EXPLORING EFFECTS OF TAI CHI ON BALANCE IN OLDER ADULTS

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INTRODUCTION

The ability to maintain balance declines as individuals age. These declines in balance are associated with increasing rates of falls in older adults. Certain forms of exercise may reduce these problems. Tai Chi, an ancient Chinese martial art that has been used by millions of people in China, has been promoted to older adults as an intervention to improve physical and mental fitness [1] and prevent falls [2]. Wolf et al. found that Tai Chi may reduce the risk of falls in elderly adults by almost 50 percent [3]. Practitioners of Tai Chi (TC) report that their balance improves as a consequence of TC; however, research studies on balance are inconclusive. In addition, few investigators have examined how TC practice leads to changes in the underlying postural control mechanisms.

Some studies have found significant differences in certain measures of standing balance, while others have found none (see [4] for review). Previous studies that specifically included measures center-of-pressure (COP) have found mixed results in "static" balance tests, performed while standing quietly, with either a decrease [5] or no significant difference in postural sway [6-8]. However, none have applied the technique of stabiliogram-diffusion analysis, which has been found in some cases to be more sensitive to variations in postural behavior than traditional, statistical measures of sway [9]. This technique examines the stochastic fluctuations of quiet-stance COP through random-walk analyses. It provides insight into postural control by describing the mechanisms in terms of open-loop and closed-loop feedback control. Furthermore, while these same TC studies consistently found significant changes in postural sway during "dynamic" balance tests, these studies used perturbations that were continuously applied. However, most real-life disturbances to balance tend to be sudden and transitory; therefore, it may be more realistic to examine sudden, impulse-like perturbations and their associated transient responses to better understand how TC may affect the dynamic postural control system. Finally, studies that explored the effect of TC on lower extremity muscle activity have been limited to measurements recorded prior to a self-induced perturbation in order to assess anticipatory postural adjustment muscle behaviors [5]. None have examined muscle activity during quiet stance or after an unexpected external disturbance to balance.

Therefore, the purpose of this initial study was to better characterize the effects of TC experience on static and dynamic postural control and muscle activity in elderly adults. To assess these effects, a cross-sectional study between healthy elderly TC practitioners and non-practitioners was performed. The overall goal of our research program is to explore how postural control mechanisms and strategies may be affected as a consequence of practicing Tai Chi.

METHODS

Fifteen elderly TC practitioners (9 females; mean age 69 ± 4 yrs) and thirteen elderly controls matched by age, gender, and activity level (8 females; mean age 69 ± 2 yrs) were tested. Of the TC practitioners, two (one male and one female) had 33 years of experience. The other thirteen TC practitioners had an average of 3.2 ± 1.6 (SD) years of experience (range of 1.5 to 7 years). All subjects were community-dwelling, had no neurological, gait, or postural disorders. Informed consent was given by all subjects.

Twenty randomized trials were conducted on each subject: 10 quiet-standing trials and 10 perturbed trials, all 30s in duration. For all twenty trials, the subject was instructed to maintain a quiet, upright posture throughout the recording (Figure 1). The subject stood with both feet on a forceplate, arms crossed at the chest, and eyes open. To initiate a perturbation, which was a weak impulse disturbance (a backward tug), a mechanical trigger was activated that released a 2.3 kg mass. After the weight fell, the perturbation mechanism caused the tether to quickly slacken, thus allowing the subject to adjust to an upright posture. The tug necessitated only a postural sway response, i.e., the subject did not need to take a step to maintain balance. The trigger was activated after a random delay of 10-20 s from the start of the trial. The subject received no cues as to if or when the perturbation would occur.

COP data were determined from forceplate recordings, which were originally sampled at 1500Hz and then resampled to 100Hz. Quiet-stance COP data were analyzed using techniques from both stabilogram-diffusion analysis, SDA, [9] and more commonly-reported or traditional sway analysis procedures, e.g., maximum COP displacement, sway speed, and swept area (e.g., [10]). For the perturbed-stance trials, the maximum posterior COP displacement immediately after the tug was determined. Each parameter was averaged over the ten quiet- or perturbed-stance trials for each subject.

Surface electromyography (EMG) bilaterally monitored four lower extremity muscles: tibialis anterior (TA), soleus (SO), vastus lateralis (VL), and biceps femoris (BF). EMG data were collected at 1500Hz. Raw EMG signals were bandpass-filtered (20-450Hz, inverse Chebyshev), processed with a 40ms running window RMS to obtain a linear envelope, adjusted to mean baseline offsets determined from relaxed seated data, and finally normalized to mean maximum voluntary isometric contraction measurements. In addition to this normalized RMS activity level for each muscle, the percentage of activation time was computed. The percent times of muscle co-contraction for the thigh (VL and BF) and shank muscles (TA and SO) were also computed. For the quiet-stance data, the muscle activity parameters were bilaterally averaged to get mean values over each 30s trial and then averaged over all ten trials for each subject.

RESULTS AND DISCUSSION

For the quiet-stance data, no significant differences were found between TC practitioners and controls in any EMG or COP analysis parameters, except for the SDA term of critical time interval in the radial direction ($p = 0.03$). The critical time interval approximates the transition from open-loop to closed-loop postural control. Non-statistically significant trends in the data ($p > 0.05$) were noted among the SDA and EMG parameters. SDA short-term diffusion coefficients tended to be larger for controls. Larger coefficients imply greater instability. Controls also tended to have their muscles active during more of the trial period than TC practitioners. Additionally, they had greater muscle activity and more co-contraction in their thigh muscles and less activity in their shank muscles than TC practitioners.

For the perturbed-stance data, we found an unexpected trend in the maximum backward sway amplitude immediately after the tug. TC practitioners were found to have significantly greater posterior sway than controls (32 $\pm$ 8 mm and 25 $\pm$ 6 mm, respectively; $p = 0.01$). These results may imply that individuals who practice Tai Chi are less inhibited from utilizing their entire base of support while attempting to restore balance.

CONCLUSIONS

Similar to previous studies with older adults by Wolf et al. [7] and Lin et al. [8], these results suggest that practicing Tai Chi may not necessarily reduce quiet-standing postural sway. TC may influence static postural control mechanisms more subtly. Future studies with larger sample sizes and better control of TC proficiency may be able to validate our quiet-stance data trends and detect statistically significant differences in SDA parameters and muscle activity.

The results from perturbed-stance trials are consistent with previous studies [4-8] and suggest that TC training may be most influential on how individuals respond to external disturbances to balance. Our results suggest that elderly Tai Chi practitioners are more willing to allow larger excursions within their base of support after a perturbation than non-trained elderly counterparts. Interestingly in a pilot study that also examined peak sway after a backward tug, similar (non-statistically significant) trends were found when comparing young adults, 21-30 yrs, to healthy older adults, 66-73 yrs [11].

Recent work by Rosengren et al. has shown that individuals who practice Tai Chi adopt different postural strategies (wider base of support, more knee flexion) than non-practitioners [12]. We are currently examining how stance width and knee flexion in TC practitioners may influence postural control and stability. Results from that study coupled with the presented results may help explain why Tai Chi may be an effective intervention for preventing falls in older adults.

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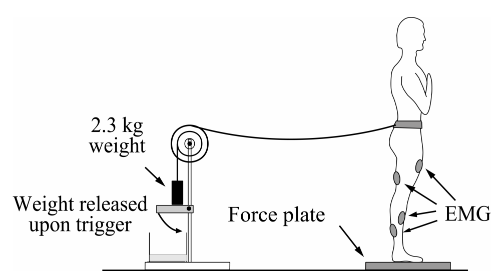

Figure 1. Experimental set-up.