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# SAGITTAL AND FRONTAL LOWER LIMBS KINETICS DURING STEPPING DOWN IN TAICHI ELDERLY

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The aim was to compare the kinetic characteristics of the beginning stance phase during stepping down in Taichi and normal elderly. Nine elderly taichi subjects and eleven matched controls participated in the study. Whole body kinematics and ground reaction forces (GRF) were recorded using 10 Vicon cameras (250Hz) and two Kistler force plates (1000Hz). Sagittal and frontal kinetic parameters were calculated by using Visual3D software. Differences in variables between groups were tested using t-test. The results indicated hip extensor / knee flexor / ankle plantarflexor / support moment and peak hip/knee/ankle power were greater in Taichi group. It was concluded that Taichi group has ability to translate forward movement (hip moment / power), to control body (knee moment /power) and to absorption energy (ankle moment / power) in sagittal plane.

**KEY WORDS:** Body control, joint moment, power

**INTRODUCTION:** During stepping down, decreasing height was accompanied with potential changing to kinetic energy. Stair negotiation required higher joint moments in the lower limbs (Reeves et al., 2008B). However, physical abilities of elderly adults would decline with age, stepping down became a challenge task. Fall risks and impacts would cause daily life activities more dangerous. Injuries related to falls include muscle strains, fractures and even more serious complications. Falls during descent occur at least three times more frequently than during stair ascent (Christina & Cavanagh, 2002). View of dynamic stability, stairs descent is more challenge than ascent.

Dieën et al. (2007) found that falls after unexpected stepping down were due to the inability to generate a rapid forward step, rather than due to buckling of the leading leg. That ability of elderly was poor. Bento et al. (2010) also indicated that the reduced ability to rapidly develop torque seems to be a typical characteristic in the elderly. Nadeau et al. (2003) emphasized the importance of the hip abductors in controlling the pelvis during stair negotiation, and Costigan et al. (2002) reported the significance of an internal knee abductors moment throughout stance for stabilization. Novak and Brouwer (2010) further found that hip abductor moments were larger to maintain lateral stability in the older adults.

Among all exercises, Tai Chi has been promoted and is also widely accepted, and the motion characteristic is quite suitable for older people. Nowadays, many studies about the effects of Tai Chi on human body focused on physiological test, gait and balance control, while there are still few studies on joint torques cooperation of functional movement in diary environment in Tai Chi elderly adults. The purpose of this study is to investigate the sagittal and frontal lower limbs kinetics between Tai Chi exercise and normal elderly at the beginning of the stance phase when stepping down, in order to understand the effects of Tai Chi exercise on the lower extremities joint moments and power between two groups.

**METHOD:** Nine Tai Chi elder subjects (Taichi period: 8.8±7.7years; age: 74.6±5.5 years; height: 1.63±0.06 m; weight: 61.9±6.26 kg ) and eleven matched controls (age: 76.5±6.8 years; height: 1.68±0.06 m; weight: 67.75±7.23 kg) participated in the study. Ten Vicon high-speed cameras (250Hz), two force plates (1000Hz) were synchronized to collect data. Each subject performed one stepping down (20cm) and then forward walking. Sagittal and front plane kinetic parameters were calculated by kinematics and GRF using Visual3D software. Differences in kinetic variables between two groups were assessed using t-test. A significance level set $\alpha$=.05.

**RESULTS:** The data of sagittal and frontal lower limb joints moment / power are shown in Table 1 to Table 4. In sagittal plane, Taichi group had greater hip extensor / knee flexor / ankle plantarflexor / support moment and hip / knee / ankle joint power. In front plane, no significant differences in lower limb joints moment/ power between taichi group and control group were found.

**Table 1**
**Sagittal peak lower limb joint moments**

| Max Moment (Nm/kg) | Hip Extensor * | Knee Flexor * | Knee Extensor | Ankle Plantarflexor * | Support Moment * |
|---|---|---|---|---|---|
| TaiChi group | 1.32±0.50 | 0.71±0.27 | 0.44±0.22 | 1.43±0.16 | 2.25±0.34 |
| Control group | 0.59±0.34 | 0.43±0.09 | 0.29±0.21 | 1.23±0.28 | 1.59±0.48 |

**p<.05*

**Table 2**
**Sagittal peak lower limbs power**

| Max Power (W/kg) | Hip joint * | Knee joint * | Ankle joint * |
|---|---|---|---|
| TaiChi group | 0.68±0.30 | 1.73±1.15 | -7.17±0.74 |
| Control group | 0.32±0.19 | 0.93±0.51 | -4.92±1.38 |

**p<.05*

**Table 3**
**Frontal peak lower limb joint moments**

| Max Power (W/kg) | Hip Abductor | Knee Abductor | Ankle Invertor |
|---|---|---|---|
| TaiChi group | 0.97±0.20 | 0.41±0.18 | 0.36±0.14 |
| Control group | 0.99±0.18 | 0.42±0.11 | 0.43±0.17 |

**p<.05*

**Table 4**
**Front peak lower limbs power**

| Max Power (W/kg) | Hip joint | Knee joint | Ankle joint |
|---|---|---|---|
| TaiChi group | -0.56±0.24 | -0.23±0.26 | -0.14±0.09 |
| Control group | -0.57±0.24 | -0.20±0.16 | -0.19±0.15 |

**p<.05*

**Table 5**
**Sagittal peak lower limb joint moments compared to previous study**

| Peak moment (Nm/kg) | Hip Extensor | Knee Extensor | Ankle Plantarflexor | Support |
|---|---|---|---|---|
| Stair Descent | | | | |
| Salsich et al. (2001) | 0.53 | 0.78 | 1.47 | 2.16 |
| Protopapadaki et al. (2007) | 0.52 | 0.46 | 1.38 | |
| Beaulieu et al. (2008) | 0.42 | 1.0 | 1.05 | 1.55 |
| Reeves et al. (2008) | - | 0.83 | 1.03 | |
| One stepping down | | | | |
| Dieën et al. (2007) | 1.42 | 2.01 | 1.80 | |
| present study **(taichi)** | 1.32 | 0.44 | 1.43 | 2.25 |
| present study **(control)** | 0.59 | 0.29 | 1.26 | 1.59 |

**DISCUSSION: Sagittal Plane:** Compared to previous study, we could find that the hip joint moment during stepping down was greater than those with stair descent (Table 5). It speculated that hip extensor moment at the beginning of the stand phase during stepping down could "put" the trunk forward, for translation movement to forward and prevent trunk forward rotation. Peak hip extensor moment found in the Taichi group (1.32 Nm/kg) is greater than that in the control group (0.44 Nm/kg), it means Taichi group would have better ability to generate forward trunk motion while one step descent.

Dieën et al. (2007) found that peak knee extensor moment occurred during expected stepping down. In our study, we found that peak knee moment performed during knee flexed at the beginning of stand phase. Checking for video, the trailing leg still supported upon the step while knee flexor moment acted. Our results also showed that peak knee flexor moment (0.71 and 0.43 Nm/kg) larger than previous studies (0.18 ~ 0.40 Nm/kg) of descent (Table 6). It suggested that knee flexors would move the COP closer to the knee joint center thereby reducing the external knee moment (Salsich et al., 2001). Taichi group had greater knee flexor moment than control group, it caused by greater body control in Taichi group.

**Table 6**
**Sagittal peak knee joint moments compared to previous study**

| Moment (Nm/kg) | Peak Knee Extensor | Peak Knee Flexor |
|---|---|---|
| Stair Descent | | |
| Salsich et al. (2001) | 0.68 | 0.22 |
| Protopapadaki et al. (2007) | 0.14 | 0.40 |
| Beaulieu et al. (2008) | 1.00 | 0.18 |
| Reeves et al. (2008) | 0.75 | 0.23 |
| One stepping down | | |
| Dieën et al. (2007) | 2.01 | 0.84 |
| present study **(taichi)** | 0.44 | 0.71 |
| present study **(control)** | 0.28 | 0.43 |

Ankle moments predominantly contributed to extensor support in the sagittal plane (Novak & Brouwer, 2010). Lark (2004) indicated that ankle joint producted nearly all the support during the single-stance phase of gait. Our findings displayed similar with previous studies. As stair descent, the older adults used "toe landing" more often than young adults (Dieën & Pijnappels, 2009; Dieën et al., 2007). Toe landing produced more negative work by leading leg to reduce the kinetic energy that body gain, forward velocity, and prevented balance loss. Riener et al. (2002) found that stair descent showed a strong ankle power absorptions.

Table 2 showed the sagittal plane lower limbs power. Both groups presented positive hip and knee power at the beginning of stand phase, only ankle power was negative. It showed that ankle plantarflexor muscles lengthen (eccentric contraction) for absorption the energy body gains. Taichi group (-7.17 W/kg) had greater negative ankle plantarflexor power than control group (-4.92 W/kg), it seemed to indicate Taichi group had better ability to absorb energy and prevent balance loss while stepping down.

All of lower limb joints power in Taichi group were greater than Control group. It mean that Taichi group would has better ability to translate to forward movement (hip moment/power), to control body (knee moment /power) and to absorption energy (ankle moment / power) in sagittal plane.

**Table 7**
**Front peak lower limb joint moments compared to previous study**

| Peak moment (Nm/kg) | Hip Abductor | Knee Abductor | Ankle Invertor |
|---|---|---|---|
| Novak and Brouwer (2010) | 0.74 | 0.39 | 0.12 |
| present study **(taichi)** | 0.97 | 0.41 | 0.36 |
| present study **(control)** | 0.99 | 0.42 | 0.43 |

**Frontal plane:** No significant differences in hip abductor/ knee abductor/ ankle plantarflexor moment/ power between taichi group and control group were found during one stepping down. It mean that two group were similar in frontal plane kinetics. Compared to previous study (Table 7), our results were larger. It was because of step height (20cm vs. 15cm) and different experimental design. In order to close to the actual diary situation, stair descent then down to ground would be further investigated.
Our findings indicated similar hip and knee moments contributions (Costigan et al., 2002; Nadeau et al., 2003; Novak and Brouwer, 2010), and all of frontal lower limb joints power presented negative referred absorbing energy.

**CONCLUSION:** In summary, the present study shows that Taichi would better ability to translate to forward movement (hip moment/power), to control body (knee moment /power) and to absorption energy (ankle moment / power) in sagittal plane. Frontal plane kinetics represented similar between two groups.

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