TOE-IN GAIT REDUCES THE FIRST PEAK IN THE KNEE ADDUCTION MOMENT DURING WALKING IN KNEE OSTEOARTHRITIS PATIENTS

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INTRODUCTION

The external knee adduction moment (KAM) typically shows two peaks during the stance phase of gait. The first, and larger, peak occurs during early stance and has been linked to the severity [1] and progression [2] of medial compartment knee osteoarthritis (OA), while the second, smaller peak occurs during late stance. Gait modification is a conservative method of reducing the KAM. Toe-out gait has been proposed as one type of gait modification, but this only lowers the second peak of the KAM [3]. Medial thrust gait has been shown to reduce both peaks of the KAM [4], but it also increases the external knee flexion moment, which can cancel out the medial compartment force reduction from a lower KAM [5]. Our aim was to use haptic (touch) feedback to train OA patients to reduce the first peak KAM without increasing the external knee flexion moment. We hypothesized that toe-in gait would move the knee medially, which would shorten the lever arm of the resultant ground reaction force (GRF) and reduce the KAM without increasing the knee flexion moment.

METHODS

Twelve subjects (5F/7M; age 60±12y; BMI 27±4) with medial compartment knee OA participated in this study. Subjects were required to have radiographic evidence of medial compartment knee OA, symptoms of medial compartment pain during the previous six weeks, and the ability to walk without assistance for at least 25 minutes. Gait retraining was focused on the leg with self-reported greatest knee pain. Three-dimensional lower extremity motion (60Hz) and forces (960Hz) were recorded using a Vicon motion capture system and a Bertec instrumented treadmill, respectively. Subjects walked at a self-selected pace with a previously-described marker set [6]. Subjects performed two trials: a baseline ‘normal’ gait followed by a toe-in gait in which they were encouraged to decrease foot progression angle by moving their toes inward. Gait kinematics and haptic feedback actuations were both conducted in real-time to help subjects learn to toe-in. A vibration motor was placed on the lateral shank and vibrated each time the frontal plane tibia angle was not decreased 0.75 deg from the baseline walking trial. Because foot progression angle and tibia angle are correlated [7], and because it is easier for subjects to sense vibrations from a motor placed on the shank than from one placed on the shoes [8], giving feedback on tibia angle is an effective method of training foot progression angle. Baseline and toe-in trials lasted two minutes each and the last 10 steps were recorded and averaged for analysis. Paired t-tests were used to detect differences between gait parameters at the p ≤ 0.05 significance level.

RESULTS AND DISCUSSION

Toe-in gait reduced the first peak of the KAM but did not increase the knee flexion moment (Table 1, Fig. 1). In early stance, the knee shifted medially toward the GRF (Fig. 2). This shortened the lever arm of the GRF and reduced the KAM. In late stance, the knee remained medially shifted but this shift was offset by a medial shift in the center of pressure. This moved the GRF medially, away from the knee (Fig. 2). Thus, there was no net difference in KAM or lever arm at the time of the second peak of the KAM (Table 1).

Toe-in gait moved the knee position medially, reducing the lever arm of the GRF in a similar way as medial thrust gait [4]. However, medial thrust gait requires the foot progression angle to remain constant which may be unnatural since tibia angle and foot progression angle movements are naturally correlated [7]. Achieving a medial thrust gait may also require an increased knee flexion angle and a corresponding elevated knee flexion moment [5]. Toe-in gait allows the foot and shank to move together and does not increase the knee flexion
Figure 1: Ensemble curves (n=12). Positive lever arm distance occurs when knee center is lateral of GRF. Toe-in gait reduced the KAM in early stance.

CONCLUSIONS

Toe-in gait reduces the first peak knee adduction moment, which has been linked to the progression and severity of knee OA. Teaching OA patients to

toe-in is a promising alternative to invasive surgical procedures.

REFERENCES


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Table 1: Kinematic and kinetic variables at the first and second peak knee adduction moment (KAM)

<table>
<thead>
<tr>
<th>At First Peak KAM</th>
<th>At Second Peak KAM</th>
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<tbody>
<tr>
<td><strong>Normal</strong></td>
<td><strong>Toe-In</strong></td>
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<tr>
<td>Knee Add. Moment (Nm/kg)</td>
<td>0.54 ± 0.24</td>
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<tr>
<td>Lever Arm (mm)</td>
<td>51.9 ± 20.7</td>
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<tr>
<td>Knee Flex. Moment (Nm/kg)</td>
<td>0.25 ± 0.25</td>
</tr>
<tr>
<td>Foot Progression Angle (deg)</td>
<td>3.3 ± 4.6</td>
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Figure 2: Components affecting the lever arm (solid line is normal gait, dashed line is toe-in gait, circles represent knee center position, arrows represent GRF line of action). In early stance, the tibia angle with toe-in gait causes a shift of the knee center medially which shortens the GRF lever arm. In late stance this is offset by the medial shift in center of pressure, which shifts the GRF medially.