk test showed that most variables were normally distributed, except the TPE in the ML and vertical directions and tactile sensation thresholds. Compared to the control group, the Tai Chi group had less TPE in the vertical direction (p=0.019, d=0. 848) and in three-dimensional space (p=0.003, d=1.065). Tai Chi group had less proprioception (dorsiflexion: p=0.029, d=0.886; plantarflexion: p=0.012, d=1.025) and tactile sensation (great toe: p=0.015, d=0.932; arch: p=0.019, d=0.855; heel: p=0.027, d=0.930) thresholds than control group. Among the Tai Chi group, Vertical TPE was correlated to their proprioception during plantarflexion.Conclusion: Long-term Tai Chi practitioners exhibited superior visuospatial ability upper limb perturbation, which was associated with sensitive proprioception and tactile sensation.

Key words: Tai Chi quan, coordination, target positioning error, TPE