Tibiofemoral Rotation During Sit-to-Stand Activity After TKA

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Abstract

The objective of this study was to describe how tibiofemoral internal/external rotation varies in patients after total knee arthroplasty (TKA) when compared with control participants during a sit-to-stand (STS) maneuver. Motion analysis was used to measure internal/external knee rotation during STS in the control and TKA groups. Fourteen participants were included in the study. Six patients with 7 TKA knees (6 posterior stabilized and 1 cruciate-retaining TKA) were compared with 8 control participants with 8 knees from the current authors’ laboratory database. Participants performed 3 STS maneuvers, and the average internal/external rotation of the femur with respect to the tibia was compared. All control participants and 2 TKA participants had internal rotation of the femur with respect to the tibia, whereas 4 TKA participants had external rotation, and 1 had no rotation during STS. Further investigation into the surgical and patient- and implant-related factors that affect this resulting reverse kinematic profile seems to be warranted. [Orthopedics. 2016; 39(3):S41-S44.]
steps back with one foot while bending the knee of interest. The lunge maneuver does not occur nearly as often as rising from a seated position where both lower extremities are involved in a symmetric activity to move into a standing upright position. The kinetics and kinematics for these 2 types of activities will vary significantly.

The authors used state-of-the-art motion analysis technology to better understand how TKA affects knee motion when rising from a chair. TKA patients were analyzed during a STS activity to determine if the internal-external rotation of the TKA knees differed from the knees of control participants from the current authors’ laboratory database. The authors hypothesized that the TKA transverse plane kinematics (internal/external rotation of the knee) would differ from those of normal knees.

### Materials and Methods

This study was performed in the current authors’ motion analysis laboratory. The laboratory consists of 3 force plates (AMTI, Watertown, Massachusetts) and 10 video-based optoelectronic cameras (Qualisys AB, Gothenburg, Sweden). Institutional review board approval was granted, and informed consent was obtained prior to testing. The testing protocol was the same for both the TKA and control groups.

### Participants

Fifteen knees in 14 participants were analyzed for the study. Seven knees in 6 patients (3 male and 3 female) who had received a TKA (6 posterior stabilized [Vega Aesculap Implant Systems, Tuttingen, Germany], 1 cruciate-retaining, [Columbus, Aesculap Implant Systems, Tuttingen, Germany]) were compared with 8 (6 male and 2 female) control participants. The demographics of the TKA patients can be viewed in the Table. The mean body mass, height, and body mass index (BMI) of the TKA patients were 96.5 kg (SD, 20.6 kg), 1.7 m (SD, 0.1 m), and 31.9 kg/m² (SD, 5.0 kg/m²). The mean body mass, height, and BMI of control participants were 107.0 kg (SD, 18.5 kg), 1.6 m (SD, 0.1 m), and 31.5 kg/m² (SD, 5.0 kg/m²). Control participants had no history of lower extremity injury or pathology that may have affected the ability to perform the task.

### Data Collection

Retroreflective markers were placed over bony landmarks of the torso, pelvis, and lower extremities, and arrays of 4 markers were attached to the thighs and shanks using elastic wrap on each participant. Virtual markers were constructed at the left and right anterior superior iliac spine (ASIS) using a digitizing pointer (C-Motion Inc, Germantown, Maryland) for participants with BMI greater than 25 kg/m² whose additional mass might obscure pelvic markers. These virtual markers were identified relative to 3 visible, physical markers attached to the pelvis. A 10-camera, video-based optoelectronic system (Qualisys AB, Gothenburg, Sweden) was used for 3-dimensional motion capture. Participants were barefoot and seated on a 46-cm armless bench. Participants were instructed not to use their arms to push off the bench. All movement data were collected at 100 Hz and interpolated over a maximum of 10 frames. Movement data were low-pass filtered at 10 Hz using a fourth-order Butterworth digital filter.

### Table

<table>
<thead>
<tr>
<th>Patient</th>
<th>Gender</th>
<th>Age (y, mo)</th>
<th>Height (m)</th>
<th>Weight (kg)</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>TKA1 (R)</td>
<td>Male</td>
<td>57, 6</td>
<td>1.85</td>
<td>124.3</td>
<td>L ankle fusion (14 years), L knee OA/Pain. No L malleolus for marker. R leg longer than L. Squat—cannot keep L foot flat. STS OK.</td>
</tr>
<tr>
<td>TKA2 (L)</td>
<td>Male</td>
<td>56, 4</td>
<td>1.88</td>
<td>111.1</td>
<td>R ankle rebuilt (23 years) not fused—has motion. R toe locks when walking. R heel lifts slightly during squat. Squat—goes up on toes in deep flexion. R knee OA. L knee makes clicking sound at 70° flexion, not in extension.</td>
</tr>
<tr>
<td>TKA3 (L)</td>
<td>Male</td>
<td>51, 12</td>
<td>1.82</td>
<td>94.3</td>
<td>L PCL reconstruction. 12 years before TKA</td>
</tr>
<tr>
<td>TKA4 (R),(L)</td>
<td>Female</td>
<td>65, 12</td>
<td>1.60</td>
<td>66.2</td>
<td>OA in feet</td>
</tr>
<tr>
<td>TKA5 (R)</td>
<td>Female</td>
<td>66, 7</td>
<td>1.66</td>
<td>82.6</td>
<td>OA in toes</td>
</tr>
<tr>
<td>TKA6 (R)</td>
<td>Female</td>
<td>70, 2</td>
<td>1.60</td>
<td>100.7</td>
<td>OA in L knee-pain-stiffness, pain in L toes-stairs sideways 1 at a time</td>
</tr>
</tbody>
</table>

Abbreviations: L, left; OA, osteoarthritis; PCL, posterior cruciate ligament; R, right; STS, sit-to-stand; TKA, total knee arthroplasty.

*All patients have Aesculap posterior stabilized implant except TKA4(L), which is an Aesculap cruciate-retaining implant.*
Data Analysis

Only the STS portion of the task was analyzed. The beginning of the STS cycle was defined as the point at which the C7 marker began to move forward in the sagittal plane. The end of the STS cycle was defined as the point of maximal knee extension. The affected limb was analyzed for the TKA patients, and the right leg was selected for analysis in control participants. The musculoskeletal model used in this study was a rigid segment model consisting of 8 segments each linked by 6° of freedom joints, including the torso, pelvis, thighs, shanks, and feet (Visual 3D, C-Motion Inc, Germantown, Maryland). The CODA pelvis (Charnwood Dynamics Ltd, Leicestershire, United Kingdom) was used, and the hip joint center position was defined based on the equations described by Bell (1990). This model was used to calculate the flexion-extension, adduction-abduction, and internal-external rotation angles at the knee defined as the femur relative to tibia. Internal/external rotational angles were considered zero at full standing. Fisher’s exact test was used to test for differences in the proportion of knees moving externally and internally in each of the 2 groups (TKA and control) during STS.

RESULTS

Transverse plane motion of the femur was compared for each group (TKA and control). Femurs in the control group rotated internally with respect to the tibia as participants rose from the chair (Figure). Two of the TKA knees displayed a similar pattern of femoral internal rotation as the knees extended. However, 4 TKA knees displayed the opposite pattern, and 1 TKA knee showed no rotation during the STS maneuver. The 2 groups had a significant variations among participants comparing the position at the start of the STS maneuver (Fisher’s exact test $P<.01$). The average Knee Society Score for the 6 TKA patients who were all 1 to 2 years out from their TKA surgery was 95.4±3.2. The average range of motion of the TKA patients was 121.2°, while the average patient-reported satisfaction was 50/55 points.

DISCUSSION

Results show a reverse tibiofemoral rotational pattern in 4 of 7 TKA knees compared with 8 control knees. These results are similar to those reported in fluoroscopic studies in which a single leg lunge activity is performed. The more demanding STS activity analyzed in this report seems to result in similar findings to an asymmetrically performed lunge maneuver.

Several reports have determined that both surgical technique and implant design may influence the final motion patterns of a knee after arthroplasty. Some have shown that gap balancing techniques result in less kinematic variation, while others have shown how small variations in transverse plane positioning of implants may affect the final kinematic profile of a TKA. Keeping in mind how these many variables may play a role in TKA kinematics during demanding activities, it may be beneficial for implant designs to be more forgiving and less constraining in the transverse plane. Others may suggest that it means more accurate surgical techniques should be employed to assure proper rotation and a more functional means of implant positioning needs to be utilized during surgery. A previous report using kinematic modeling by 2 of the authors of this study has shown that variations of as little as 5° in the transverse plane between the femoral component and tibial baseplate can result in significant variations in kinematic profiles of the knee.

In this study, patients with a posterior stabilized implant (Vega, Aesculap Implant Systems, Tuttlingen, Germany) had a design that allowed minimized transverse plane constraint while the post and asymmetric cam are designed to guide a medial pivot. The design features of this implant are such that it

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**Figure.** The femur in control participants rotates internally relative to the tibia during sit-to-stand movement, whereas the knees of some total knee arthroplasty (TKA) patients exhibit the opposite rotational pattern. For ease of comparison, internal/external rotation has been normalized to zero at full extension.
imparts minimal constraint in the transverse plane. Therefore, the knee may be allowed to follow a path other than the guided medial pivot that the asymmetric cam is designed to mimic. Therefore, during an STS maneuver the knee is not forced to perform a medial pivot. The resulting kinematic profiles in this subset of patients seem to suggest that the design features do not constrain the knee to follow a medial pivot.

It should be pointed out that all of these patients had excellent range of motion and excellent Knee Society Scores. They all had high ratings in their patient satisfaction score as well (average of 50/55 points, range, 46-53). The presence of a reverse or paradoxical transverse plane rotation during an STS activity does not seem to affect the functional outcome of their TKA during the timeframe tested. Only long-term studies that investigate multiple parameters will determine if these transverse plane kinematics affect long-term survivorship.

One downfall of this study is the small number of participants. While only 7 post-TKA knees were studied, 4 had reverse tibiofemoral rotational patterns. In comparison, there have been reports that this pattern has been seen around 30% of the time, so the numbers of opposite transverse plane rotation are similar. Although the study may have a low power, it shows that for this implant design, transverse constraint is not inhibiting this tibial transverse rotation reported by others. Another downfall may be the use of gait markers vs fluorokinematic imaging. Although there may be a larger variation in reported motions using visual-marker-based investigations, this would not change the fact that opposite rotation of the tibia occurred in 4 out of the 7 knees that had received TKA.

Finding a similar reversal in STS is significant due to the necessity and frequency of the STS activity during daily living and warrants further investigation. More in-depth analysis incorporating the positioning of implants and surgical techniques may be warranted before a significant improvement in patient function and satisfaction after TKA can be realized. Intuitively, this may have to include robotic and functional positioning of implants based on patient-implant-design related factors.

REFERENCES