THE BENEFITS OF TAI-CHI EXERCISE ON BALANCE CONTROL IN ELDERLY DURING STAIR-TO-FLOOR TRANSITION

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The purpose of this study is to investigate the benefits of Tai-Chi Exercise on balance control in elderly during the stair-to-floor transition. Twelve Tai-Chi elder participants and 12 normal healthy elderly were recruited. A Kistler force plate (1000Hz) obtained the COP (center of pressure) data and kinematics calculated from ten Vicon high-speed cameras (250Hz). Results revealed that Tai-Chi group descended at a faster speed and had larger step length. Tai-Chi group also had larger A-P (anteroposterior) COM-COP separation, A-P COP path and faster COP average velocity. The results indicated that long-term Tai-Chi exercise can improve the balance in elderly during the stair-to-floor transition.

KEYWORDS: center of pressure, step length.

INTRODUCTION: Falls were the leading cause of injuries in elderly (CDC, 2014), and fatal injuries occurred during stair walking. Falls during the descent of stair negotiation occur at least three times more frequently than those associated with stair ascent (Svanstrom, 1974). The stair-to-floor transition is the unique anticipation of the upcoming surface between stair and level walking (Sheehan & Gottschall, 2011), it would be higher fall risks than stair and level walking,

The change of center of pressure (COP) reflects the response of the central nervous system to the movement of the body's center of mass (COM), and the displacement of COP is used as a key factor of posture control and balance (Mao, Li, & Hong, 2006a). To modulate COP within the appropriate range of COM-COP separation is the key to maintaining dynamic stability and avoiding falls. To avoid falls, elderly adopted safer strategies while stair descent, including smaller A-P (anteroposterior) and M-L (mediolateral) COP displacement and slower COP movements (Kim, 2009a). During level walking and crossing obstacles, elderly reduced the A-P COM-COP separation to maintain balance (Hahn & Chou, 2004; Scarborough, Krebs, & Harris, 1999). However, the A-P distance is limited by the width of the ladder during stair descent, A-P COM-COP separation was no difference between the elderly and the young adults (Mian et al., 2007).

Tai-Chi is a popular traditional Chinese exercise for elderly, and the slow-motion characteristics of movement are quite suitable for older people. Tai-Chi gait emphasizes lowering the center of gravity and larger steps, showed more challenge to the balance ability and the lower limb muscles than the normal gait (Wu, 2008), and large A-P COP movement (Mao, Li, et al., 2006a). Tai-Chi exercise also improved the dynamic balance, increased the balance of single leg stand (Mao, Li, & Hong, 2006b) and reduced the fear of falling (Logghe et. Al., 2010). Even while the single-legged jumping and single-legged landing, the Tai-Chi elderly had better performance (Gyllensten, Hui-Chan, & Tsang, 2010). It indicated that Tai-Chi exercise improved the dynamic balance of elderly, and it might also affect the performance of the daily life. Therefore, the purpose of this study is to investigate the benefits of Tai-Chi exercise on balance control in elderly during the stair-to-floor transition.

METHODS:

Twelve elderly that were regular Tai-Chi practitioners (eight males and four females) (Tai-Chi group), and twelve healthy elderly (eight males and four females) (normal group) participated in this study. Exclusion criteria were any known neurological or orthopedic disease and any current difficulties impeding their typical locomotion. Ethical approval was obtained from the Joint Institutional Review Board at Taipei Medical University. All participants provided their written informed consent before participation in our investigation. Tai-Chi group practiced

Yang style Tai-Chi which included 108 different body postures for an average of 10 years with a range between 2 to 15 years, four to five days per week, for a minimum of one hour per session. Control group of elderly performed leisure exercises (e.g. jogging, swimming) approximately over the same period per session but did not regularly perform Tai-Chi.
A ten camera motion system sampling at 250Hz and one Kistler force plate sampling at 1000Hz were synchronized to collect three-dimensional body motion and COP data. The 46 cm staircase consisted of a series of three steps, each step with a rise 18 cm and a run of 28 cm. Participants walked down the stairs starting with their dominant (right) leg with barefoot at a self-selected speed in a step-over-step manner and ended after the participant walked forward on level ground for approximately 5 m. The speed and step lengths were not restricted to simulate their typical performance. All participants completed at least five successful trials where the entire lead foot mad contact with the force plate.
The stair-to-floor transition analysis began with toe-off of the right leg from the middle step (36cm height) to toe-off of the right leg from ground level. The COM velocity was calculated by averaging the 3-dimensional velocity of COM. Step length was defined as the anteroposterior distance between right toe and left toe during right leg ground contact and right leg toe-off the ground (shown in figure 1). An independent samples t-test was used to examine differences between groups. The alpha level (α) was set to 0.05 and all statistical analyses were conducted within SPSS 21.0.

RESULTS: The information of participants are shown in table 1. There were no significant differences in body weight and height, except in age. Tai-Chi group were older than the normal group.

Table 1: Information of participants.

	Tai-Chi group	Normal group	*p*
Age (years)*	72.7 ± 5.1	67.5 ± 2.7	<.01
Height (m)	1.63 ± 0.07	1.62 ± 0.06	
Weight (kg)	57.9 ± 0.07	63.5 ± 5.7	

The data of COP, temporal and kinematic variables are shown in table 2. Tai-Chi group descended at a faster speed and had larger step length. Tai-Chi group also had larger A-P COM-COP separation, M-L COP displacement and faster COP average velocity.

Table 2: COP, temporal and kinematic variables.

	Tai-Chi group	Normal group	*p*
A-P COM-COP separation			
1st peak (cm)*	24.8 ± 3.5	21.4 ± 3.4	.02
2nd peak (cm)*	35.1 ± 2.6	30.2 ± 4.0	<.01
M-L COM-COP separation (cm)	12.3 ± 2.6	11.3 ± 2.6	.32
A-P COP path (cm)	11.6 ± 2.7	10.2 ± 2.0	.16
M-L COP path (cm)*	10.7 ± 3.5	7.0 ± 1.5	<.01
COP average velocity (cm/s)*	100.2 ± 66.1	56.7 ± 14.3	.04
Stance time (s)	0.66 ± 0.08	0.68 ± 0.10	
1st step length (m)*	0.51 ± 0.07	0.41 ± 0.07	<.01
2nd step length (m)*	0.58 ± 0.04	0.53 ± 0.05	.02
COM velocity (m/s)*	0.93 ± 0.10	0.77 ± 0.12	<.01

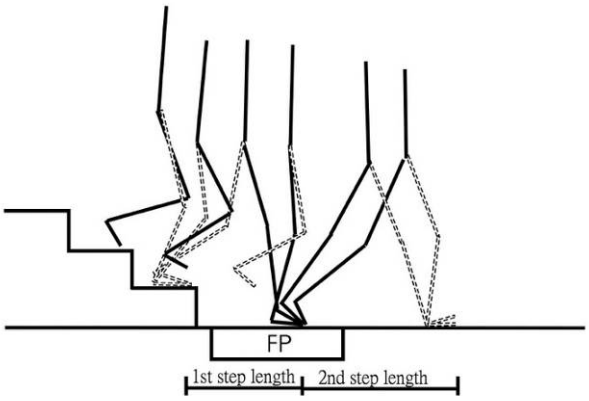

Figure 1. 1st step length and 2nd step length during the stair-to-floor transition.

DISCUSSION: Modulating the translation between COM and COP is an important factor to maintain dynamic stability. The backward displacement of the COP can generate the momentum for forwarding motion (Polcyn, Lipsitz, Kerrigan, & Collins, 1998). Because of weakness in lower extremities muscles, elderly would reduce forward motion of COM and backward displacement of COP. After Tai-Chi exercise intervention, COP displacement increased while level walking, crossing obstacles and descending stairs (Kim, 2009b; Kim, Han, & Cho, 2009). The results showed that Tai-Chi group had larger A-P COP displacement, which is consistent with the previous studies. To simulate the performance in daily life, the study didn't restrict the descending speed and step length. Tai-Chi group had faster speed during stair descent, and a larger step length could modulate the forward rotational momentum (van Dieën, Spanjaard, Konemann, Bron, & Pijnappels, 2007). During gait, greater A-P COM-COP separation provided data that support more mechanic loading and improve ability to tolerate unsteadiness after Tai-Chi training (Gatts & Woollacott, 2007), therefore, older adults used a compensatory strategy by reducing the A-P COM-COP separation to maintain balance (Hahn & Chou, 2004; Scarborough et al., 1999). In this study, the larger 1st peak of A-P COM-COP separation is due to greater step length in Tai-Chi group. It indicated that Tai-Chi group had better ability to maintain dynamic stability during contact ground. At the end of the stair-to-floor transition, Tai-Chi group showed larger 2nd step length and the 2nd peak of A-P COM-COP separation, which COM was front from COP. Due to faster COM velocity and similar stance time, larger A-P COM-COP separation represented Tai-Chi exercise could increase COM path. (Gatts & Woollacott, 2007).

In the frontal plane, Tai Chi exercise could increase the M-L COP path in elderly while contact ground (Kim et al., 2009), and increased M-L COP path indicated an improvement of coordination between hip adduction and abduction muscles after Tai-Chi training (Winter, Patla, Ishac, & Gage, 2003). During stair descent, the hip abductor muscles of the contralateral leg shifted COP to lateral side, and then the hip joint and the ankle joint muscles propelled COM forward until contralateral leg contact ground, therefore, the muscular coordination of frontal hip joint muscles is important for the elderly to maintain lateral stability during the stair-to-floor transition. The study showed that Tai-Chi group had greater M-L COP path, which indicated that Tai-Chi group had better lateral stability during contact ground.

The COP average velocity provided important information on how to modulate the steps when facing challenges, such as stairs (Reid, Novak, Brouwer, & Costigan, 2011). Slower COP average velocity in elderly than that in young adults, because the slower COP average velocity is easier to maintain postural stability (Kim, 2009a; Reid et al., 2011). Previous study indicated COP average velocities were about 102~145cm/s and 58~85cm/s in young adults and elderly, respectively (Kim, 2009b). The results of the study showed that the Tai-Chi group had a faster COP average velocity, and it resembled the performance of young adults, which might reflect that Tai-Chi exercise improved the ability to maintain dynamic balance. The age of all participants in the study was above 65 years or older, the muscular power and work decreased by an average of 6% per decade (Daubney & Culham, 1999). In this study

Tai-Chi group were older than normal group, the better dynamic performance and balance control of Tai-Chi group indicated the benefits of long-term practicing Tai-Chi exercise on dynamic performance and balance control during stair-to-floor transition than the normal elderly.

CONCLUSION: Long-term Tai Chi exercise participant could improve the balance in elderly during the stair-to-floor transition. It is recommended that participation in Tai-Chi exercise will improve the balance and performance in daily activities.

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