THE EFFECTS OF TAI CHI ON POSTURO-RESPIRATORY SYNCHRONIZATION IN FRAIL OLDER ADULTS

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INTRODUCTION

The deterioration of postural control that often accompanies aging is associated with decreased balance and increased fall risk [1]. When standing, posture is maintained by a complex system—comprising sensory elements, the spinal cord, brain, muscles and skeleton—that functions to maintain the body's center-of-mass within its base-of-support.

The postural control system dynamically interacts with the respiratory system [2], as spontaneous respiration alters the body's center-of-mass. In order to study this multi-system interaction, we introduced a new metric termed posture-respiratory synchronization. This metric quantifies the effect of respiration on the body's postural sway (as measured by center-of-pressure, COP, movement under the feet). Here, greater synchronization reflects greater impact of respiration on postural sway. Using this metric, we previously demonstrated cross-sectionally that normal biological aging from adulthood into senescence, as well as chronic brain tissue damage caused by cerebral infarction, is associated with increased posturo-respiratory synchronization; in other words, a reduced ability to minimize the impact of respiration on postural sway [2].

Tai Chi is one potential intervention that improves balance in numerous older adult populations [3]. As a mind-body therapeutic exercise, this ancient form of Chinese martial arts combines mindfulness with slow, purposeful movements that are integrated with respiration [4]. As such, Tai Chi training may be particularly well suited to improve the dynamic interaction between postural control and respiratory systems. We therefore hypothesized that Tai Chi training improves the ability to minimize the impact of respiration on postural sway in older adults; i.e., decrease the strength of posturo-respiratory synchronization.

METHODS

An ongoing randomized controlled trial is being completed to test the effects of a 12-week Tai Chi training program as compared to an education-control program on cardiorespiratory and physical function in men and women aged > 70 years living in supportive housing facilities.

Interventions: The *Tai Chi intervention* was conducted within a common area in each housing facility. Two, one-hour, instructor-led group training sessions were completed per week for 12 weeks. The program consisted of five essential Tai Chi movements and a complementary set of traditional Tai Chi warm-up exercises. The *educational-control intervention* was time-matched for attention. Subjects attended group sessions twice weekly within a common area of each housing facility. Sessions were led by research personnel and included health-related topics and material from published Patient Education Forms.

Assessments: Baseline and follow-up assessments included a battery of cardiovascular and physical function tests. Standing postural control was assessed during two, 60 second trials of eyes-open and eyes-closed standing on a stationary force plate. Postural sway (i.e., COP) and respiration (as recorded by a respiratory belt) were simultaneously recorded.

Traditional metrics of respiration and postural sway: Mean respiratory rate was extracted from the extracted respiratory mode. Traditional postural sway metrics included the average speed and area of COP fluctuations.

Posturo-respiratory synchronization index: The strength of synchronization was calculated with a three step procedure.

1. Ensemble Empirical Mode Decomposition (EEMD) was used to extract the dominant respiratory oscillations and the corresponding oscillations within the anterior-posterior (AP) and medio-lateral (ML) COP signal.
2. The instantaneous phase differences at each time point along the extracted oscillatory modes were calculated. Instantaneous phase was calculated using the Hilbert-Huang transform. Phase differences between respiration and AP and ML sway were calculated separately.
3. A phase synchronization index was calculated based on Shannon Entropy. The synchronization index ranges from 0 to 1 with larger values indicating stronger phase synchronization between oscillating signals.

Validation of posturo-respiratory synchronization: A surrogate data analysis technique was used to determine if the strength of observed synchronization was greater than that due to chance. Results indicated that for all subjects, non-random synchronization was present between respiration and AP COP fluctuations, but *not* ML COP fluctuations. Thus, we only examined the effects of Tai Chi on posturo-respiratory synchronization in the AP direction.

Statistical Analysis: To determine the effects of Tai Chi on the posturo-respiratory synchronization index, repeated measures ANOVAs were used with group (Tai Chi, control) and time (baseline, follow-up) as between and within factors. We separately analyzed the effects of intervention on the synchronization indices derived from eyes-open and eyes-closed conditions, as well as the percent change from the eyes open to closed conditions. Similar methods were used to examine the effects of intervention on traditional respiratory and postural sway conditions.

RESULTS AND DISCUSSION

Table 1 shows group characteristics. Groups did not differ in age, gender distribution, height, body mass or attendance. Respiratory rate was similar between groups and across visual conditions, and was unaffected by either intervention. Traditional sway parameters (speed, area) were similar between groups at baseline, greater in the eyes-closed compared to eyes-open conditions ($p<0.05$), yet were unaffected by intervention.

Effects of Tai Chi on posturo-respiratory synchronization: The influence of Tai Chi training on the strength of synchronization between respiration and AP COP fluctuations is presented in Figure 1A.

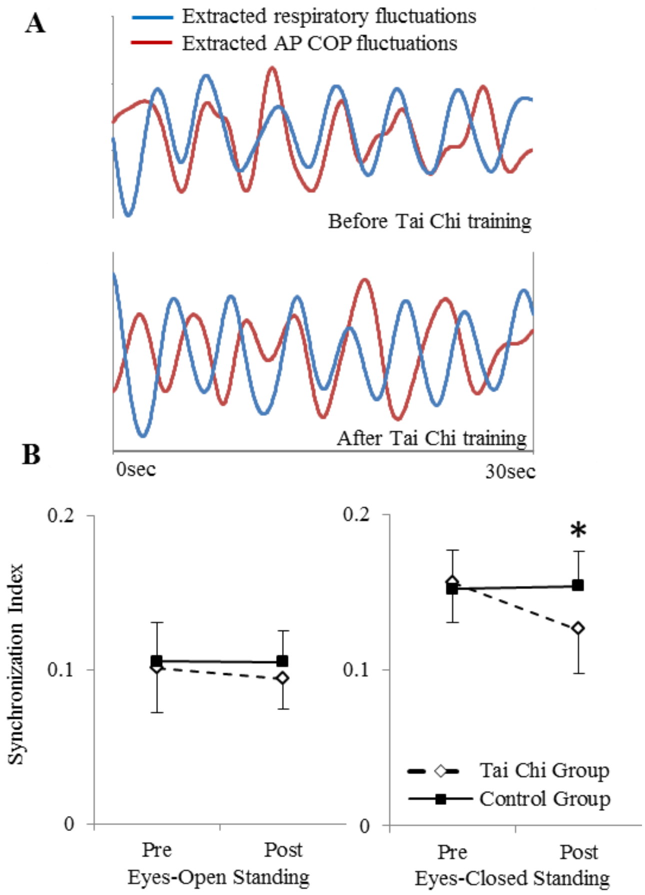

Figure 1: A) The dominant mode of respiration, along with the corresponding mode of the AP COP signal, before and after the Tai Chi intervention in a single subject (83 year old male). Each mode was derived from the raw respiratory and COP signal, which are not pictured. **B)** Group effects of Tai Chi on posturo-respiratory synchronization when standing with eyes open and closed. Greater index values reflect stronger synchronization. *indicates a significant (p=002) group by time interaction; i.e., index values were similar between groups at baseline, were unaffected by the education-control intervention, yet decreased following the Tai Chi intervention.

When standing with eyes open, posturo-respiratory synchronization was similar between groups at baseline and did not change following either intervention ($p = 0.12$) (Figure 1b). When standing with eyes closed, the strength of synchronization also did not differ between groups at baseline. Following the interventions, however, synchronization strength was reduced, but only in the Tai Chi group ($p = 0.002$).

Due to the observation that closing the eyes resulted in a significant increase in the strength of posturo-respiratory synchronization, we also examined the effects of Tai Chi on the within-subject percent change in synchronization from the eyes open to eyes closed condition. Across all subjects at baseline, closing the eyes resulted in a 53 ± 26% increase in synchronization strength. Following the Tai Chi intervention, but not the control intervention, the effect of closing the eyes on synchronization strength was reduced (i.e., 20 ± 12%, $p = 0.001$).

CONCLUSIONS

By using a novel metric to quantify posture-respiratory synchronization, we observed an interaction between respiration and postural sway, but only in the AP direction. Across all subjects, this synchronization was stronger when standing with eyes closed as compared to open. These observations are supported by our previous study in older adults both with and without stroke [2].

In the current cohort, Tai Chi training reduced the impact of closing the eyes on the strength of posturo-respiratory synchronization when standing. Tai Chi may therefore reduce the role of vision in the control of multi-system interaction. Future studies are therefore warranted to identify the functional implications of the interaction between the respiratory and postural control systems.

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Table 1: Group Characteristics

	Tai Chi Group		Control Group	
	Pre	**Post**	**Pre**	**Post**
N	20	-	24	-
Sex (Males/Females)	3 / 17	-	7 / 17	-
Age (years)	85 ± 5	-	84 ± 7	-
Height (inches)	60 ± 4	-	62 ± 4	-
Weight (lbs)	140 ± 28	147 ± 27	155 ± 34	151 ± 37
Attendance (classes missed)	-	2.3 ± 1.9	-	3.0 ± 2.5