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BIOMECHANICAL ANALYSIS OF THE EVADING WITH PUSHING TECHNIQUE IN TAI CHI PUSH HANDS

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The traditional Chinese martial arts, Tai Chi (TC), include different forms and advanced interactive movements called Push Hands. Very few studies on the biomechanics analysis of TC push hands have been published. To investigate the characteristics of Tai Chi Push Hands, an experienced master was asked to perform the ‘evading with pushing technique’ when he was pushed by another person for three trials. The master’s movements were videotaped and digitized using a motion analysis system combining electromyography and force plate data. The results indicated that the master lowered his COG, shifted his body weight to rear foot, twisted his waist to evade the push, and pushed back with the strength from the lower limbs. It is concluded that the evading with pushing technique is a efficient and effective way to strike back.

KEY WORDS: Taijiquan, coordination, postural adjustment, martial arts, EMG.

INTRODUCTION: Tai Chi (TC) includes two kinds of practice, i.e. forms and Push Hands. The former are basic routines performed by a single person, while the latter are more advanced movements requiring an opponent to practice with. Although Tai Chi was developed from traditional Chinese martial arts, it has become a popular exercise worldwide, especially among the elderly. Proficiency in Push Hands will lead to abilities to feel the incoming force (Ting Chin), to know the appropriate reaction (Tung Chin), and to deal with all kinds of attacks with poise (Omnipotence).

TC exercise has been shown beneficial for the elderly in preventing falls due to enhanced proprioception, which is the afferent information involving conscious sensation, joint stability, and postural equilibrium (Lephart, Pincivero, Giraldo & Fu, 1997). Xu et al. (2004) indicated that people practicing TC had better proprioception than other sport groups. The center of gravity (COG) has been shown to remain low with well coordinated joint motions during TC push movements (Chan, Luk & Hong, 2003) in performing routines. Compared to normal gait, TC gait has less single-support duration, and direction of motion is changed more frequently. Moreover, larger plantar pressure was found at the first metatarsal head and the great toe in TC exercise during single-support (Wu, Liu, Hitt & Millon, 2004). Although both forms and Push Hands are important in TC exercises, far researchers focused extensively on the analysis and effects of the former. When encountering a push or other kinds of attack, TC masters are capable of maintaining their balance (Cheng, 1985; Chen, Cheng, Liu, Chiu & Cheng, 2010), but the technique of defending while attacking back remains unclear. Thus the purpose of the present study is to investigate evading the attack with pushing techniques in TC Push Hands.

METHODS: A TC master (age 69; height 1.60 m; weight 70 kg) participated in the study after given written informed consent. He has been practicing the TC form (Cheng Tzu’s style) and Push Hands for 40 and 30 years, respectively.

Eight Eagle video cameras (Motion Analysis Corporation) at 200 Hz, two Kistler Type 9281B force plates at 1000 Hz, and a MA-300 EMG System (Motion Lab Systems, Inc.) at 1000 Hz were synchronized during data acquisition. Helen Hays Marker Set (with 25 markers) was used to indicate anatomical landmarks.

Two force plates obtained kinetic data on each foot of the master. Surface electrodes were placed on the right side of the upper body muscle groups including the triceps, deltoid, latissimus dorsi and erector spinae, and on both sides of lower body muscle groups including the rectus femoris, semitendinosus, and the medial head of gastrocnemius.

Before the actual experiment, the master performed a maximal isometric voluntary contraction (MVC) of the muscles of interest against manual resistance. In the formal experiment the master squatted with the right leg forward as the 'ready' posture. He first laid his hands under the arms of the attacker in receiving maximal pushing force, and then performed the evading with pushing technique for three trials. After the start of data collection, it took about 5 s for the master to move onto the force plates and get ready for the push.
The kinematic, kinetic, and EMG data were integrated by EVaRT Version 4.4.1 (Motion Analysis Corporation, Santa Rosa). A Butterworth filter with low-pass frequency of 6 Hz was used to smooth the kinematic data. With the estimated center of gravity (COG) position and mass of each body segment (Winter, 1990), the whole body COG position could be calculated. From the above calculation, the extent of COG displacements in the horizontal and vertical directions were analyzed in detail. EMG data were full-wave rectified, filtered by the Butterworth fourth order band-pass filter of 10-400 Hz, band-stop filter of 60 Hz, and then normalized by MVC values before getting the integrated EMG (IEMG) values.

RESULTS: In receiving the push, the master initially lowered his COG position and then rose to push the opponent away. In the horizontal direction the COG first moved forward and to the left (positive Y and negative X) (Fig. 1), and then moved backward. Maximum COG displacement in the downward direction is about 78 mm.

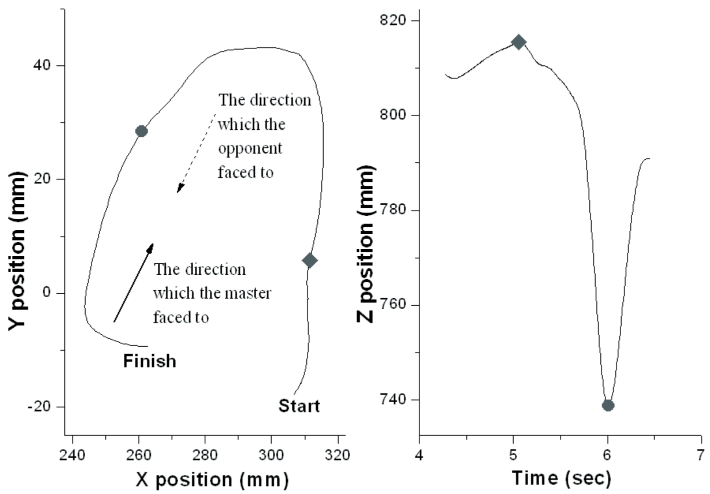

Figure 1: The path of the COG in the horizontal (X- and Y-axis) and vertical (Z-axis) directions. The solid diamond and circle denote the highest and lowest COG position, respectively. The evading with pushing started when the COG was approximately at the highest position.

Except for the right ankle, lower limb joints generally flexed when the master transferred his body weight from front foot to rear foot in receiving the opponent's push. In general, joint angles started to extend after the COG passed through the lowest point. But the left hip and right ankle joint extend earlier in the process of body weight shifting. Furthermore, the left hip began to flex before the end, but the right ankle continued extending until the end (Fig 2).
Due to the initial pushing force, the master's total vertical GRF was 1.10 BW (front foot 0.68 BW; rear foot 0.42 BW) (Fig. 3). When he started the evading with pushing technique, his weight quickly shifted to the rear foot. Vertical GRF on the rear and front foot were 1.02 BW and 0.62 BW, respectively, when the master's COG was at the lowest position.
The left (L) rectus femoris muscles showed the greatest activity, while the right (R) erector spinae muscles had the largest IEMG value in the upper body (Table 1). Relatively high EMG activities were found in most muscles before the master started to push (Fig. 4).

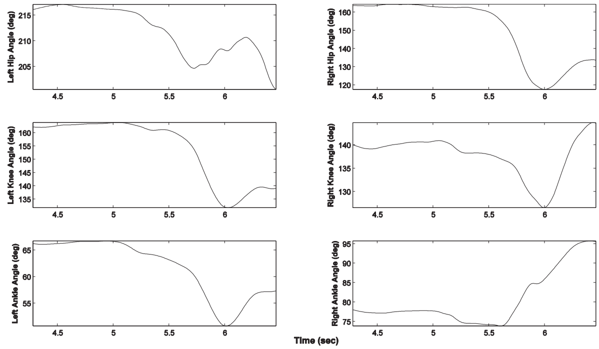

Figure 2: Variations in joint angles during the evading with pushing movement.

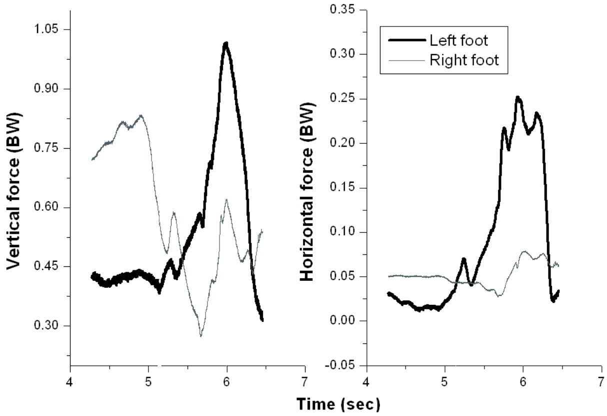

Figure 3: Vertical and horizontal GRF on the left and right foot of evading with pushing technique.

Table 1
Average IEMG values of ten muscle groups on the evading with pushing

Muscle groups	IEMG values
1. L gastrocnemius	0.0249
2. R gastrocnemius	0.0441
3. L rectus femoris	0.2441
4. R rectus femoris	0.1204
5. L semitendinosus	0.0385
6. R semitendinosus	0.0208
7. R erector spinae	0.1222
8. R latissimus dorsi	0.1058
9. deltoid	0.0379
10. triceps	0.0179

DISCUSSION: Initially the front foot bore more body weight because of the semi-squat posture with forward leaning. The reason the master's COG moved downward may be due to avoiding the pushing force, so that the opponent could not lay direct forces onto the master's body. During this period, the GRF on the rear foot raised continuously while decreasing on the front foot. Relatively obvious EMG activities of trunk muscles occurred just before the master pushed the opponent, but activities of upper limbs were still low. The master twisted

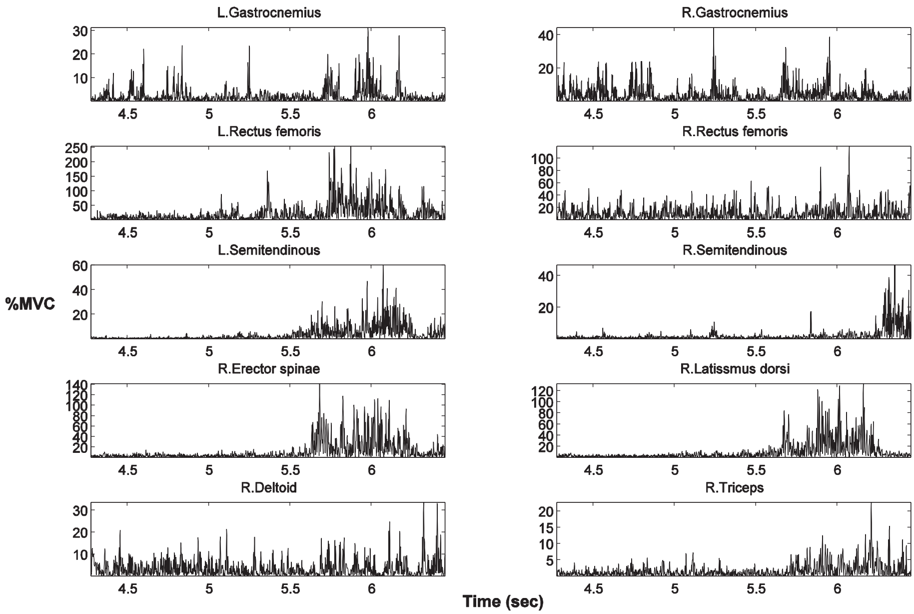

Figure 4: Selected muscle activities of upper and lower limbs in evading with pushing.

his body to let the opponent lose balance, and this also can be seen in the EMG activities of the R. erector spinae and R. latissmus dorsi.

The COG was raised when the master started to push the opponent with all the lower limbs extended. The EMG activities of R. erector spinae were merely less than those of L. rectus femoris which remained high, suggesting the technique of directing strength from the lower limb to the upper body through the waist.

CONCLUSION: The current study examined the kinematics, kinetics, and EMG characteristics of an evading with pushing technique of TC Push Hands. As an efficient and effective way against the attacker, an experienced TC master will evade the pushing from the opponent by moving the COG downward and twisting the waist, followed by pushing the opponent away.

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