

THE CHARACTERISTICS OF THE PLANTAR PRESSURE CENTER DURING TAI CHI EXERCISE

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The purpose of this study was to describe and quantify the plantar pressure distribution characteristics during Tai Chi (TC) exercise. Sixteen elite TC masters participated in this study. The Pedar-X insole system was used to record the plantar forces during practicing the five typical TC movements and during normal walking respectively. Results showed that in TC movements, the locations of the centre of pressure (COP) were more medial and posterior at initial contact ($p < 0.05$), while more medial and anterior at end contact with the ground ($p < 0.05$). The range of motions (ROMs) of COP were significantly wider ($P < 0.05$) in mediolateral direction in forward, backward, and sideways TC movements. The ROM was significantly larger ($p < 0.05$) in anteroposterior direction in forward TC movement when compared with normal walking.

KEY WORDS: Tai Chi exercise, Plantar pressure distribution, Centre of pressure, Muscle strength

INTRODUCTION: Numerous studies suggested that the COP under the foot have important biomechanical meanings (Han, 1999). Steven and Paul (1995) quantified the effect of spatial alignment between the COP and the coordinates of the foot on resultant joint torques in the lower extremity during the stance phase of gait. They found that shifting the COP posteriorly or anteriorly will induce significant changes of torques in ankle, knee, and hip joints of the present leg. In addition, a few studies demonstrated that with the increasing of the displacements of COP, not only the intensity of EMG (Sztur, 1998) but also the number of muscles to be used of lower extremities were increased when disturbances occurred (Nakamura et al., 2001). TC is an ancient Chinese martial art. The broad consensus showed that TC exercise could improve balance control and muscle strength of lower extremities of human being (Li, 2001; Hong, 2000). However, the mechanisms by which TC improves balance control and subsequently prevents falls in old people are still unclear. The objective of this study was to describe and quantify the plantar pressure distribution characteristics with forward, backward, sideways, up-down and fixing of TC fundamental movements and try to illustrate why TC movements benefit the muscle strength.

METHODS: Sixteen gender matched elite TC masters (8 females, 8 males, ages 23.1 ± 5.5 years, body height 166.0 ± 7.6 cm, body weight 62.2 ± 7.8 kg, experience of practicing 8.1 ± 5.7 years) with no previous diseases or injuries that may affect the performance one year before the study were recruited. Five typical movements were selected from a set of 42-form TC, they are Brush Knee and Twist Steps, Step Back to Repulse Monkey, Wave Hand in Cloud, Kick Heel to Right, and Grasping the Bird's Tail which represent stepping forward, backward, sideways, up-down, and fixing respectively. The Pedar-X insole system (Germany) was used to collect the plantar forces during performing the above TC movements. The sampled rate was set at 50 Hz. With the aid of the trublu calibration device, all sensors of the system were individually calibrated before test. Due to the fact that most TC movements were symmetry (Editor, 2000), only the data obtained from left foot were selected and analyzed.

The foot movements during practising the five typical TC movements are described as in Figure 1.

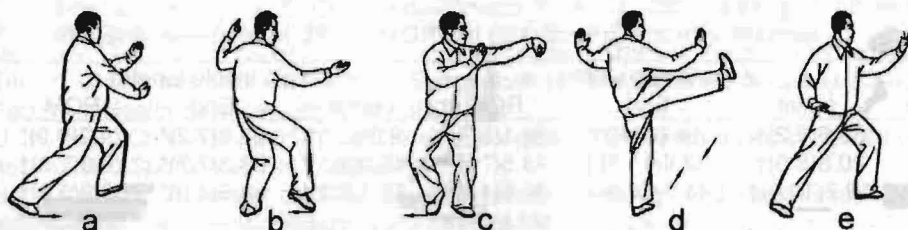


Figure 1 The feet movements during five typical TC movements. a) forward movement; b) backward movement; c) sideways movement; d) up-down movement; e) fixing movement.

Each subject performed three trials of the five typical movements. After the performance of five typical movements, each subject was asked to walk 15 m three times at their free speed and the plantar force data were recorded. All subjects used the identical socks and the Chinese TC shoes. Before testing, the subjects completed consent forms and were given sufficient time to warm up.

According to the definition of Pedar-X insole coordinates system, for the left foot, the most medial and posterior point was defined as the origin (zero point), as illustrated in Figure 2. The coordinates X and Y of COP were normalized (%) to the maximum width and maximum length of the insole respectively. The locations (X and Y coordinates) of COP at initial and end contact with the ground and the ROMs in mediolateral and anteroposterior directions were extracted from each of the five typical movements and normal walking. One-way ANOVA of SPSS for Windows with Post Hoc multiple comparisons using Bonferroni's adjustment was used and the significance level was set at 0.05.

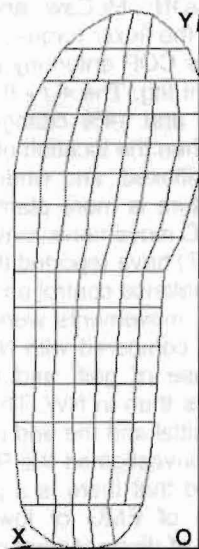


Figure 2 The divided plantar regions.

RESULTS: Table 1 showed that compared with normal walking, the X coordinates of COP at initial and end contact were significantly less ($p < 0.05$) in forward, backward, sideways, and fixing movements, indicating the positions were more medial. The Y coordinates of COP at initial contact were significantly greater ($p < 0.05$) in backward and sideways movements, and the figures showed that the contact positions were located at forefoot region. The Y coordinates of COP at initial contact were significantly less ($p < 0.05$) in forward, fixing movements, indicating that the positions of contact were more posterior. The Y coordinates of COP at end contact were significantly greater ($p < 0.05$) in forward, backward, and sideways movements, and the figures showed that the positions were more anterior. In addition, the forward, backward, and sideways have significantly wider ROMs ($p < 0.05$) in mediolateral direction. The forward movement has significantly larger ($p < 0.05$) ROM in anteroposterior direction.

Table 1 The mean (SD) of X, Y coordinates of COP at initial and end contact with the ground and the ROMs in TC movements and NW.

Move ments	X (% insole width)			Y (% insole length)		
	Initial	End	ROM	Initial	End	ROM
FW	59.6(6.2)†	18.8(9.8)†	53.1(6.5)*	9.8(3.7)†	84.0(7.2)*	74.2(9.9)*
BW	20.8(8.5)†	32.0(11.6)†	43.5(7.6)*	83.2(5.1)*	83.3(7.7)*	29.0(2.3)†
SW	19.7(10.4)†	41.7(12.9)†	38.9(4.8)*	83.3(6.5)*	88.6(4.9)*	33.9(3.8)†
UD	-	-	21.8(3.7)	-	-	12.6(2.9)†
FX	62.9(8.4)†	-	12.0(2.7)†	10.9(6.1)†	-	58.4(4.2)†
NW	68.7(4.1)	45.1(5.0)	24.3(2.1)	15.4(3.0)	81.6(2.1)	66.3(3.7)

*: significantly greater than NW ($p < 0.05$); †: significantly less than NW ($p < 0.05$).

DISCUSSION: McCaw and DeVita (1995) reported that shifting the COP posteriorly increased the flexor torques at the ankle, knee, and hip joints of the present leg. Conversely, shifting the COP anteriorly increased the extensor torques at ankle, knee, and hip joints of the present leg. The $+/- 0.5$ cm and $+/- 1.0$ cm shifts in the location of the COP caused about 7% and 14% changes respectively in maximum joint torque and angular impulse values. When the location of the COP is more posterior at initial contact, the ankle posture is more dorsiflexed, and when the location of the COP is more anterior at end contact, the ankle posture is more plantarflexed. The increase in the ROM of the ankle in the sagittal plane in TC movements may thus be expected. Some studies (Mecagni et al., 2000; Whipple, et al., 1987) have reported that there is a positive relationship between the ROM of the ankle joint and balance control and muscle strength in the lower extremities. The locations of COP during TC movements were more medial both at the initial and the end contact with the ground as compared with NW. The previous study (Mao, 2004) demonstrated that the step length, base of gait, and the angle between two feet were significantly greater in TC movements than in NW. These increases may cause the more medial at locations of COP both the initial and the end contact with the ground in TC movements than in NW. Szturm et al. (1998) investigated the ROM of COP under the foot and EMG when disturbance occurs. They found that there is a positive relationship between the displacement of COP and the magnitude of EMG of lower extremities. Nakamura et al. (2001) found that with the increasing of displacement of COP, not only the magnitudes of EMG but also the number of muscles to be used were increased in the lower extremities. From this point, the larger of ROM of COP in TC movements may induce the lower extremities to recruit more muscles to participate and contracted in a higher level (Wu et al., 2004) when compared with NW.

CONCLUSION: In TC movements, the COP was extended as compared with normal walking. It is speculated that these unique plantar pressure redistribution characteristics in TC movements may benefit to increase the muscle strength of the lower extremities.

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