EFFECTS OF TAI CHI EXERCISE ON GAIT PATTERN IN THE ELDERLY

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The purpose of this study was to examine the normal walking pattern of 21 older adults who had practiced Tai Chi for more than 5 years (TC group) and 20 older adults who often performed other kinds of physical activity (CTRL group). The results of the study indicated that there were significant differences in kinematic parameters of the hip joint angles, and the curve of ground reaction force versus time between the two groups.

KEY WORDS: older adults, Tai Chi, gait

INTRODUCTION: The frequency of falls and fall-related injuries increases with age. There is Increasing evidence that exercise in the form of Tai Chi (TC) does enhance human body function, the structure/motion regulating system and mental attitude.
The aim of this study was to examine whether or not there are differences in gait index measurements between older adults, some who had and some who had not practiced TC in the past 5 years.

METHODS: 41 older adults, aged 60.5±4.5 years and with no history of any lower extremity disease, were divided into two groups identified as Tai Chi (TC) group and control (CTRL) group. There were 21 subjects in TC group who were all Tai Chi practitioners with Tai Chi experience for at least 5 years. The 20 subjects in CTRL group often took part in other kinds of physical activities such as jogging and aerobic dance.
A schematic of the gait analysis system used in this study is illustrated in Figure 1. Video camera was used to videotape the sagittal plane movements. The record was synchronized with the work of 3-D force plate (60cm×45cm). The whole system was calibrated by videotaping a precisely calibrated proportional scale.
All subjects were asked to walk at a self-selected speed (comfortable speed) straight through the force plate over 5m distance that was within the area for videotaping. Videotaping for the project was performed at a frequency of 25 Hz (50 Fields/Second).
The videotape records were digitized and analyzed using Engine Video Analysis System. A single step was defined as the period from the point when one heel came in contact with the force plate to when the other heel contacted the ground. Definitions for ankle angle (c), knee angle (b) and hip angle (a) are illustrated in Figure 2. All data from force plate were analyzed automatically by self-made program. The curve of vertical components of the ground reaction force versus time (Fz-T) were generated and analyzed statistically.
T test was used to detect the statistical difference in the measured parameters between the two groups.

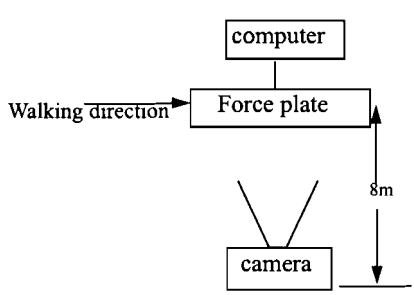

Figure 1 - A schematic of the gait analysis system.

RESULTS AND DISCUSSION: The division of gait cycle is illustrated in Figure 3. The division method used in this study is to emphasize the distinct characteristics of older adults'

gait, especially their characteristics at the point of heel contacting the ground, heel taking off ground and during the double support phase.
The stride length, stride length/height, percentage of double support time in the total gait cycle, maximal hip angle, minimal hip angle were averaged in both groups and values are shown in Table 1.

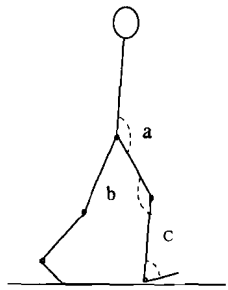

Figure 2 - Definitions for ankle angle (c), knee angle (b) and hip angle (a).

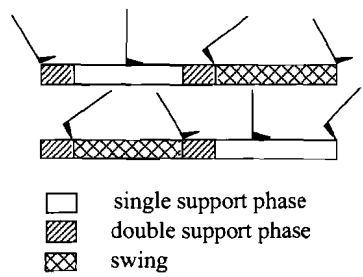

Figure 3 - The division of gait cycle.

Table 1 Some Kinematic Parameters

	Stride length (meter)	Stride length/height (meter)	Double support duration/total gait cycle duration (second)	Minimal hip joint angle of the swing leg (degree)	Maximal hip joint angle of the swing leg (degree)
TC group	0.714 ± 0.044	1.44± 0.033	0.297± 0.036*	147.77± 5.72	190.43± 7.14
Control group	0.70± 0.08	0.43± 0.048	0.318± 0.035*	149.26± 6.37	187.08± 7.59

At the point of one heel contacting the ground (this also means the onset of double support phase), the ankle joint was kept in dorsiflexion for a very short time. Then it was changed to plantarflexion, which was caused by the contraction of triceps muscle of calf. Also in this deceleration phase, against the influence of gravity, quadriceps muscle and gluteus maximus etc. contracted passively and helped knee and hip joints to flex gradually. As indicated in the Table 2-a, percentage of double support duration in a gait cycle was less in TC group (29.7±0.036%) than in CTRL group (31.8±0.035%). The difference is significant ($p<0.01$). This may indicate the strength of gluteus maximus, quadriceps muscle and triceps muscle of the older adults in the CTRL group was weaker, compared with the subjects in TC group. As a result they were much slower in ground contact of heels, ankle plantar flexion and knee flexion (Zhao, Zhou, 1998). Table 3 presents the kinematic data of male and female subjects separately. There was significant difference in the mean percentage of double support duration in the gait cycle between the two female subgroups. The mean percentage is 0.287±0.047 for the TC female subgroup, 0.326±0.031 for the CTRL female subgroup and the difference is significant ($p<0.05$).
In the double support phase, the length from tip of one foot to the other or the length from one heel to the other was identified as stride length. In order to preclude the influence of body height on stride length, the ratio between stride length and height was studied and it was hoped that positive effects of Tai Chi would be found on stride length. However, there was no significant difference in stride length between TC group and CTRL group.

Table 2 Some Kinematic Data

		Stride length (meter)	Stride length/height (meter)	Double support duration/one gait cycle duration (second)	Minimal hip joint angle (degree)	Maximal hip joint angle (degree)
TC group	Male	0.719± 0.051	0.42± 0.03	0.306± 0.022	148.7± 4.2021	190.2± 8.093
	Female	0.709± 0.036	0.45± 0.03	0.287± 0.047	146.74± 7.1232	190.7± 6.345
Control group	Male	0.7± 0.081	0.425± 0.046	0.311± 0.038	152.8± 5.398	187.4± 8.452
	Female	0.7± 0.096	0.446± 0.05	0.326± 0.031	144.7± 4.508	186.7± 6.974

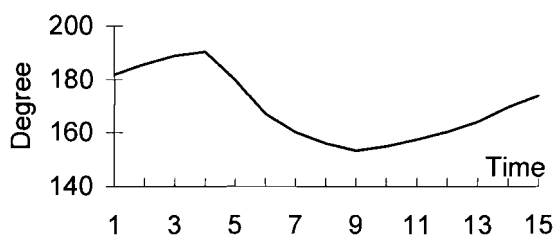

Figure 4 - Typical curve of hip angle (on the side of the swing leg) versus time.

This study investigated the right hip angle while the right leg was acting as the swing leg in one gait cycle. Figure 4 shows a typical curve of hip angle (on the side of the swing leg) versus time. There are two peak values in the curve. After the left leg contacts the ground, the trunk moved forward gradually to the upright position. In this process the right hip extends to its maximal joint angle. The mean peak value was 190.43±7.14°for the TC group and 187.08±7.59°for the CTRL group. Then, hip joint angle reached its minimal magnitude, which was the second peak value in the curve. The minimal value of the hip joint angle was 147.77±5.72° for the TC group and 149.26±6.73° for the CTRL group. Therefore, the TC group had a wider range of motion (ROM) of hip joint than those measured in CTRL group and the average values of the range were 42.66±9.59°and 37.8±9.59° for the two groups respectively.

The ground reaction forces were sampled by a 3-D force plate during the time that elapsed from one heel contacting the force plate to ground contact of the other heel. The work was done in the vertical direction only. One typical Fz-T curve of older adult walk is presented in Figure 5.

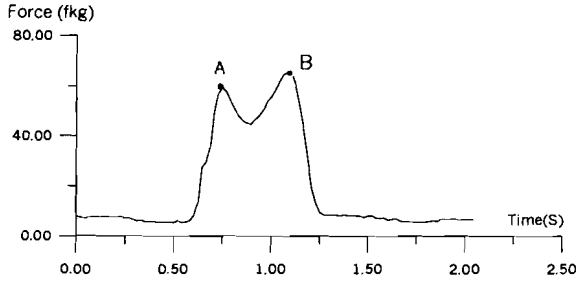

Figure 5- One typical Fz-T curve of older adult walk.

In the deceleration phase, immediately following the heel contacting ground, the ankle plantarflexed and the center of body mass (CM) rose gradually. In this upward movement of CM, the Fz reached its first peak value (A). Therefore, the magnitude of this peak value is closely correlated with vertical acceleration of CM. Thereafter, also in the deceleration phase, knee joint and hip joint flexed and the acceleration of CM moved downward. In the state of losing gravity, Fz decreased to a minimal value. This is the second peak value (B) of the Fz-T curve. Then the heel of the swing leg contacted the ground and entered the double support phase. Hip, knee and ankle joint extended to accelerate the body upward and forward. When the vertical acceleration of CM reached its maximum, Fz came to its third peak value. In the Fz-T curve, the kinetic characteristics of older adults' gait were mainly demonstrated by the first peak value (p_1), the second peak value (p_2), the third peak value (p_3), the width of the differences between these peak values, the time interval between these peak values etc. In order to preclude the influence of inter-individual variation in body weight on Fz, the peak values were divided by body weight (P/G). Similarly, p_1/G-p_2/G and p_3/G-p_2/G were used to show the width of the differences between the peak values. The average values of these parameters in each group are listed in Table 3.

Table 3 Some Kinetic Parameters

		p1/G	P2/G	p3/G	p1/G-p2/G	p3/G-p2/G
TC group	Male	1.156± 0.16	0.812± 0.07	0.219± 0.101	0.344± 0.163	0.407± 0.084
	Female	0.19± 0.159	0.782± 0.088	0.255± 0.059	0.407± 0.152	0.472± 0.067
Control group	Male	0.066± 0.018	0.797± 0.008	0.129± 0.361	0.269± 0.293	0.333± 0.008
	Female	0.157± 0.248	0.831± 0.144	0.192± 0.176	0.325± 0.163	0.361± 0.075

For male subjects in the TC group, p1/G and p3/G is 1.156±0.16 and 1.219±0.101, respectively. The value of these two parameters is 1.066±0.018 and 1.129±0.361 in the CTRL group respectively. Similar significant differences ($P<0.05$) are also shown in the female subjects between TC group and CTRL group.

CONCLUSION: There was a significant difference in the percentage of double support duration in a total gait cycle between two groups, 29.7% for the TC group and 31.8% for the CTRL group. Compared with the TC group, the subjects in the CTRL group did not extend their hip joint completely and their swing legs were not lifted as high. Precluding the influence

of body weight, TC group showed larger average peak values of vertical ground reaction force.

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