COULD TAI CHI EXERCISE IMPOVE STABILITY IN ELDERLY? STRATEGIES OF STEPPING OVER OBSTACLES

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Stepping over obstacles challenges stability and is a leading cause of falls in older adult populations. The purpose of this study was to evaluate the obstacle-crossing strategies of long-term Tai Chi (TC) practitioners and exercise walkers. Thirty healthy older women (average age: 65.7 years) with either TC (n=15) experience (average experience: 8.2 years) or walking exercise (n=15; average experience: 8.8 years) participated in this study. We used three trial conditions: 1) normal walking, 2) crossing a 15cm (20% of leg length) obstacle, and 3) crossing a 23cm (30% of leg length) to assess obstacle-crossing strategy. Results showed Individuals with a TC background crossed the obstacle significantly faster with a significantly longer step relative to the exercise walkers; plantar pressure profiles between the two groups also differed. Our results suggest that obstacle-crossing strategies were affected by the type of long-term exercise.

KEYWORDS: obstacle crossing, single leg stance, long-term exercise.

INTRODUCTION: Falls account for a number of injuries in elderly. Over 30% of adults over age 65 fall annually(Hausdorff,J.M,et.al.2001). Stepping over obstacles and imbalance during gait are particularly problematic for the elderly and account for nearly 50% of falls in this population(Tinetti et al.,1995).Crossing obstacles during gait challenges stability and forces the reorganization of the gait pattern. As people age, their ability to perform these tasks can deteriorate, increasing the likelihood of falling(St et al.,2007). Walking is recommended as a means for increasing physical activity and reducing fall risk.(Nelson et al.,2007). Studies have demonstrated the positive effects of walking programs on postural stability(Melzer et al.,2003) and muscle strength (Cheng et al.,2009) in the elderly. TC, a Chinese martial art, has also been shown to be an effective exercise program for fall prevention in community-dwelling older adult populations(Low et al.,2009). The beneficial effects of TC include improved muscle strength, flexibility, fitness(Hong et al.,2000), postural stability(Wong et al.,2009) and proprioception(Hong et al.,2000), all of which may contribute to the reduced fall risk associated with this practice(Low et al.,2009).
By investigating obstacle-crossing patterns, researchers gain insight into dynamic balance and motor control strategies that affect fall risk(Chen et al.,1991). Previous studies have examined obstacle-crossing speed, vertical foot clearances, lower extremity joint angles, center of mass displacement, stride length and so on(Chen et al.,1991). To the authors' knowledge, few studies have investigated the plantar pressure profiles during obstacle-crossing in healthy, active, elderly. Evaluating the plantar pressure profiles of TC practitioners and exercise walkers provides insight into stability and motor pattern strategies during obstacle-crossing.Therefore,the purpose of this study was to evaluate the obstacle crossing strategies of long-term TC practitioners relative to long-term exercise walkers. As obstacle-crossing patterns of TC and non-TC practitioners are different, we speculate that the obstacle-crossing strategy will also differ based on the type of long-term exercise.

METHODS: Participants: A convenience sample of 30 healthy, active older adult women participated in this study. Fifteen women (age:65.8±5.6 years; height:156.6±4.8 cm; body mass: 62.3±8.4 kg; leg length: 75.3±3.6 cm; TC experience: 8.2±2.9 years) who regularly practiced TC exercise one hour per day participated in the study as the TC group (TCG).

Fifteen women (age: 65.6±4.2 years; height: 155.4±3.7 cm; body mass: 67.1 ± 9.7 kg, leg length: 75.3 ± 3.2 cm; walking exercise experience: 8.8±2.6 years) who consistently walked one hour per day participated in this study as the walking group (WG). **Testing Protocol:** A digital camera was placed 5m from the front, back and right side of a plantar pressure platform. Video was recorded at a 50 frames per second using an APAS motion capture system. The plantar pressure platform was a 2m Rsscan mat. The obstacle was a 2 cm×100 cm (width × length) wood dowel placed on adjustable stands positioned at the middle of the pressure mat. There were five successful trials for each of the three experimental conditions: 1) normal walking, 2) crossing over a 15cm (20% of leg length) obstacle, and 3) crossing over a 23cm (30% of leg length) obstacle[12]. **Data Collection:**Data collected from the pressure mat system was used to analyze the vertical ground reaction force (vGRF) during obstacle-crossing. In addition to the kinematic values, the single-leg stance time was also measured. Single-leg stance time was the amount of time standing on one foot as the leading foot crossed the obstacle. **Data Reduction:** The vGRF was normalized by body weight. **Data Analysis:** A repeated measures multivariate analysis of variance (MANOVA) was used to examine the multiple dependent variables (i.e., plantar pressure and obstacle-crossing kinematic variables). We used a 3 (condition: normal gait, crossing a 15cm obstacle, and crossing a 23cm obstacle) X 2 (group: TCG and WG) MANOVA with a Fisher's Least Significance Difference to detect differences. We used a between-within repeated measures MANOVA for the post-hoc power analysis from the means and variance-covariance matrix.

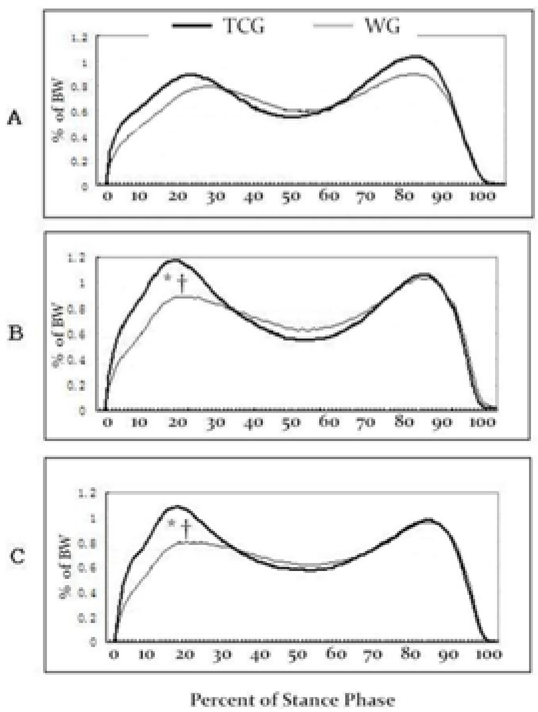

Figure 1: Vertical ground reaction force.

RESULTS: The TCG normalized toe distance was significantly longer compared to the WG during both obstacle-crossing conditions (Table 1). The TCG's normalized heel distance was greater only during the 23cm obstacle-crossing. The TCG's foot clearance was significantly higher than the WG's at both obstacle-crossing heights, but not during normal walking. There were no significant differences between the two groups in maximum foot clearance. The TCG obstacle-crossing velocity was also significantly greater compared to the WG in the obstacle-crossing conditions, but not during normal walking. The results of vGRF of the trailing foot showed that the TCG increased their loading response for the 15cm and 23cm obstacle-crossing conditions compared to normal walking. There was no significant change in the WG's vGRF. Further, in the obstacle-crossing conditions, the initial loading phase of vGRF significantly differed between groups (Figure 1).

Table 1: Kinematics comparison of Tai Chi group (TCG) and walking group (WG).

	Walking Group			Tai Chi Group		
	Normal	15cm	23cm	Normal	15cm	23cm
Stride Length (cm)	108. 9 ± 5.0*	112. 5 ± 5.7*	110. 2 ± 7.7*	116. ± 3 7.9*	117. 3 ± 7.1*	116. 2 ± 7.7*
Toe Distance (cm)	--	± 17.1 14.5*	± 15.8 14.6*	--	± 21.3 12.0*	± 19.9 11.1*

Normalized Toe Distance (%)	--	15.2 ± 3.6*	13.7 ± 3.7*	--	18.2 ± 3.3*	17.1 ± 3.4*
Heel Distance (cm)	--	20.9 ± 12.3	20.0 ± 11.1*	--	18.8 ± 14.3	24.4 ± 10.2*
Normalized Heel Distance (%)	--	18.6 ± 3.8	18.1 ± 2.8*	--	16.8 ± 4.3	21.0 ± 3.3*
Foot Clearance (cm)	2.2 ± 1.1	5.5 ± 6.6*	8.1 ± 8.3*	2.5 ± 1.6	11.8 ± 4.4*	12.3 ± 6.3*
Maximum Foot Clearance (cm)	--	23.6 ± 6.6	21.7 ± 8.0	--	22.6 ± 3.2	21.4 ± 5.9
Crossing Velocity (m/s)	1.35 ± 0.22	0.94 ±0.21*	0.85 ± 0.22*	1.47 ±0.31	1.33 ± 0.32*	1.14 ± 0.34*
Single-Leg Stance Time (s)	0.80 ± 0.23	1.20 ± 0.27*	1.31 ± 0.21	0.79 ±0.25	0.88 ± 0.22*	1.02 ± 0.19

DISCUSSION: Trailing Foot Strategy during Obstacle-Crossing: The TCG used a longer toe distance and greater vGRF during the loading phase, whereas the WG had a constant vGRF throughout the trials. The increased loading response of the TCG increases the force generation to accommodate a longer stride length and toe distance. With increases in force and loading response, more momentum can be generated, which may explain the faster obstacle-crossing of the TCG(DeVita et al.,2000). Moreover, the longer toe distance of the TCG reduces the risk of the leading foot's contact with the obstacle. **Leading Foot Strategy during Obstacle-Crossing:** The differences in obstacle-crossing velocity and single-leg stance time may indicate the adaptations that occur within each long-term exercise. In TC, the practitioner learns to maintain balance and stability in various postural positions(Wong et al.,2001). TC also uses repeated up-and-down stepping motions that lift one foot above knee height of the trailing leg for a few seconds before returning it to the ground(Wong et al.,2001). Regular practice of this exaggerated stepping movement may enable the practitioner to develop greater control during single-leg stance. The relatively faster obstacle-crossing of the TCG suggests that the TC practitioners have greater balance control, as older adults who lack sufficient balance control will slow their velocity to reduce the risk of falling(Kaya et al.,1998) In contrast, the slower moving lead foot of the WG leads to longer single-leg stance time and requires greater leg strength. Thus, the strategy most prevalent by group may reveal benefits of their long-term exercise program. Because of the focus on balance and stability in TC exercise long-term practitioners may have more developed movement control, whereas the exercise walkers have developed the necessary leg strength for sustained single-leg stance time. The foot clearance of the TCG was greater than WG during the obstacle-crossing conditions. The TCG maximized the foot height when it was above the obstacle, whereas the WG maximized the height prior to reaching the obstacle. The longer heel distance of the leading foot in the TCG is a result of the maximizing the foot clearance above the obstacle. The longer heel distance strategy also decreases the risk of heel-obstacle contact when the foot is stepping forward(Skelton et al.,1999).

CONCLUSIONS: Compared to long-term exercise walkers, TC practitioners use a longer toe and heel distance to the obstacle, reducing the likelihood of foot-obstacle contact. Finally, long-term TC practice may encourage better postural control relative to walking, yielding faster obstacle-crossing with reduced single-leg standing. Together, these results suggest that long-term TC practice may reduce risk of tripping by enabling individuals to develop unique obstacle-crossing strategies.

REFERENCES:
Chen, H.C., Ashton-Miller, J.A., Alexander, N.B. & Schultz, A.B.(1991). Stepping over obstacles: gait patterns of healthy young and old adults. *Journal of Gerontology.* 46(6), M196-203.
Cheng, S.P., Tsai. TI., Li,i Y.K., Yu, S., Chou, C.L. & Chen, I.J.(2009). The effects of a 12-week walking program on community-dwelling older adults. *Res Q Exerc Sport* ,80(3), 524-32.

DeVita, P. & Hortobagyi, T. Age causes a redistribution of joint torques and powers during gait.(2000). *Journal of Applied Physiology.* 88(5), 1804-11.
Hausdorff, J.M., Rios, D.A. & Edelberg, H.K. (2001). Gait variability and fall risk in community-living older adults: a 1-year prospective study. *Archives of Physical Medecine Rehabilitation.* 82(8), 1050-6.
Hong, Y., Li, J.X. & Robinson PD.(2000) .Balance control, flexibility, and cardiorespiratory fitness among older Tai Chi practitioners. *British Journal of Sports Medicine.* 34(1), 29-34.
Kaya, B.K., Krebs, D.E. & Riley, P.O.(1998). Dynamic stability in elders: momentum control in locomotor ADL. *J Gerontol A Biol Sci Med Sci*.53(2), M126-34.
Low, S., Ang, L.W., Goh, K.S. & Chew, S.K.(2009) .A systematic review of the effectiveness of Tai Chi on fall reduction among the elderly. *Arch Gerontol Geriatr.* 48(3), 325-31.
Melzer, I., Benjuya, N. & Kaplanski, J.(2003). Effects of regular walking on postural stability in the elderly. *Gerontology.* 49(4), 240-5.
Nelson, M.E,, et al.(2007). Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Circulation.* 116(9), 104-105.
Skelton, D.A. & Dinan, S.M.(1999). Exercise for falls management: Rationale for an exercise programme aimed at reducing postural instability. *Physiotherapy Theory and Practice.*15(2), 105-120.
St, George., R.J., Fitzpatrick, R.C., Rogers, M.W. & Lord ,S.R. (2007). Choice stepping response and transfer times: effects of age, fall risk, and secondary tasks. *J Gerontol A Biol Sci Med Sci.* 62(5), 537-42.
Tinetti, M.E., Doucette, J., Claus, E. & Marottol,i R.(1995). Risk factors for serious injury during falls by older persons in the community. *J Am Geriatr Soc.*43(11), 1214-21.
Wong, A.M., Pei, Y.C., Lan, C., Huang, S.C., Lin ,Y.C. & Chou ,S.W.(2009). Is Tai Chi Chuan effective in improving lower limb response time to prevent backward falls in the elderly? *Age (Dordr).* 31(2),163-70.
Wong, A.M., Lin, Y.C., Chou, S.W., Tang FT & Wong, P.Y. (2001). Coordination exercise and postural stability in elderly people: Effect of Tai Chi Chuan. *Arch Phys Med Rehabil.* 82(5), 608-12.