INFLUENCE OF TAI CHI ON KINEMATICS DURING MULTI-DIRECTIONAL GAIT INITIATION

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INTRODUCTION
Tai chi intervention has been shown to be effective in improving the balance and reducing the falls among older adults [1]. Tai chi incorporates body movement in different directions, and attentional training to improve posture. Two common activities of daily living with these inherent qualities are gait initiation and turning. Gait initiation is the beginning of locomotion and involves transition from a stationary stable double limb support to a dynamic unstable single limb support. Turning is a motor task that is impaired in the geriatric population. Previous studies reported that older adults exhibit reduced spatio-temporal parameters and alternate strategies during turning while walking [2-3]. However, few studies have investigated the kinematics related to turning while initiating gait. Limited research investigating this multi-directional gait initiation task among older adults is particularly surprising because initiating stepping motion in different directions is a common activity of daily living (for example, walking away after closing the refrigerator door or choosing an aisle in supermarket). The purpose of the current study was to investigate the effect of tai chi on the kinematics of multi-directional gait initiation among older adults. We hypothesized tai chi will enhance performance of older adults in terms of kinematics during multi-directional gait initiation.

METHODS
Seven older adults (6 females; 76±4 years; 1.60±0.06 m; 75.0±18.5 kg) with difficulty walking a quarter mile or climbing a flight of stairs participated in the study. They practiced Yang style short form for one hour, 3 times a week for 16 weeks. They focused on physical relaxation and kinesthetic awareness of the body in space with a slow and relaxed rotation of the torso with shifting of the body weight. Testing was done before and immediately after the tai chi intervention Kinematic data were collected with a seven camera motion capture system using 25 retro-reflective markers (60Hz; Motion Analysis Corp., Santa Rosa, CA). Testing involved participants doing gait initiation in four directions: stepping 45° medially by crossing the swing leg over the stance leg (M45); stepping forward (FWD); stepping laterally 45° (L45); and stepping 90° laterally (L90). The forward stepping was performed first and order of the other directions was randomized. Participants performed three gait initiation trials for each direction at a self-selected pace, maintaining consistent stance-width and using the same self-selected leg to initiate gait. The dependent variables used were: spatio-temporal parameters (step length, velocity, time, time to heel-off and toe-off) for both the legs, and turning-related parameters (amount of rotation of head, trunk and pelvis at heel-off, toe-off and heel-strike events). All the trials were analyzed from the start of gait initiation. The step length, velocity and time were defined using the movement of the heel marker from the start of the gait initiation to heel-strike event. The head, trunk and pelvic angles were defined in the horizontal plane using the markers placed bilaterally on the temple, acromion process and anterior superior iliac spine respectively. All the dependent variable values were computed using custom MATLAB code (MathWorks Inc., Natick, MA). To assess the effects of tai chi intervention, a 2 (time: pre, post) x 4 (direction: M45, FT, L45, L90) repeated measures ANOVA was performed for the spatio-temporal measures. For the turning-related parameters, a 2 (time: pre, post) x 3 (segment: head, trunk, pelvis) ANOVA was performed for each turning direction.

RESULTS AND DISCUSSION
Spatio-temporal parameters: Significant interaction between time and direction was observed for step velocities of both the legs (P<=0.03; Figure 1A and 1B). After tai chi, participants stepped faster with
their swing leg (1st stepping leg) in three directions (M45, FWD, and L90) and decreased in L45 direction. Participants also stepped faster with their stance leg (2nd stepping leg) in the M45 and L90 directions but slower in the L45 direction after the intervention. Significant time main effect was found for the time to heel-off and toe-off events of both the legs ($P<0.02$; Table 1). Specifically, participants lifted their heel and toe faster after the tai chi intervention. Turning-related parameters: In the M45 direction, there was a significant interaction between segment and time at swing leg heel strike. After tai chi, participants reduced their head rotation while increasing their trunk and pelvic rotation (Figure 1C). Also, in the L90 direction, a significant time main effect showed that participants produced an overall lower segmental rotation with heel-off and toe-off events (Table 1).

Overall, the influence of tai chi seemed was dependent on the direction of gait initiation. In the M45 direction, participants completed their steps faster that may reflect a greater confidence in doing the task. Lower head rotation combined with greater trunk and pelvic rotation at the completion of swing leg heel-strike may suggest an alteration strategy with gait initiation. Though eye movement was not tracked, the changes in rotation may reflect lower reliance on visual input and greater kinesthetic awareness of the body segments during the challenging single support phase (on stance leg). Change of strategy was also seen in the L90 direction where the participants stepped faster while decreasing overall segmental rotation after the intervention. Perhaps they were more confident moving into the single stance phase with lower segment rotation. The impact of tai chi was small for gait initiation to the L45 direction. Participants only decreased stepping velocity suggesting a more cautious strategy. Alternatively, they may have perceived initiating gait in this direction as easier and were able to perform it more slowly than in the other directions.

CONCLUSIONS
In older adults with mobility disability, tai chi improved performance of multi-directional gait initiation. The extent of this impact was dependent on the direction-of gait initiation.

REFERENCES

ACKNOWLEDGEMENTS
Funding provided by the University of Florida Opportunity Grant and the National Institute of Health (Grant No. 5R03HD054594-02).

Table 1: Mean (SE) of dependent variables with significant main effects of time*($P<0.05$)

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>PRE</th>
<th>POST</th>
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<tbody>
<tr>
<td>Time to Swing Leg Heel-Off (s)</td>
<td>0.58 (0.02) *</td>
<td>0.51 (0.01)</td>
</tr>
<tr>
<td>Time to Swing Leg Toe-Off (s)</td>
<td>0.65 (0.02) *</td>
<td>0.57 (0.02)</td>
</tr>
<tr>
<td>Time to Stance Leg Heel-Off (s)</td>
<td>1.11 (0.02) *</td>
<td>1.04 (0.03)</td>
</tr>
<tr>
<td>Time to Stance Leg Toe-Off (s)</td>
<td>1.32 (0.01) *</td>
<td>1.23 (0.02)</td>
</tr>
<tr>
<td>Segment Rotation at Swing Leg Heel-Off in the L90 direction (°)</td>
<td>15.83 (2.87) *</td>
<td>8.24 (1.88)</td>
</tr>
<tr>
<td>Segment Rotation at Swing Leg Toe-Off in the L90 direction (°)</td>
<td>18.55 (3.61) *</td>
<td>10.37 (2.46)</td>
</tr>
</tbody>
</table>