INTRODUCTION

The prevalence and adverse effects of knee osteoarthritis (OA) are well documented [1]. It has been shown that individuals with knee OA exhibit abnormal kinetic and kinematic gait patterns [2]. While individual joint moments at the hip, knee, and ankle have often been examined during gait, few studies have investigated the intersegmental coordination and distribution of lower extremity joint moments. The total support moment has been shown to be a reliable method of measuring the kinetic synergy of the lower extremity [3]. While many knee OA studies have examined the affected limb, very few have evaluated the contralateral unaffected limb and the degree of symmetry [4]. The objective of our study was to investigate the symmetry of gait in persons with knee OA by examining the magnitude and distribution amongst joints of the peak total support moment between the affected and unaffected limbs. We hypothesized that the magnitude of the peak total support moment would be similar between limbs, but the distribution amongst joints would be asymmetric with the affected limb exhibiting reduced knee loading.

METHODS

Subjects were recruited locally and gave written informed consent to participate in the study. Twenty-three healthy subjects (age: 58.9 ± 10.1 yrs, BMI: 26.3 ± 4.5, K-L grade ≤ 1) and 23 knee OA subjects (age: 61.6 ± 8.6yrs, BMI: 28.9 ± 4.4, K-L grade ≥ 2) were analyzed. The affected limb was determined to be the more painful knee which also had an equal or greater K-L grade than the contralateral knee. Subjects walked at their self-selected walking speed on an instrumented, split-belt treadmill with dual force plates (Bertec Corp., Columbus, OH, USA). Three-dimensional kinematics were measured using an eight camera Motion Analysis reflective marker system (Santa Rosa, CA, USA). Marker data was processed using a 4th order, phase corrected, Butterworth filter with a cutoff frequency of 6 Hz (Cortex 1.0, Motion Analysis Corp.). Inverse dynamics were calculated using Orthotrak 6.3.4 (Motion Analysis) and all kinetic data was normalized to the individual’s body mass. All gait cycles for each subject were time normalized to 101 points and then averaged for each variable. Total support moment was calculated as the summation of the hip, knee, and ankle internal extensor moments for each time step [4,5]. Peak total support moment and relative joint contributions at the corresponding time step were used to evaluate differences in total support moment. In order to investigate within group statistical differences in peak total support moment and individual joint contributions between limbs, separate repeated measures ANOVAs were used. For between group comparisons, separate ANCOVAs with speed as a covariate were used. All statistical tests were performed using SPSS software version 18 (Chicago, IL, USA).

RESULTS AND DISCUSSION

In the healthy group, no significant differences were found between limbs for peak total support moment (p=0.474), hip contribution (p=0.197), knee contribution (p=0.550), or ankle contribution (p=0.782) (Fig. 1) (Table 1). This result is evidence of interlimb symmetry in healthy individuals. The peak total support moment and hip contribution for the knee OA group were not significantly different between the affected and unaffected limbs (p=0.157 and p=0.386 respectively) (Fig. 1) (Table 1). The knee OA group exhibited significant differences at the knee (p=0.016) and ankle (p=0.015) (Fig. 1) (Table 1). This suggests interlimb asymmetry exists
at the knee and ankle in individuals with knee OA. The results of the ANCOVAs comparing the OA unaffected limb with healthy limbs did not show significant differences in total support moment (p=0.547), or hip (p=0.679), knee (p=0.807), or ankle (p=0.840) contributions.

Table 1: Means and standard deviations for peak total support moment and individual joint contributions for the affected and unaffected limb of each group.

<table>
<thead>
<tr>
<th>Group</th>
<th>TSM (Nm/kg)</th>
<th>Hip (%)</th>
<th>Knee (%)</th>
<th>Ankle (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-Aff</td>
<td>1.21 ± 0.31</td>
<td>36.9 ± 18.3</td>
<td>48.9 ± 21.3</td>
<td>14.2 ± 15.2</td>
</tr>
<tr>
<td>H-UnA</td>
<td>1.19 ± 0.27</td>
<td>33.7 ± 19.3</td>
<td>51.2 ± 20.2</td>
<td>15.1 ± 13.7</td>
</tr>
<tr>
<td>OA-Aff</td>
<td>1.24 ± 0.45</td>
<td>29.4 ± 16.8</td>
<td>34.2 ± 19.6</td>
<td>36.4 ± 20.2</td>
</tr>
<tr>
<td>OA-UnA</td>
<td>1.16 ± 0.38</td>
<td>26.6 ± 19.2</td>
<td>48.9 ± 22.1</td>
<td>24.5 ± 9.0</td>
</tr>
</tbody>
</table>

Figure 1: Total support moment and individual joint contributions by group. *: p<0.05.

We observed redistribution of loading amongst joints within the OA affected limb, although the overall peak total support moment is similar to the unaffected limb. Consequently, this suggests that when the loading of the affected knee joint is reduced, the displaced loading is not shifted to the unaffected limb, but rather to the ipsilateral ankle joint. This is evidence of interlimb asymmetry with respect to joint moment distribution.

Self-selected walking speed was used for analysis in an effort to understand the most common loading strategy specific to each subject. The use of ANCOVAs with speed as a covariate statistically accounted for the significant difference in walking speed between groups. One limitation of this study was that the OA group was non-homogenous, meaning both unilateral and bilateral OA subjects were used.

While our results demonstrate that redistribution of joint contributions to the peak total support moment is a quality of OA gait, it is not clear as to whether this is a governing control strategy or a consequence of one of many other known compensatory strategies. Several of the gait strategies and qualities of individuals with OA such as decreased knee excursion [2], increased adduction moment [2], decreased walking speed [2,4], and decreased quadriceps strength [6] could be responsible for causing interlimb redistribution of joint moments. In future research we plan to analyze the kinematics, quadriceps strength, and spatiotemporal parameters in order to better understand the mechanisms of this compensatory joint moment redistribution.

CONCLUSIONS

Although peak total support moments are similar, individuals with knee OA exhibit interlimb asymmetry by significantly reducing knee and increasing ankle contributions in their affected limb. The unaffected OA limb is not significantly different from that of healthy individuals. Further research will be conducted to provide a more complete understanding of this asymmetric compensatory mechanism and will hopefully provide insight into disease progression.

REFERENCES


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