PRELIMINARY STUDY OF TRAINING COMPONENTS ON SENSORIMOTOR SYSTEM IN TAI CHI

Xu Dongqing[1], Jinxian Li[1], Youlian Hong[1], Mao Dewei[1] and Chan Kaiming[2]
[1]Department of Sports Science & Physical Education
[2]Department of Orthopaedics & Traumatology
The Chinese University of Hong Kong, Shatin, NT. Hong Kong

The purpose of this study was to identify if Tai Chi (TC) movements are full with the training components on sensorimotor system by movement kinematics and electromyography (EMG) analysis. Two TC masters performed a typical TC movement- "brush knees and twist steps" twice. Motion analysis showed that joint angles (ankles, knees and hips) of eight different postures, height and velocity of center of gravity (C.G.) of the whole movement had no significant difference in two trials. The results indicated that the TC masters had good awareness of joint position and movement and spatial position sense. Moreover, EMG analysis showed that muscles activated from full relaxation to vigorous contraction and the similar EMG patterns of each muscle in two trials suggested the good training effect of TC on muscle coordinative contraction.

KEY WORDS: Tai Chi, sensorimotor system, proprioception, motion analysis, EMG.

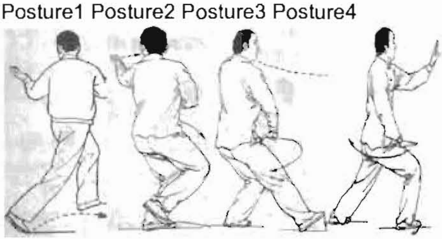
INTRODUCTION: Tai Chi (TC), a traditional Chinese exercise, has been practiced for centuries in China by the elderly and youth for agility, balance and postural control. A number of cross-sectional and longitudinal studies provided positive evidence that TC practitioners not only have better cardiorespriratory function (Lai, Lan, Wong & Teng, 1995; Qu, 1986; Young, Appel, Jee & Miller, 1999) but also performed better in balance control, flexibility and muscle strength test (Hong, Li & Robinson, 2000; Jacobson, Chen, Cashel & Guerrero, 1997; Lumsden, Baccala & Martire, 1998). Although a lot of studies demonstrated the effects of TC exercise on balance control for the elderly, little effort has been devoted to the underlying mechanism. Proprioception and neuromuscular control are important components of sensorimotor system. Postural equilibrium needs proprioceptive acuity and precise neuromuscular control. In elderly, proprioception and motor response have been shown to diminish with age (Kaplan et al, 1985; Petrella, Lattanzio, & Nelson, 1997). Age-related deficit at either of these stages is likely to result in alteration of postural control, ultimately leading to the falls dreaded by the elderly people (Manchester, Woollacott, Zeberbauer-Hylton & Marin, 1989). TC exercise requires continuous, slow movement with small to large of motion, the shift of body weight from unilateral to bilateral, and circular movements of the trunk and extremities, involving both isometric and isotonic contractions. All forms of TC emphasize on conscious awareness of body position and movement, which seem to contain the characteristics of proprioceptive exercise. Thus we hypothesized that TC exercise might be full with the training components on sensorimotor system. The aim of this study was to identify the training components of TC on sensorimotor system by movement kinematics and electromyography analysis, which is critical to explain the mechanism that TC exercises improve the balance control.

METHODS: "Brush knees and twist steps" is a typical movement in many TC schools, which reflects fundamental essentials of TC exercise. So it was analyzed in this study. Two TC masters (male, 20 years) individually performed this movement twice. In order to get good TC movement sequence, the previous and the following movements of "brush knees and twist steps" were also preformed. During exercise, two video cameras (Sony, 50Hz filming rate) and EMG system (Delsys, USA) were used to synchronously collect data by an external light trigger. The EMG signals from rectus femoris (LR, RR), semitendinous (LS, RS), gastrocnemius (LG, RG), anterior tibialis (LA, RA) of both left and right sides were sampled with a frequency of 2000 Hz using Labview Software. According to the movement of feet, " brush knees and twist steps" was divided into eight different postures (Figure1). Motion analysis system (APAS, USA) was used to calculate the joint angles of ankles, knees and hips of both left and right sides and height and velocity of C.G. in two trials. Because TC movements are continuous, the different joint angles in the 500 ms interval were averaged to represent the value at this posture. Height and 3D velocity of C.G during the whole movement were time normalized to percentage. The raw EMG data were high-pass filtered at 10 Hz, full rectified, and linear enveloped with a cut-off frequency of 10 Hz. The mean integrated EMG (iEMG) values of 500 ms in each posture were calculated. The iEMG of each muscle were normalized to its corresponding maximum voluntary contraction (MVC).

Data analysis All parameters were expressed as means and standard deviation. Paired-sample t-tests were applied to compare the difference of joint angles (for eight postures), height and velocity of C.G. (for all normalized time points) between two trials. The significance level was set at 0.05.

Posture1 Right leg weight-bearing stance, left leg forward with toe touch down
Posture2 Right leg weight-bearing stance, left leg rising with knee and hip maximum flexion
Posture3 Right leg weight-bearing stance, left leg forward with heel touch down
Posture4 Left leg forward in a bow stance

Posture1 Posture2 Posture3 Posture4



Posture5 Left leg forward in a bow stance, right leg backward with toe touch down
Posture6 Left leg single stance, right leg rising with knee and hip maximum flexion
Posture7 Left leg weight-bearing stance, right leg forward with heel touch down
Posture8 Right leg forward in a bow stance

Posture5 Posture6 Posture7 Posture8

Figure 1. Eight different postures in "brush knees and twist steps".

RESULTS: Figure 2 illustrates the changes of joint angles in two trials. No significant difference was found (P>0.05), indicating that the TC masters had very good joint position sense and joint kinesthesia. Moreover, the values of position and velocity of C.G during the whole movement were very close in two trials and there were no significant differences (Table2). Table 2 demonstrated the muscles activity level in different postures. The normalized iEMG values showed remarkable variation: from full relaxation to vigorous contraction (i.e., for LR, minimum value is 0.14% MVC, maximum value is 42.51% MVC). In addition, the EMG patterns of each muscle were very similar in two trials (Figure3 was a sample showing the similar EMG pattern of LR in two trials).

Table 1. The muscle activity levels in different postures.

IEMG%MVC	P1	P2	P3	P4	P5	P6	P7	P8
LR	0.14	0.98	6.45	5.47	0.56	1.12	42.51	11.08
LS	2.70	6.08	1.13	8.90	5.30	6.08	2.93	0.68
LG	27.99	15.78	0.84	10.31	3.58	5.26	17.68	1.89
LA	0.83	1.24	21.66	3.04	26.21	31.04	13.52	34.77
RR	10.02	9.18	23.07	8.33	10.51	9.66	18.24	10.99
RS	0.86	1.14	0.86	0.38	0.57	0.48	0.48	1.81
RG	6.68	9.31	4.06	0.48	5.73	5.97	0.72	1.91
RA	0.87	1.83	1.06	4.05	1.25	1.06	16.69	16.88

Table 2. The position and velocity of C.G during the whole movement in two trials.

	Trial1	**Trial2**
Position of C.G (m)	.720 (.039)	.714 (.039)
Velocity of C.G (m/s)	.336 (.210)	.327 (.198)

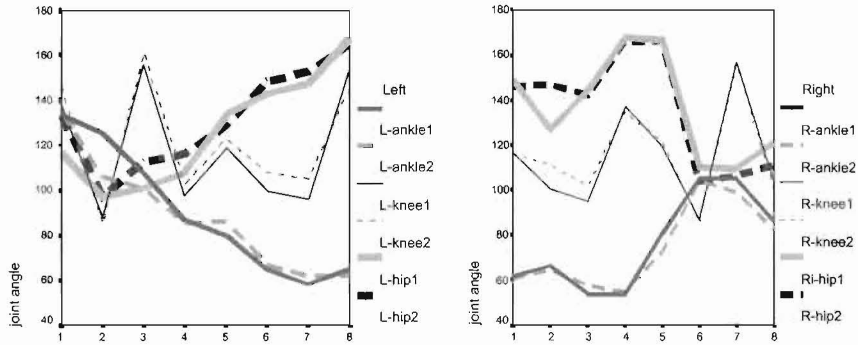


Figure 2. The comparison of different angles in two trials.

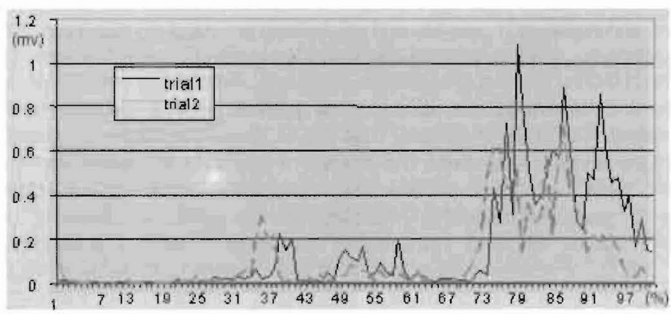


Figure 3. Time normalized EMG pattern of LR in two trials.

DISCUSSION: Recognition of the effects of proprioception and neuromuscular control on joint and posture stability has led to an emphasis on restoring proprioception to enhance dynamic joint stability (Irrgang & Neri, 2000). Exercise has shown to have a beneficial effect on proprioception. Lephart and coworkers (1997) describes taxonomy for classification of proprioceptive exercises that includes activities designed to enhance conscious awareness of joint position and movement, activities to enhance balance, and activities to enhance neuromuscular control of movement. TC exercise seems to contain all these characteristics.

TC movements are gracefully fluent and consummately precise because specificity of joint angles and body position is of critical importance in accurately and correctly performing each form (Jacobson, Chen, Cashel, & Guerrero, 1997). In this study, the subjects have practiced TC for several years. During the two trials, the changes of joint angles had no significant difference and the position and velocity of C.G. were very similar. The result indicated that the TC masters not only have good awareness of joint position and movement but also have good spatial position sense. This might be contributed to that all forms of TC emphasize on conscious awareness of body position and movement. So long term and regular TC exercise has beneficial effects on proprioception. Neuromuscular control of joint motion requires development of muscle strength and endurance, as well as development of appropriate recruitment patterns to regulate the timing and force of contraction to produce efficient movement and provide dynamic joint stabilization (Irrgang & Neri, 2000). In performing this form, there was considerable range of ankles, knees and hips. Muscle contraction type presented quite often alteration in eccentric, concentric and static. Moreover, the shifting of C.G. was quite often and slow, which make the loading of muscle varying continuously. The normalized iEMG values showed that the muscles activity level had remarkable variation among different postures: from full relaxation to strong contraction (i.e., for LR, minimum value is 0.14% MVC, maximum value is 42.51% MVC), which should be related to enhancing the muscle strength and endurance by TC exercise. In addition, the EMG patterns of each muscle were very similar in two trials, showing that TC exercises make the subject precisely regulate the timing and force of muscle contraction. The consummate goal in the practice of TC is exactness in performing each movement. Explicit replication of form in terms of precise joint angles and positioning, steady posture and balance, and appropriate hip, knee, and ankle strength for low, sweeping movements is demanded by the nature of the activity. These characteristics may produce positive effects on sensorimotor system, which may be one of reasons that TC improves balance control.

CONCLUSION: Comparing measured parameters between two trials of TC, no significant difference was found in the joint angles, height and velocity of C.G. , which indicated that the TC masters not only have good awareness of joint position and movement but also have good spatial position sense. EMG analysis showed that muscles activated from full relaxation to vigorous contraction and the similar EMG patterns of each muscle in two trials, suggesting the training effect of TC on muscle strength and coordinative contraction.

REFERENCES:

Hong, Y., Li, J. X., & Robinson, P. D. (2000). Balance control, flexibility, and cardiorespiratory fitness among older Tai Chi practitioners. *Bri J Sports Med*, **34**, 29-34.

Irrgang, J. J., & Neri, R. (2000). The rationale for open and closed kinetic chain activities for restoration of propriception and neuromuscular control following injury. In S. M. Lephart & F. H. Fu (Eds.), Proprioception and neuromuscular control in joint stability, 363-374. *Human Kinetics*.

Jacobson, B. H., Chen, H. C., Cashel, C., & Guerrero, L. (1997). The effect of Tai Chi Chuan training on balance, kinesthetic sense, and strength. Perceptual & Motor Skills, **84**(10), 27-33.

Kaplan, F. S., Nixon, J. E., Reitz, M., Rindfleish, L., & Tucker, J. (1985). Age-related change in proprioception and sensation of joint position. Acta Orthop Scand, **56**, 72-74.

Lai, J. S., Lan, C., Wong, M., & Teng, S. (1995). Two-year trends in cardiorespiratory function among older Tai Chi Chuan practitioners and sedentary subjects. J Am Geriatr Soc, **44**, 1222-1227.

Lephart, S. M., Pincivero, D. M., Giraldo, J. L., & Fu, F. H. (1997). The role of proprioception in the management and rehabilitation of athletic injuries. Am J Sports Med, **25**(1), 130-137.

Lumsden, D. B., Baccala, A., & Mrtire, J. (1998). T'ai Chi for osteoarthritis: an introduction for primary care physicians. Geriatrics, **53**(2), 84, 87-88.

Manchester, D., Woollacott, M., Zederbauer-Hylton, N., & Marin, O. (1989). Visual, vestibular and somatosensory contributions to balance control in the older adult. J Geron, **44**(4), M118-M127.

Petrella, R. J., Lattanzio, P. J., & Nelson, M. G. (1997). Effect of age and activity on knee joint proprioception. Am J Physi Med Rehab, **76**(3), 235-241.

Qu, M. Y. (1986). Taijiquan: A medical assessment. In C. S. E. Board (Ed.), Simplified Taijiquan . Beijing: China International Book Trading.

Acknowlegement: The work described in this paper was fully supported by a grant from the Research Grants Council of the Hong Kong Special Administrative Region. (Project no. CUHK4360/00H).