BIOMECHANICAL CHANGES DURING STAIR CLIMBING AT THE KNEE, HIP, AND TRUNK AFTER TOTAL KNEE ARTHROPLASTY

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INTRODUCTION

Osteoarthritis (OA) is the most common cause of disability in the United States and its prevalence continues to increase [1]. Total knee arthroplasty (TKA) is used to treat end-stage knee OA and is generally considered successful; however, patients with OA and TKA tend to have decreased stair climbing performance compared to healthy adults [2].

Peak knee adduction moment (pKAM) provides an estimate of the balance between the medial and lateral compartments of the knee. Higher pKAM is associated with medial compartment knee OA but is typically reduced to match those of healthy controls after TKA [3]. Peak knee flexion angle (pKFA) and peak knee flexion moment (pKFM) are typically less in knee pathology populations compared to healthy controls [4]. Increased trunk lean is seen in OA and TKA populations and is thought to decrease demand at the quadriceps, but may also increase demand on the hip extensors [5, 6].

Although these abnormal kinematic and kinetic patterns are well defined in knee OA and TKA populations, it remains unknown whether TKA alters the biomechanics from the preoperative status, or if a patient’s pre-TKA biomechanical adaptations persist after TKA. We hypothesized that the biomechanical variables would change after TKA to more closely match those of healthy controls. Specifically, pKFA and pKFM would increase, while pKAM, trunk lean, peak hip flexion angle (pHFA) and peak hip flexion moment (pHFM) would decrease after TKA.

METHODS

20 patients (7M / 13F, age: 59.4 ± 6.1 y, mass: 92.0 ± 14.3 kg, ht: 1.7 ± 0.1 m) with predominantly medial compartment osteoarthritis were recruited by three orthopedic surgeons at The Ohio State University Wexner Medical Center and provided IRB-approved informed consent. All participants underwent a primary TKA, using a posterior stabilized (PS) prosthesis. (Zimmer, NexGen LPS Flex; Warsaw, IN). Biomechanical assessments were completed approximately 1 month before and approximately 6 months following surgery.

During the biomechanical assessment, each patient performed stair ascent and descent trials foot over foot on a custom made 3-step staircase (tread depth: 25.5 cm, tread height: 20 cm). The first two steps of the staircase were attached to force plates (Bertec 4060-10; Columbus, OH) embedded in the floor to capture stair climbing ground reaction forces at 1500 Hz. A modified point-cluster marker set in conjunction with a functional hip joint center was used to calculate lower extremity kinematics for the involved limb (10 Vicon MX-F40; Oxford, UK). Marker and force data were filtered with fourth order low-pass Butterworth filters at a cutoff frequency of 6 Hz. All moments were expressed as externally applied to the joint of interest and were normalized by body weight times height. Forward trunk lean angle was calculated using the vector created by the markers placed on the 10th thoracic and 7th cervical vertebrae relative to global vertical axis in the sagittal plane.

Only 17 of the 20 study patients (6M / 11F, age: 59.5 ± 6.5 y, mass: 91.8 ± 14.2 kg, ht: 1.7 ± 0.1 m) were able to descend the staircase foot over foot. Paired t-tests were used to test for a difference between each variable of the involved limb during stair ascent and descent, before and after TKA.
RESULTS AND DISCUSSION

During both stair ascent and descent, pKAM significantly decreased after TKA (Table 1), suggesting that TKA results in a more equally distributed load between the medial and lateral compartments. Although there was a significant change in pKFA and pKFM during stair ascent, the change was a decrease, which contradicted our hypothesis (Table 1). Hip biomechanics and trunk lean during both stair ascent and descent, and sagittal plane knee biomechanics during stair descent did not change after TKA (Table 1).

The results of this study suggest that many biomechanical adaptations utilized by patients with knee OA persist after TKA. It is possible that these biomechanical adaptations persist due to neuromuscular adaptations learned during the progression of OA that are not easily changed. Quadriceps strength deficits are still visible six months after TKA, and therefore, the trunk lean and hip extensors may still be used to compensate for quadriceps weakness. Clinicians should be aware of these potential adaptations when a patient increases stair climbing speed, and may want to focus on decreasing the role of the hip extensors, and increasing the role of the knee extensors. This could promote more normal knee biomechanics and ultimately improve stair climbing ability after TKA.

In addition to the measurement and estimation limitations associated with optical motion capture, force platforms and inverse dynamics, a potential limitation of this study is the fact that all participants received a PS prosthesis. Changes in femoral rollback have previously been observed with PS designs [5], but the in vivo functional consequences of altered femoral rollback remain an avenue for future investigation.

CONCLUSIONS

TKA using a PS prosthesis yielded sagittal plane stair climbing biomechanics that were not different from the biomechanics observed before surgery. The only result that supported our hypothesis was in the frontal plane where pKAM did decrease after TKA, indicating that intraoperative realignment and soft-tissue balancing corrected the varus deformity associated with medial compartment OA. Clinicians may want to focus decreasing the amount of trunk lean in patients with TKA to promote more normal kinematic and kinetic patterns. Further analysis is needed to differentiate between biomechanical adaptations used by patients with OA that persist after surgery and those that form due to the surgery itself.

REFERENCES


ACKNOWLEDGEMENTS

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Table 1: Mean±StDev for OA and TKA variables with p-value of the paired t-test

<table>
<thead>
<tr>
<th>Variable</th>
<th>Ascent (n=20)</th>
<th>TKA</th>
<th>p-value</th>
<th>Descent (n=17)</th>
<th>TKA</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pKFA (°)</td>
<td>72.7±5.8</td>
<td>68.4±5.8</td>
<td><strong>0.009</strong>*</td>
<td>89.3±4.4</td>
<td>87.4±7.8</td>
<td>0.422</td>
</tr>
<tr>
<td>pKFM (%bw*ht)</td>
<td>4.0±1.1</td>
<td>3.1±1.3</td>
<td><strong>0.039</strong>*</td>
<td>5.2±1.3</td>
<td>4.6±1.2</td>
<td>0.098</td>
</tr>
<tr>
<td>pKAM (%bw*ht)</td>
<td>2.5±1.2</td>
<td>1.9±1.1</td>
<td><strong>0.005</strong>*</td>
<td>3.0±1.5</td>
<td>1.8±1.1</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>pHFA (°)</td>
<td>73.0±5.8</td>
<td>70.8±4.9</td>
<td>0.213</td>
<td>33.3±7.5</td>
<td>32.4±7.4</td>
<td>0.677</td>
</tr>
<tr>
<td>pHFM (%bw*ht)</td>
<td>5.9±1.0</td>
<td>6.4±1.3</td>
<td>0.122</td>
<td>1.8±1.3</td>
<td>2.0±1.1</td>
<td>0.357</td>
</tr>
<tr>
<td>Trunk Lean (°)</td>
<td>26.6±7.6</td>
<td>23.5±5.9</td>
<td>0.211</td>
<td>14.8±5.7</td>
<td>13.4±5.5</td>
<td>0.312</td>
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