BIOMECHANICAL ANALYSIS OF THE ATTACK TECHNIQUE IN TAI CHI PUSH HANDS

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Tai Chi (TC) is a form of exercise developed from the martial art folk traditions of China. The force used in TC includes different principles of mechanical advantage. Push Hands are more advanced movements of TC exercise. No studies on the biomechanics analysis of TC push hands have been published. To analyze the kinematics, kinetic and electromyographic characteristics of TC Push Hands, an experienced TC master was asked to exhibit TC and normal pushing against another person for three trials. The movements were videotaped and digitised using a motion analysis system combine electromyographic and two force plates. The results indicated that the TC master cannot push the opponent over in normal pushing. The COG trajectories, kinetics, and EMG patterns are very different in normal and TC pushing. It is concluded that TC pushing is more strategic than normal pushing because its technique requires much less effort to cause the opponent's imbalance.

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

INTRODUCTION:

Tai Chi (or Tai Chi Chuan, Taijiquan) is a kind of physical exercise usually described by the following aspects: slow, focus, breathing, and relaxing. Although Tai Chi (TC) is developed from traditional Chinese martial arts, it has become a popular exercise all over the world, especially among the elderly. In the process of development many different styles of TC have been created, such as Chen, Yang, Wu, and Sun. Each style has its own unique characteristics but the principles of TC remain the same.

Complete TC exercise consists of forms (routines composed of sequences of single movements) and push hands. Forms are basic practices in TC, while Push Hands are more advanced movements. The abilities of "Listening to Strength" (Ting Chin, which means feeling the opponent's incoming force), "Interpreting Strength" (Tung Chin, understanding how to react to the opponent's movement), and "Omnipotence" are all based on proficiency in Push Hands (Cheng, 1985).

TC exercise has been shown beneficial for the elderly in preventing falls due to enhanced proprioception. Proprioception is a kind of afferent information associated with conscious sensation (muscle sense), segmental posture (joint stability), and total posture (postural equilibrium) (Lephart, Pincivero, Giraldo & Fu, 1997). Maintaining postural equilibrium needs proprioceptive acuity and precise neuromuscular control. Xu et al. (2004) indicated that older people practicing TC had better proprioception than the swimming and jogging groups.

Biomechanical analysis revealed that center of gravity is always low and joints are well coordinated during TC push movements (Chan, Luk & Hong, 2003) in performing forms. Compared to normal gait, Tai Chi gait has less single-support duration, and direction of motion is changed more frequently. In addition, during single-support in TC exercise, larger plantar pressure occurs at the region of the first metatarsal head and the great toe (Wu, Liu, Hitt & Millon, 2004). Although both forms and Push Hands are essential in TC exercise, to date researchers focused extensively on the analysis and effects of practicing forms. To the best of the authors' knowledge, there has been no specific investigation on TC Push Hands. When encountering pushing or any other kinds of attack, TC masters are capable of stabilizing themselves while impairing the opponent's balance (Cheng, 1985), but the scientific theory behind this technique remains unclear. Thus the purpose of the present study is to characterize the pushing techniques employed in TC Push Hands, and compare those with normal pushing by biomechanical analysis.

METHOD:

Data Collection: A TC master (age 69; height 1.60 m; weight 67 kg) participated in the study after given written informed consent. He has been practicing Tai Chi form (Cheng Tzu's style) and Push Hands for 40 and 30 years, respectively. He was asked to exhibit normal and TC pushing against another person who had no previous experience in TC.
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 during the two kinds of push movement. The 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 was asked to perform a maximal voluntary contraction (MVC), by isometric contraction against manual resistance, of each muscle group of interest. In the formal experiment the master placed his left foot (backward) on the first force plate, and right (forward) foot on the second plate. A comfortable posture for the push technique was adopted with both legs slightly flexed and the left leg more extended. The master was asked to exhibit normal and TC pushing against another person who had no previous experience in TC for three trials. The person the TC master pushed needed to do his best to resist the pushing.
Data Analysis: The software, EVaRT Version 4.4.1 (Motion Analysis Corporation, Santa Rosa) was used to integrate kinematic, kinetic, and EMG data. The kinematic data was smoothed by a Butterworth filter with low-pass frequency of 6 Hz. With the estimated center of gravity (COG) position and mass of each body segment (Winter, 1990), the whole body COG position can be calculated. From the above calculation, the extent of COG displacements in the horizontal and vertical directions were analyzed in detail. All integrated EMG (IEMG) values 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.
RESULTS:

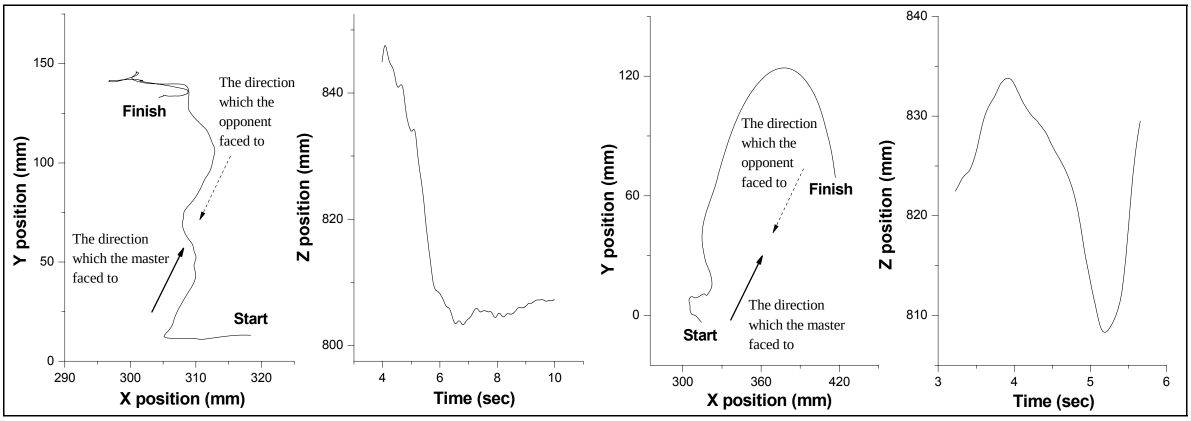

Figure 1: The COG trajectories in normal push (left two, Fig. 1a) and TC push (right two, Fig. 1b) in the vertical and horizontal directions.

In TC pushing, the master used less time to push the opponent over, but in normal pushing, the master could not move the person. Since the results from the three trials are very consistent, data from only one trial is presented. The whole action took 6.0 seconds and 3.2 seconds in normal and TC pushing, respectively. In the former, the master initially lowered his vertical position and the COG remained at approximately the same height thereafter. The COG moved slightly to the negative X and considerably to the positive Y direction (Fig. 1a). In TC pushing, the results contrast with those in normal pushing in that the upward COG displacement occurred after the initial downward movement. In the horizontal direction, the master COG moved to positive X and Y direction (Fig. 1b).

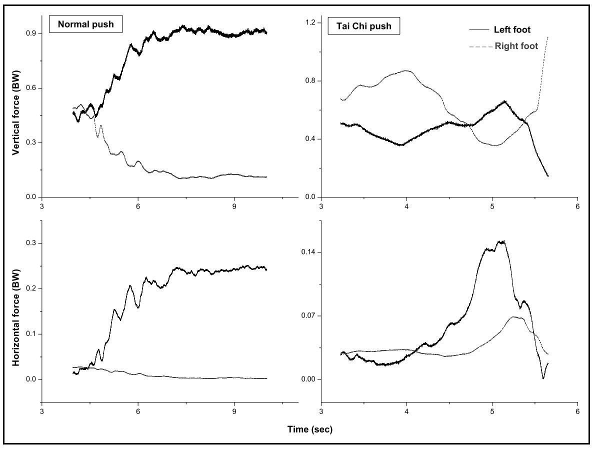

Figure 2: Vertical and horizontal GRF on the left and right foot of normal push (left) and TC push (right).

Changes in GRF shown by two force plates indicate a distinct pattern during TC and normal pushing (Fig. 2). In the former, initially more body weight was on the front foot. About 4 sec after the onset of data recording, weight started to transfer to the rear leg. At the end (when the opponent lost balance), the front foot exerted a force slightly larger than body weight. In normal push, initially body weight equally distributed on both feet. Although most of the master's weight was shifted to the rear foot during the push, the opponent could still maintain balance.

Table 1 Average IEMG values of ten muscle groups on Normal and TC pushing.

Muscle groups	IEMG (Normal push)	IEMG (TC push)
L gastrocnemius	0.0076	0.0269
R gastrocnemius	0.0255	0.0392
L rectus femoris	0.1482	0.3521
R rectus femoris	0.0868	0.0554
L semitendinosus	0.0094	0.0188
R semitendinosus	0.0096	0.0092
R erector spinae	0.1916	0.0388
R latissimus dorsi	0.1482	0.0362
R deltoid	0.0344	0.0475
R triceps	0.0227	0.0638

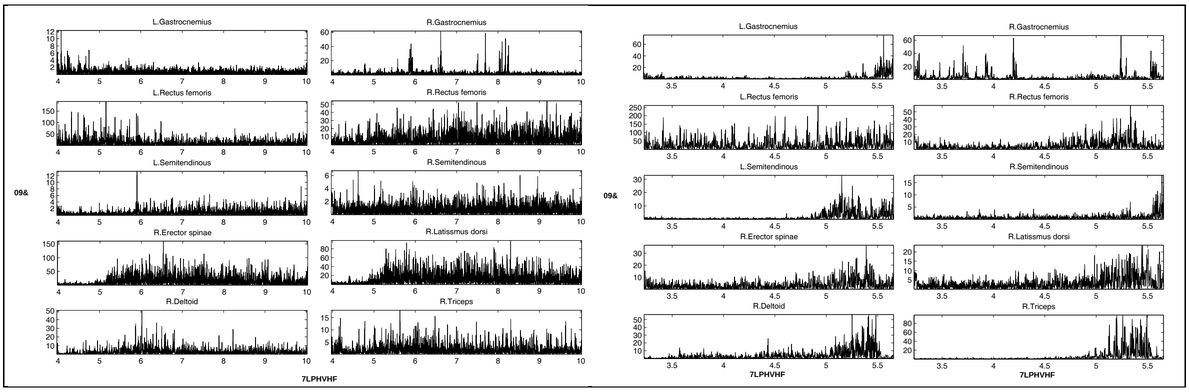

Figure 3: Muscle activities of selected upper and lower limbs in normal (left, Fig. 3a) and TC (right, Fig. 3b) pushing.

Normalized EMG values of different muscle groups are illustrated as time functions (Fig. 3) and IEMG values are listed (Table 1). Among the muscle groups examined, lower EMG activities occurred in the left (L) and right (R) medial hamstrings in both normal and TC push.

The highest EMG values are observed in the left rectus femories and the erector spinae for TC pushing and normal pushing, respectively.

DISCUSSION:
The kinematics, kinetics, and EMG characteristics of a fundamental attack technique of TC Push Hands were examined. The COG trajectories of the TC and normal push are very different. In the former the master lowered and then raised his COG to cause the opponent to lose balance. In the latter, even though the COG was also lowered and body weight was transferred to the rear leg, the master was still unable to impair the opponent's balance.
The GRF pattern of TC push shows that force was exerted for a short period, while in normal push the force was exerted for a longer duration without effectively causing the opponent to lose balance.
It is also clear from the EMG patterns that obvious muscle activities occurred only for a short period, while in normal push substantial activities were remained for a longer duration, especially in the upper limbs. Only the rear foot rectus femoris was highly activated during the whole TC push process. Both the GRF and EMG patterns indicate that the TC push is certainly a skillful maneuver.

CONCLUSION:
The current study was the first known study examining the kinematics, kinetics, and EMG characteristics of a fundamental attack technique of TC Push Hands. The major difference between normal and TC pushing is that the former is more strategic a technique. In contrast to ineffectively using a lot of force (and corresponding substantial muscle activities), the TC pushing technique requires much less effort to cause the opponent's imbalance.

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