THE EFFECTS OF A 16-WEEK TAI CHI INTERVENTION PROGRAM ON NEUROMUSCULAR RESPONSES AND MUSCLE ACTIVITY OF THE LOWER EXTREMITY IN ELDERLYS

Jing Xian Li[1, 2], Dong Qing Xu[2,3], and Youlian Hong[3]

[1]University of Ottawa, Ottawa, Canada
[2]Tianjin University of Sport, Tianjin, China
[3]The Chinese University of Hong Kong, HKSAR, China

This study examined the effects of a 16-week Tai Chi (TC) training program on muscle strength and endurance of the knee and the ankle, as well as the neuromuscular response to perturbation among elderly people. Forty elderly individuals participated in and completed the study. They were randomly placed into either the TC intervention group (n=22) or the control group (n=18), after which pre- and post-intervention measurements were conducted. The maximum concentric strength and endurance of the knee and ankle were measured by an isokinetic dynamometer. The neuromuscular response indicated by the reaction time of the muscles in the lower limb was examined by measuring the onset latency of the muscles to perturbations on the ankle joint through an electromyography system. The results showed that the 16-week TC intervention the significantly increased knee flexor strength and improved the latency of semitendinous muscle.

KEY WORDS: knee, ankle, electromyography, Tai Chi, aging

INTRODUCTION:

Aging is associated with a progressive reduction of neuromuscular responses, and some of the challenges faced by aging people nowadays is decreased postural stability and increased risks for falls. Declining muscular strength, particularly ankle strength, as well as changes in gait characteristics have been associated with falls among older adults (Whipple, Wolfson, & Amerman, 1987). As a traditional Chinese exercise, TC has been widely accepted due to its particular benefits for postural stability in older people by acting on a number of sensorimotor systems that contribute to postural control. A number of studies have shown that TC has a positive effect on balance capacity, proprioceptive function, and muscle strength (Hong, Li, & Robinson, 2000; Jacobson, Chen, & Cashel et al. 1997; Xu, Hong, & Li, et al. 2004).

Tai Chi movements contain many training components for balance control, such as the shifting of body weight from a unilateral to a bilateral position, and changing between dual-stance and single-stance maneuvers. However, to date, the effect of TC intervention on postural reaction that are related to muscle strength and the latency of muscular activation has not yet been reported. Therefore, the objective of the study was to examine the effects of a 16-week TC training program on muscle strength and endurance, and the latency of muscular activation in the lower extremity in elderly subjects through a comparison with those receiving general education for a comparable time period. This information will be helpful in designing effective exercise intervention programs for elderly people and in increasing our understanding of neuromuscular adaptation to TC exercise.

METHOD:

Community-dwelling adults, aged 60 years or older, were recruited through questionnaire administration and follow-up interviews. Those who reported any of the following conditions: neurological diseases which impair mobility, dementia, cardiovascular disease which is symptomatic during moderate exercise, poorly controlled hypertension, and use of specific medications which are known to impair balance were not included in this investigation. In addition, those subjects who already perform TC or other forms of exercise regularly were also excluded. A total of 50 elderly people, who all live independently and regularly participate in social and recreational activities outside of their home on a minimum of two occasions per week, were deemed suitable to participate in this project. The subjects were randomly divided into two groups: the TC intervention group (n = 25) and the control group (n = 25). An informed consent form was given to each subject prior to participation. This study was approved by the local medical ethics committee.

The subjects in the TC intervention group participated in a 16-week TC training program, which was organized and monitored by one qualified TC instructor. In the first six weeks, the subjects were taught 24-form TC for at least four sessions per week, with each session lasting for 60 minutes. The subjects in the sedentary control group were instructed not to change their exercise levels throughout the study. They met weekly for an hour with the researchers to discuss topics of interest to older people, such as pharmacological management, sleep disorders, and so on. It was promised that they, too, would be taught TC after this intervention.

Testing protocol and outcomes The latency of muscular activation indicated by muscle latency was assessed through EMG of the leg muscles to an unexpected perturbation in the ankle (Xu, Li, Hong, 2005). A customized trap door with an 18° tilt angle was used to stimulate an ankle inversion situation. When the subjects stood barefoot on the trap doors, the surface EMG in four muscles on the right leg of each subject (rectus femoris, semitendinous, gastrocnemius, and anterior tibialis) and the onset signals of the trap door tilting were simultaneously recorded. In order to reduce anticipatory effects, both feet were separately tilted randomly at least seven times. The onset latency of the muscles is measured through the time interval in milliseconds (ms) between the initiation of the trapdoors and the first rising front of the EMG burst from the baseline to a clear activity, which is determined by visual inspection.

The muscle strength and endurance test included the performance of isokinetic contractions of the participants on the dominant knee and ankle joint, using the Cybex Norm isokinetic dynamometer system (Cybex Corporation, USA) (Xu, Hong, Li, 2006). The entire test was divided into two sessions. The first one was for assessing the strength and endurance of the knee extensors and flexors. After 20 min of relaxation, the strength and endurance of the ankle dorsi-plantar flexors were then evaluated in the second session. The subjects performed three maximum concentric contractions for knee extensors and flexors at the angular velocities of 30°/s. The highest peak torque (PT) was recorded and normalized by kilogram of body weight (relative PT) for subsequent analyses. After 3 min of relaxation on the bicycle ergometer, the dynamic endurance of the knee extensors and flexors was assessed using the records of 40 repeated maximum isokinetic contractions with an angular velocity of 180°/s. The work from a knee angle of 80° to10° was also recorded. The endurance index was defined as the ratio of work during the last 5 contractions over the first 5 contractions.

Meanwhile, ankle dorsiflexor and plantarflexor strength were measured at an angular velocity of 30°/s. The subjects were instructed to push their foot away from them and then pull it toward them at the maximum velocity for each action. Peak torque was determined as the highest torque generated from the three trials, and the relative PT data were then analyzed.

Statistics The differences in baseline data were analyzed by unpaired t-tests. In order to control the differences within and across groups, analysis of variance (ANOVA) with repeated measurements was used to determine the effects on the measurements of different groups and different time durations (pre- and post-intervention), as well as the interaction of these two variables. When ANOVA analysis revealed significant time and time-by-group interaction effects, paired t-tests were used to compare the changes in measures within groups using one way analysis of covariance (ANCOVA), which was used to compare the differences between groups at the post-test, with the pre-test scores as covariates. The significance level was set at 0.05.

RESULTS:

A total of forty participants completed the study. The baseline values were similar for each group in demographic characteristics and in all measures (Table 1). Although the mean values for some muscle strength and latency parameters in the control group were slightly

better than those in the TC intervention group, there were no statistical differences between the groups.
For muscle latency, a significant time-by-group intervention was only found in the semitendinous muscle (P = .042). Further analysis indicated that TC intervention significantly improved the response of this muscle (P = .014), while the same muscle in the control group showed no significant changes (P = .83).

Table 1 Demographics and Performance on Measures at Pre- and Post-intervention of the TC and Control groups (mean ± SD)

	TC intervention group		Control group	
	Pre-test	Post-test	Pre-test	Post-test
Demographics				
Female/male	12/13	11/11	13/12	9/9
Age (years)	64.9 (3.2)	65.2 (2.9)	65.6 (3.5)	64.5 (2.2)
Height (cm)	164.1 (7.9)	162.7 (6.9)	163.8 (6.6)	162.3 (7.0)
Weight (kg)	69.5 (10.8)	66.7 (9.5)	66.04 (10.3)	67.1 (10. 5)
Muscle strength (Nm/kg)				
Knee flexors	71.39 (14.38)	85.60 (17.14)*	76.11 (21.21)	83.20 (22.11)
Knee extensors	117.94 (24.17)	123.78 (24.50)	117.93 (20.94)	124.72 (21.38)
Ankle dorsiflexors	17.63 (4.01)	18.85 (4.32)	19.81 (5.46)	19.07 (5.03)
Ankle plantarflexors	62.87 (18.67)	77.08 (23.10)	57.28 (14.71)	72.13 (14.70)
Muscle endurance index				
Knee flexors	0.52 (0.15)	0.51 (0.14)	0.49 (0.10)	0.48 (0.13)
Knee extensors	0.59 (0.13)	0.60 (0.12)	0.57 (0.09)	0.57 (0.13)
Latency (milliseconds)				
Rectus femoris	91.23 (9.33)	88.64 (12.05)	87.83 (9.93)	89.76 (11.78)
Semitendinosus	88.15 (9.83)	82.29 (8.08) *	82.56 (9.93)	82.99 (11.29)
Gastrocnemius	95.21 (9.95)	89.83 (9.82)	91.59 (9.78)	88.95 (11.23)
Anterior tibialis	87.64 (6.96)	85.18 (6.46)	84.10 (9.83)	82.74 (9.87)

*P<0.05, Pre-test vs post-test, and TC group vs Control group.

A significant time effect was found in the onset latency of the gastrocnemius muscle (P = .008). The TC practitioners had faster reaction time on this muscle at the post-test than at the pre-test (P = .013). However, there was no time-by-group interaction. For the rectus femoris and anterior tibialis muscles, neither time nor interaction effects were found.
For muscle strength, all strength parameters showed significant time effects except for ankle dorsiflexor strength. However, a significant time-by-group interaction was only found in the knee flexors (P = .046). Further analysis showed that both TC practitioners and control group subjects significantly increased their knee flexion strength with time, but these gains were not similar for both groups. The TC group showed greater improvements than the control group.
Although knee extensor strength and ankle plantarflexor strength also showed significant improvements in both groups at post-test, no time-by-group interaction indicated that these improvements were not significantly different between the two groups. Significant time effects might simply imply a learning effect for the strength measures. In summary, neither time effects nor time-by-group interaction was found in ankle dorsi-flexion strength and the endurance of the knee flexors or extensors.

DISCUSSION AND CONCLUSION:

The 16-week TC training program gave the practitioners better scores than the control group subjects in terms of knee flexor muscle strength and semitendinous muscle latency. However, the intervention program did not result in a significant improvement in the muscle strength of the knee extensors, ankle joint muscle strength, and endurance. In performing TC, the roles of the muscles continuously change between those of stabilisers and movers, weight-bearers and non-weight-bearers, and contraction and relaxation. Specifically, TC movements demand guided motions in different directions of the hip, knee, and ankle joints. These movements also require concentric and eccentric contractions of the hip, knee, and ankle muscles. These movements are similar to resistance exercises, such as lunges, knee bends, and squats, in terms of degrees of hip and knee flexion and extension required. In a study by Lan et al. (1998), a 12-month TC program was found to be effective in enhancing the strength of the knee joint. Notably, a 20.3% improvement for extensors and 15.9% improvement for flexors were revealed. In our study, significant improvements in strength were only shown in the knee flexors, but not for the extensors. This might be due to the shorter training duration used in our program (16 weeks) than in Lan et al.'s study (12 months). Likewise, no significant improvements were seen in the muscle strength of the ankle joint in the study. These results are consistent with the findings of a research conducted by Laura and co-workers (2004). They reported that 8-week home exercise programs for elderly people could not significantly improve the muscle strength either in the hip or ankle joint. The muscle strength of the ankle joint is important in postural stability and fall prevention. Research found that elderly subjects with a history of falls demonstrated weaker ankle dorsiflexors (Daubney, Culham, 1999; Studenski, Duncan, & Chandler, 1991; Whipple, et al. 1987) and ankle plantarflexors (Roach, & Miles, 1991) when compared to those who have not fallen. Therefore, regular longer-term exercise intervention programs are required toward the improvement of the muscle strength and endurance of the ankle in elderly people.

The present study shows that TC intervention could significantly decrease the reaction time in the semitendinosus muscle, but not in other muscles. Improved muscle latency is helpful in maintaining postural control among older people. The beneficial effects of TC on muscle reaction have been demonstrated in long-term TC practitioners with over four years of TC experience. The results indicate that maintaining regular TC exercise carried out for longer period of time, is definitely needed in order to reap benefits from such an exercise program.

The 16-week TC intervention program conducted in this study provides evidence on TC's benefits among older people. However, significant improvements in strength and neuromuscular reaction were only shown in the knee flexors. The muscle strength of the knee extensors and ankle muscles, as well as the muscle endurance in the knee did not seem to reach the level produced by long-term TC exercise, which may be due to the limited intervention period. Therefore, future studies need to verify these results by employing a longer period of TC intervention.

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