BIOMECHANICAL ANALYSIS OF TAI CHI CHUAN FIXED-STEP PUSH-HAND

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INTRODUCTION: Tai Chi Chuan is a Chinese traditional martial art. It is not only helpful to health (Frye, Scheinthal, Kemarskaya, and Pruchno, 2007) but also a fighting skill. After routine training for a long time, Tai Chi Chuan learners will do an advance sparring set training, that is, Push-hand. They are trained to use their tactile sense well and apply the 'Eight Methods of Tai Chi' to attack and defend in reality (Wu, 1994) in Push-hand process. Chan, Luk, & Hong (2003) revealed the kinematic characters while a master performing the push movement in Tai Chi. Most of the principles of Push-Hand were only recorded in Tai Chi Chuan ancient books and records. Consequently, the purpose of this study was to identify biomechanical characters in Push-hand process and to expound it scientifically.

METHODS: Six male subjects (28.4±1.64 yrs, 175.2±5.42 cm, 64±7.95 kg) practicing Tai Chi Chuan at least five years were divided to three couples in this study. Subjects were asked to do fixed-steps(not moving steps) Push-hand with single hand operation – Peng style, and to put each of their feet on a force plate. There were totally 67 reflective makers placed on one subject. And these makers were placed on joints to establish spatial coordinate systems on segments. Human body was divided to fifteen segments by markers in this study, and segments were thought as rigid bodies.The ground reaction force (GRF) and reflective markers` spatial coordinates data for both subjects during performing fixed-steps Push-hand were collected by KISTLER force plates and VICON motion analysis system respectively. All data were analyzed by Visual 3D and MATLAB softwares and filtered by 6Hz low-pass filter.The motion of distal segment relatives to proximal segment, that is, joint angle were described in Euler`s angle, and the rotation sequence was flexion–extension (x), abduction–adduction (y), external rotation-internal rotation (z). Furthermore, origional three dimensional GRF data in the laboratory coordinate system were transformed to the local body coordinate systrem for describing personal motion consistently. GRF values were normalized to body weight (BW), and COM displacement were normalized to body height (BH).

RESULTS: All subjects performed the same characters in Push-hand processes. The trajectory of COM was a smooth and repeating oval trajectory, and the COM of one subject moved forward while another moved backward (figure 1). But the COM undulated small in vertical direction. Responding to the trajectory of COM, the greatest GRF on back (front) foot appeared at the maximal backward (forward) displacement of COM. In additional, maximal rotation of the waist was after the maximal backward displacement of COM and the flexion/extension motion of the waist were small. The flexion/extension motion of elbow was also revealed. Table 1 show the motion range of waist and elbow for once attack and defence of the Push-hand process. And table 2 show the GRF peak values for once attack and defence in the whole Push-hand process.

Table 1. Motion ranges of human kinematic parameters

parameter	angle
Rotation of waist	**8.28 ± 3.14**
Flexion-extension of waist	**4.65 ± 2.34**
Flexion-extension of elbow	**34.83 ± 14.3**

Table 1. GRF peak values

GRF	min (BW)	max (BW)
Back foot - Vertical	**0.277 ± 0.071**	**0.833 ± 0.056**
Front foot - Vertical	**0.161 ± 0.056**	**0.696 ± 0.086**
Back foot - Forward	**0.046 ± 0.028**	**0.104 ± 0.045**
Front foot - Backward	**0.02 ± 0.025**	**0.13 ± 0.109**

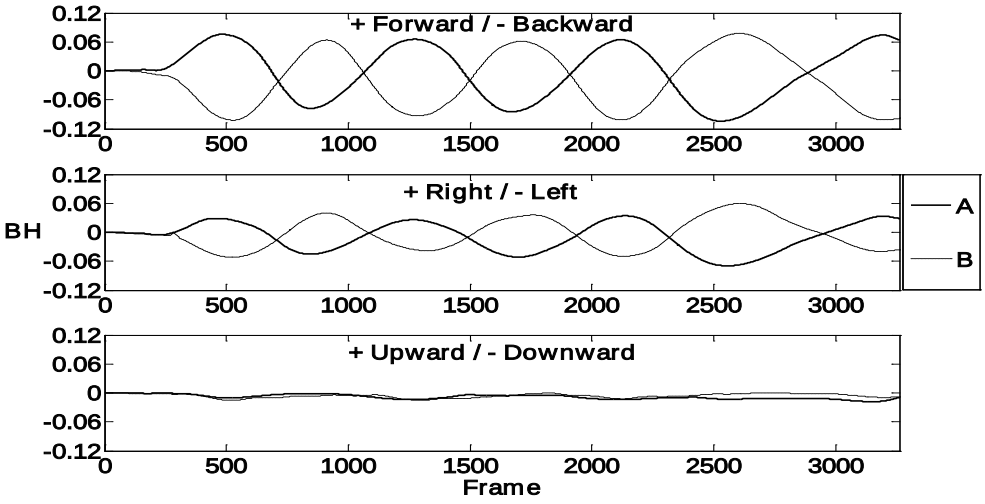

Figure 1. COM trajectories of one couple subjects. A is one subject, and B is another.

DISCUSSION: The COM trajectories showed that subjects attacked with COM moving forward. A subject needed to move backward to ward off another's attack. The movement of COM did not rely on moving steps and flexing the waist. In additional, the rotation of the waist was more important. The small flexion-extension range revealed a principle of Tia Chi Chuan, that is, keep an upright posture of the trunk. And the small displacement of COM in vertical indicated the same purpose, that is, keep balance. The GRF varied with COM motion. It was always greater than half body weight on one foot at the maximal COM displacement. These results were responded to Tai Chi Chuan theories. The flexion-extension motion of elbow was not small and it conflicted to the principles of Tai Chi Chuan. It was considered about the level of subjects.

CONCLUSION: Characters in Push-hand process were identified. The GRF and the trajectory of COM varied with each other. Additionally, the motion of COM did not only rely on rotation of waist but also combined motion of joints of lower limbs. Consequently, the joint motion of lower limbers will be investigated in future.

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