TAI CHI: MOVEMENT CHARACTERISTICS AND PREVENTION OF FALLS

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In the recent guidelines released by the American Geriatrics Society and the British Geriatric Society Tai Chi is strongly recommended the exercise form for elderly people to prevent falls. Biomechanics is the most effective way to explain the underlying mechanism of Tai Chi in improving the balance stability and posture control. This article introduces the biomechanics studies reported in the last decades to explore the kinematics, kinetics and electromyography characteristics of Tai Chi movements. Through these studies the unique contribution of Tai Chi exercise to balance stability and posture control and subsequently prevention of falls has been better understood. This article also suggest that in order to understand the neurological basis of the effects of Tai Chi exercise on falls prevention, a Magnetic Resonance Image study should be conducted.

KEYWORDS: Tai Chi; falls prevention, posture control, Balance, neuromuscular reaction

THE NEED OF BIOMECHANICAL STUDY ON TAI CHI (TAI JI): The American Geriatrics Society and the British Geriatric Society have updated their guidelines on preventing falls in older persons in 2010. Tai Chi is categorised as a strong recommendation as good evidence was found that the intervention improves health outcomes and that benefits substantially outweigh harm (American Geriatrics Society and British Geriatrics Society, 2011). Indeed, Wolf et al. (1996) reported that a 15-week Tai Chi intervention program reduced 47.5% of risk of falls. Poor balance capacity, decreased muscle strength and flexibility, and the change in gait with aging are among the risk factors related to falls in the elderly (Myers, Young, & Langlois, 1996). A number of biomechanical studies have been conducted to explore the effects of Tai Chi exercise on all factors related to balance capacity.

Balance: Biomechanical methods have been used to assess the balance capacity. Tse and Bailey (1992) reported that Tai Chi practitioners performed significantly better on single-leg stance with eyes open and heel-to-toe walking than non-practitioners. Lan et al. (1996) found that long-term Tai Chi practitioners showed better scores in a stand-and-reach test. Hong, Li, and Robinson (2000) reported that elderly long-term Tai Chi practitioners performed better in the tests of single leg stance with eyes closed and in tests of sit-and-reach than their sedentary counterparts. Tsang and Hui-Chan (2003) also examined whether elderly Tai Chi practitioners have developed better standing-balance control than elderly healthy control subjects. The body sway was measured using a force plate. Tai Chi practitioners initiated voluntary weight shifting in the limits of the stability test more quickly than control subjects. Moreover, they could lean further without losing stability and showed better control of their leaning trajectory. Using the computerized dynamic posturography, Tsang et al. (2004) compared healthy elderly Tai Chi practitioners with their sedentary counterparts in balance control when they stood under reduced or conflicting somatosensory, visual, and vestibular conditions. It was found that Tai Chi practitioners performed better than the non-Tai Chi subjects in the visual and vestibular ratios, but not in the somatosensory ratio. Tsang and Hui-Chan (2005) examined the balance capacity of older Tai Chi practitioners and their sedentary counterparts when they performed static double-leg stance and single-leg stance on platform perturbed forward or backward. The results showed that Tai Chi practitioners had less anteroposterior body sway angles in single-leg but not double leg stance than did control subjects. A number of Tai Chi intervention studies have also been reported. Schaller (1996) found that a 10-week Tai Chi exercise resulted in a significant improvement in the scores for single-leg stance with eyes open, but not in the single-leg stance with eyes closed. Jacobson, Chen and Cashel (1997) reported significantly better balance control in 12 adult Tai Chi participants than in 12 sedentary subjects after a 12-week Tai Chi intervention. Shih (1997) reported a 16-week Tai Chi intervention was associated with substantial changes in the sway velocities in anterior and posterior directions between the pre- and post-tests in 11 elderly subjects using forceplate test. All above mentioned studies proved Tai Chi an effective exercise form for improving balance capacity in older people.

Muscle strength and endurance: Tsang and Hui-Chan (2005) reported that elderly Tai Chi practitioners had higher peak torque-to-body weight ratios of their knee extensors and flexors in concentric and eccentric isokinetic contractions at an angular velocity of 30°/s than their sedentary counterparts. In another cross-sectional study, Xu, Li, and Hong (2006) found that the older long-term Tai Chi practitioners had similar magnitude to the long-term joggers but higher than their sedentary counterparts in the peak torque-to-body weight ratios of concentric isokinetic contractions in knee extensors and flexors at 120°/sec angular velocity and in ankle dorsiflexion at 30°/sec,. Moreover, compared with sedentary controls, the Tai Chi group showed pronounced dynamic muscle endurance, which was assessed by the ratio of the mean work of the first 5 to the last 5 among the 40 maximum concentric isokinetic contractions, in knee extensors at 120°/sec angular velocity. A 16-week Tai Chi intervention study showed that Tai Chi exercise significantly increased muscle strength of the knee flexors (Li, Xu, & Hong, 2009). All above mentioned studies proved Tai Chi an effective exercise form for improving lower extremity muscle strength and endurance.

Neuromuscular control: Research has shown that postural control stability is significantly affected by a decline in proprioception in the lower limb (Lord & Castell, 1991). The classic methods for testing proprioception involve the determination of the lowest threshold for the detection of joint rotation, namely kinesthesia, and the determination of joint position sense from the accuracy with which contralateral joint angles can be matched or a limb segment repositioned in three-dimensional space without the aid of visionUsing isokinetic test, Tsang and Hui-Chan (2003) found that the long-term elderly Tai Chi practitioners had better than the control subjects in knee-joint passive repositioning. Xu et al. (2004) reported that elderly Tai Chi practitioners had better ankle joint dorsiflexion and plantar flexion kinaesthesia than both the elderly swimming/running exercisers and their sedentary counterparts and better knee flexion kinaesthesia than the subjects in the sedentary group. In this study the custom-made devices were used to measure the ankle and knee kinaesthesia respectively. To date, there were only two literatures that assessed the effects of Tai Chi intervention on proprioceptive function. Li, Xu, and Hong (2008) reported that a 16-week Tai Chi intervention improved the kinesthesia of knee flexion and extension using the same methods reported by Xu, et al. (2004). Jacobson, et al. (1997) found that a 12-week Tai Chi intervention improved the position sense of glenohumeral medial rotation at 60º in adult participants. All above mentioned studies proved that Tai Chi exercise is beneficial on improving proprioceptive function of lower and upper extremities.

Pevention of falls also depends on the timely initiation of an appropriate postural response to control the body’s center of mass once a displacement occurs (Horak, Shupert, & Mirka, 1989). By measuring the latency of muscles, which was defined as the time from the moment that unexpected ankle inversion perturbation began to the moment of onset of the EMG response, it was found that the femoris and anterior tibialis muscles of long-term Tai Chi practitioners were activated as fast as those in the long-term jogger and were faster than those in the control group (Xu, et al., 2005). Moreover, a 16-week Tai Chi intervention program showed that there was also a significant decrease in semitendinosus muscle latency, which was significantly shorter than that in the control group. In these two studies, the posture perturbation was evoked by an custom-made device. The studies showed that Tai Chi exercise is helpful in improving neuromuscular reaction capacity of lower extremity muscles.

Movement characteristics: The beneficial effects of Tai Chi on fall prevention should attribute to its movement characteristics. video analysis on foot movements has identified seven support patterns and six stepping directions, which are frequently interchanged throughout the exercise of the whole set of 42-form Tai Chi. It was found that when compared with walking, the duration of single support phase was longer and the transition from one support pattern to the next or stepping in one direction to another was slower (Mao, Li, & Hong, 2006a). Moreover, the biomechanics of classic and representative individual

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movements of Tai Chi have been studied. Analysis on the “Brush knees and twist step” showed that the position and direction of the centre of gravity (CG) changed continuously throughout the movement. The three dimensional displacement, velocity and acceleration of the CG were much smaller than those in other locomotion such as walking. The range of motion (ROM) of 3-D foot-ankle complex was much larger than those in walking and running (Xu, et al., 2003).
The kinetics study using insole sensor system showed that in playing the whole set of 42-form Tai Chi, the loading on the first metatarsal head and the great toe was greater than on other regions. Compared with normal walking, the locations of the centre of pressure (COP) in Tai Chi movements were more medial and posterior at initial contact, and were more medial and anterior at the end of contact with the ground. The displacements of the COP were wider in the mediolateral direction and larger the anterposterior direction (Mao, Li, & Hong, 2006b). When performing one-leg stances, the peak pressure and pressure-time integral on the second and third and on the fourth and fifth metatarsal heads were greater in Tai Chi than in normal walking, whereas the peak pressure and pressure-time integral on the first metatarsal head and the great toe were greater than those on other plantar regions during the one-leg stance in Tai Chi exercise (Mao, Li, & Hong, 2006c).
Endeavours were also made to explain how Tai Chi practice could enhance the balance and posture control using electromyographic (EMG) methods. In a study, the EMG activities of the muscles of rectus femoris, semitendinosus, gastrocnemius, and anterior tibialis were analyzed during performance of the “Brush knees and twist step”. Except the anterior tibialis, the estimated amplitudes of the other muscles were lower than 20% maximal voluntary contraction. In addition, the EMG patterns of the agonist and antagonist showed the well-coordinated recruitment.
The movement analysis showed that the kinematics, kinetics and muscle activity challenge in performing Tai Chi movements are high. The adaptation of Tai Chi practitioners to these challenges would develop their capacity to control the posture and maintain the balance.

FUTURE DIRECTION: To date, the neurological mechanism of the beneficial effects of Tai Chi exercise on posture control, balance, and neuromuscular control has not been well understood. The MRI studies have found that exercise, such as Basketball (Park, et al., 2009), golf (Jancke, et al., 2009), diving (Wei, et al., 2009; Wei and Luo, 2010), archery (Kim, et al., 2008), can cause the structural and functional changes in brain. It is suggested that the application of Magnetic Resonance Image in Tai Chi research would explain whether Tai Chi exercise leads to the structural and functional change in human brain. The findings would have application in designing the exercise intervention program to improve the balance and posture control, which would lead to the prevention of falls.

REFERENCES:

American Geriatrics Society and British Geriatrics Society (2011). Summary of the updated American geriatrics society/British geriatrics society clinical practice guideline for prevention of falls in older persons. Journal of the American Geriatrics Society, 59, 148-157.

Hong, Y.L., Li, J.X., & Robinson, P. D. (2000). Balance control, flexibility, and cardiorespiratory fitness among older Tai Chi practitioners. British Journal of Sports medicine, 34(1), 29-34.

Horak, F.B., Shupert, C.L., & Mirka, A. (1989). Components of postural dyscontrol in the elderly, a review. Neurobiol Aging, 10, 727-38.

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

Jancke, L., Koeneke, S., Hoppe, A., Rominger, C., & Hanggi, J. (2009). The architecture of the golfer's brain. PLoS One, 4(3), 1-8.

Kim, J., Lee, H. M., Kim, W. J., et al. (2008). Neural correlates of pre-performance routines in expert and novice archers. Neurosci Lett, 445, 236-241.

Lan, C., Lai, J.S., Chen, S.Y., & Wong, M.K. (2000). Tai Chi Chuan to improve muscular strength and endurance in elderly individuals: a pilot study. Archives of Physical Medicine and Rehabilitation, 81, 604-607.

Li, J.X., Xu, D.Q., & Hong, Y. (2008). Effects of 16-week Tai Chi intervention on postural stability and roprioception of knee and ankle in older people. Age and Aging, 37, 575-578.

Li, J.X., Xu, D.Q., & Hong, Y. (2009). Changes in muscle strength, endurance and reaction of the lower extremities with Tai Chi intervention. Journal of Biomechanics, 42, 967-971.

Lord, S.R., & Castell, S. (1994). Physical activity program for older persons: effect on balance, strength, neuromuscular control, and reaction time. Archives of Physical Medicine and Rehabilitation, 75, 648-652.

Mao, D.W., Li, J.X., & Hong, Y. (2006a). The duration and plantar pressure distribution during one-leg stance in Tai Chi exercise. Clinical Biomechanics, 21, 640-645.

Mao, D.W., Li, J.X, & Hong, Y. (2006b). Plantar pressure distribution during Tai Chi exercise. Archives of Physical Medicine and Rehabilitation, 87, 814-820.

Mao, D.W., Li, J.X., & Hong, Y. (2006c) Characteristics of foot movement in Tai Chi exercise. Physical therapy, 86, 215-222.

Myers, A.H., Young, Y. & Langlois, L.A. (1996). Prevention of falls in the elderly. Bone, 18, 87-101.

Park, I.S., Lee, K.J., Han, J.W., Lee, N.J., Lee, W.T., Park, K.A., & Rhyu, I.J. (2009). Experience-dependent Plasticity of Cerebellar vermis in basketball Players. Cerebellum, 8, 334-339.

Shih, J. (1997). Basic beijing twenty-four forms of Tai Chi exercise and average velocity of sway. Percept Mot Skills, 84, 287-290.

Tsang, W.W.N., & Hui-Chan, C.W.Y. (2003). Effects of Tai Chi on joint proprioception and stability limits in elderly subjects. Medicine and Science in Sports and Exercise, 35, 1962-1971.

Tsang, W. W. N., Wong, V. W., Fu, S. N., & Hui-Chan, C. W. Y. (2004). Effects of Tai Chi on standing balance control under reduced or conflictiong sensory conditions. Archives of Physical Medicine and Rehabilitation, 85, 129-137.

Tsang, W. W. N., & Hui-Chan, C. W. Y. (2005). Comparison of muscle toque, balance, and confidence in older Tai Chi and healthy adults. Medicine and Science in Sports and Exercise, 37, 280-289.

Tse, A. K., & Bailey, D. M. (1992). Tai Chi and postural control in the well elderly. American Journal of Occupational Therapy, 46, 295-300.

Wei, G., Luo, J., & Li, Y. (2009). Brain structure in diving players on MR imaging studied with voxel-based morphometry. Progress in Natural Science, 19, 1397-1402.

Wei, G., & Luo, J. (2010). Sport expert's motor imagery: functional imaging of professional motor skills and simple motor skills. Brain Res, 1341, 52-62.

Xu, D.Q., Li, J.X., & Hong ,Y. (2003). Tai Chi movement and proprioceptive training: a kinematics and EMG analysis. Research in Sports Medicine, 11,129-143.

Xu, D. X., Hong, Y., Li, J. X., & Chan, K. M. (2004). Effect of tai chi exercise on proprioception of ankle and knee joints in old people. British Journal of Sports Medicine, 38, 50-54.

Xu, D.Q., Li, J.X., & Hong, Y. (2005). Effect of regular Tai Chi and jogging exercise on neuromuscular reaction in older people. Age and Ageing, 34, 439–444.

Xu, D .Q., Li, J.X., & Hong, Y. (2006). Effects of long term Tai Chi practice and jogging exercise on muscle strength and endurance in older people. British Journal of Sports Medicine, 40, 50–54.