JOINT LOADING INCREASED SIGNIFICANTLY IN DYNAMIC CONDITION

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SUMMARY
To study the effect Tai Chi pose on lower extremity, especially knee, joint loading, we have calculated average hip, knee, ankle joint loading during different squatting positions. Joint loading was measured by horizontal & vertical joint forces, and joint torques.

Results show knee joint loading increases with the depth of squatting posture. The maximum loading during dynamic conditions was much greater than static loading at the same joint angle.

Based on our observations, we suggest Tai Chi practitioners start Tai Chi practice with shallow squat and slow motion to avoid excessive joint loading and potential degenerative injury to the knee joint.

INTRODUCTION
Aging population is a worldwide phenomenon. Falls due to lack of balance and difficult in ambulation is a big problem among elderly population. Tai Chi has been used as effective tool for fall prevention through improve balance and mobility. Recent work in our lab has shown as little as six weeks of Tai Chi training can significantly improve functional gait among people with peripheral neuropathy [1]. Functional gait was measured with 6-minute walk and timed-up-and-go. Accompany with the functional gait improvement were reduced pain and increased foot sole sensation. We have been suggested that Tai Chi practice could lead to knee pain with excessive knee joint loading due to deep squatting position during Tai Chi practice. Although we did not observe increased knee pain prevalence in our study [2], we decided to investigate knee joint loading during different squat positions.

The purpose of the study was to investigate if knee joint loading increase significantly with deeper squat position. We also investigated if squatting motion, although slow, would add extra loading to the knee joint.

METHODS
22 male college students recruited as participants for the project. Their average age, height and body mass (+/- standard deviation) were 20.7(2.1) years old, 174.1(5.7) cm and 82.4 (18.9) kg, respectively. The project was approved by local Human Subject Review Board. The experiment procedure was explained to the participants. All questions answered to the participants’ satisfaction prior to sing the informed consent.

Data were collected at five different conditions. Participants were standing quietly at anatomical position during the first condition (Standing). The participants were asked to squat at three different depths with their thigh deviate from the upright position at 30, 60 and 90 degrees for the next three conditions. The thigh is parallel to the ground at the 90 degree condition. Participants squat down slowly from standing to the 90 degree position and then back up to standing position (Dynamic) during the last condition. The squatting down and standing up each took 5 seconds in a uniformed fashion.

Data were collected at a sampling rate of 240Hz from eight Vicon High Resolution Cameras (Vicon Motion, Los Angeles, CA, USA). The calibration volume for kinematic data collection was 6.0 X 2.0m X 2.0 m and centered at the center of the force platform. Ground reaction forces were collected using AMTI force platform (AMTI, Newton, MA, USA). The force signals were amplified and recorded by the Vicon System at a sampling rate of 960Hz.

Sagittal joint reaction forces at the hip, knee and ankle joint were calculated using inverse dynamics. Average sagittal plan hip, knee, ankle joint horizontal & vertical forces and torques were calculated along with the maximum force and torque during the dynamic condition.

Horizontal, vertical forces, torque for standing, 30, 60 90, and dynamic condition were statistically analyzed using one-way ANOVA with repeated measures for each of the three joints. Post-hoc analysis performed when necessary. Alpha level was set at .05.

RESULTS AND DISCUSSION
Average hip, knee ankle joint horizontal & vertical forces for the standing, 30, 60, 90 degree static positions, and the maximum forces for the dynamic conditions are presented in Figures 1 and 2. Figures 3 presented torque results for the same conditions.

Figure 1 displayed horizontal joint forces for each of the five conditions. All joint horizontal forces changed significantly with different conditions (P < .0001 for all three joints).

Hip joint forces increased with lower squat pose but no change observed between the 90 degree and dynamic conditions. Knee joint force increased with lower posture although no difference observed between 60 and 90 degree
positions. Maximum forces during the dynamic condition were much greater than knee joint forces in any other conditions. Ankle joint forces were consistent across all static conditions where maximum forces during dynamic conditions were greater than that of any static conditions.

The changes of vertical forces with different conditions are displayed in Figure 2. Vertical forces for all three joints changed significantly with different conditions (P < .0001 for all three joints).

Changes of joint torques with different conditions are showing in Figure 3. All torques changed with different conditions significantly (P < .0001 for all three joints).

Hip joint forces decreased with lower squat pose with similar values between 0 and 30 degree conditions. Dynamic conditions induced much greater forces at its maximum. Knee joint force decreased slightly with lower posture although no difference observed between 0, 30 and 60 degree positions. 90 degree position led to lower forces than 0 and 30 degree conditions but similar to 60 degree conditions. The maximum force during the dynamic condition was much greater than forces in any other conditions. Ankle joint forces were consistent across all static conditions where maximum forces during dynamic conditions were greater than that of any static conditions.

Changes of joint torques with different conditions are showing in Figure 3. All torques changed with different conditions significantly (P < .0001 for all three joints).

Hip joint extension torque increased with lower squat pose. Dynamic conditions did not induce greater torques even at its maximum, comparing to 90 degree condition; Knee exhibited a small flexion torque at standing position, but switched to extension torque with deeper squat pose although no difference observed between 60 and 90 degree positions. The maximum torque during the dynamic condition was much greater than torques in any other conditions. Ankle joint dorsiflexion torques were consistent across all static conditions where maximum torque during dynamic conditions were greater than that of any static conditions.

CONCLUSIONS
Tai Chi has been used for improving balance by many researchers with very good results. It has been suggested that the deep squat position employed by many Tai Chi practitioners could be problematic. We have studied joint loading when squat at three different depths, and compared the results with joint loading during standing and a slow squatting motion across the entire range from standing to deep squat. Our observations showed that increase squat depth led to increase of knee joint horizontal forces and joint extension torques, but decrease vertical forces. Although we ask the subjects move very slowly in the dynamic condition (5 second squatting down from standing to thigh parallel to the ground and then 5 seconds back up to standing), it had led to the greatest knee joint loading in both forces and the torque measurements. Therefore, to avoid potential knee joint discomfort, Tai Chi practitioners should practice with shallow squat and slow movements.

REFERENCES