The influence of total knee arthroplasty on dynamic postural control

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Introduction
Patients approaching Orthopaedic surgeons to discuss treatment options for total or partial knee replacements are getting younger and have higher expectations compared to patients of decades past. It has been reported however that contemporary arthroplasty procedures can result in functional deficiencies when treated patients are compared to matched controls (1). Typically patients will comment that their operated limb does not feel normal which may inhibit their return to activities.

Proprioception may be adversely impacted through both the disease process and arthroplasty. Less invasive surgical procedures and implants selectively treating diseased compartments are being developed and should be studied for their impact on proprioception. To date, most investigations documenting proprioception have investigated simple angular reproduction and threshold for motion, which typically involve open-chain kinematics.

The purpose of this investigation was to expand the study of proprioception to include a more functional assessment of the stability of postural control system during a series of closed chain movements that varied in difficulty. The tasks were specifically chosen to establish a continuum of movement types ranging from more static to more dynamic.

Methods
Subjects: Twelve participants gave their written informed consent to visit the lab on five occasions within 21 days. Six healthy individuals (2 males, 4 females; 58 ± 5 yrs) who had received one total knee arthroplasty (TKA) in the last 18-36 months served as our experimental group. The arthroplasty procedure used in these subjects kept the PCL intact. Six healthy adults (5 male, 1 female; 56 ±8 yrs) free of joint disease and balance disorders served as controls. Each subject was evaluated for a Knee Society Score by the same athletic trainer and filled out a KOOS survey during one of the five visits.

Protocol and instrumentation: Subjects performed each of the following five tasks while either standing on two portable force platforms (AccuSway, AMTI, Watertown, MA) or walking on a treadmill: 1) quiet stance for 15 seconds once with eyes and once with eyes closed, 2) knee bends at a self-selected pace for 15 seconds, 3) target pointing task that required them to touch a hand held pointer to a series of targets positioned on the floor in front of them, 4) center of pressure (COP) tracking task that required them to precisely match their COP to three computer-generated trajectories with real-time visual feedback. Each of these tasks were performed while standing on both legs as well as standing on either the right or left legs. Foot placement was kept constant for each subject within and across each visit.

5) Walking at a self-selected preferred walking speed on an instrumented force treadmill. Walking speed was kept constant across visits. The tasks orders were randomized among subjects.

An 8-camera digital Motion Analysis™ system was used to track the 3D movements of the trunk, pelvis, and lower extremities at 200 Hz. The analog output signals from each force platform and the instrumented treadmill were sampled synchronously with the kinematic data at 1600 Hz.

Analyses: All data were smoothed at 10 Hz. Ground reaction force data and medio-lateral and antero-posterior coordinates of the COP were used to assess postural and locomotor stability and within-subject limb asymmetries. During the non-locomotor conditions, traditional variables describing special properties of the COP pattern included: range, standard deviation, average velocity, and the area of a 95% confidence interval ellipse fit to the COP trajectory. Boundary-relevant variables included the average and minimum time to contact (TTC) (2), which indicate the temporal stability margins that subjects utilized. During walking, single and dual leg stance times were calculated as well as the difference in stance area when stepping from contra-lateral to ipsilateral and ipsilateral to contra-lateral limbs.

Reliability across visits was assessed by intra-class correlation (ICC) and between-limb and between group differences were assessed by a within-subjects repeated-measures ANOVA on the average values across visits.

Results
Reliability: Results indicate that a variety of measures were reliable across visits. All results reported had ICC coefficients between 0.60 and 0.93.

Between-limb differences: Neither group showed significant differences between their limbs during quiet stance, knee bends, and target pointing tasks (p's>0.05). However, during the COP tracking task, the TKA group showed lower minimum TTC when standing on their affected side compared to the non-affected side (p=0.02) indicating less effective control (2) when precise control of balance was required.

Between-group differences: During single leg knee bends, TKA's showed a higher average TTC than controls regardless of which foot, indicating a safer balance strategy utilized bilaterally (p<0.05).

During dual leg quiet stance, TKA's had greater COP range and standard deviation in the A/P direction than controls (p's<0.05) which was more pronounced with eyes closed.

During dual leg stance target pointing, TKA's had a greater COP range in the M/L direction indicating greater between-limb weight shifting during reaching than controls (p<0.05). This weight shift was not present during quiet stance or knee bends.

During dual leg quiet stance, knee bends, and target pointing load sharing between the limbs was similar between groups. However, during COP tracking, TKA's showed greater asymmetrical force patterns than controls (p=0.01), which placed more force on the non-affected limb.

During walking, TKA's showed greater between-limb asymmetries in single leg stance times and stance areas than controls (p's<0.01). All of these asymmetries indicated that TKA's spent more time and weight shifted toward the non-affected limb.

Discussion
The purpose of this study was to investigate the influence of TKA on postural control dynamics during a series of functional movements that elicited specific ‘self-imposed’ postural perturbations and therefore provide insight to how individuals maintain stability various everyday circumstances.

In many cases, TKA patients performed similar to the controls. However, TKA patients showed less effective control of balance than healthy individuals when standing on one foot regardless of which foot it was. Additionally, most differences between groups were not observed during single leg conditions but during dual leg conditions, a presumably more stable configuration and where both limbs contribute to control. These differences indicate that there may be centrally mediated changes in postural control strategies associated with unilateral TKA, particularly as tasks become more dynamic.

This study has identified circumstances where involved limbs differ from uninjured and where individuals who have undergone TKA differ from healthy individuals. Compromised stability during such movements may coincide with limitations in returning to functional activities and the perception of a "normal" knee.

References

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