DO BIOMECHANICAL LOADS INCREASE DURING COMMON REHABILITATION EXERCISES IN OBESE INDIVIDUALS?

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INTRODUCTION

Squat and lunge are classic exercises that have become an integral part of lower-extremity strengthening and postoperative rehabilitation programs [1]. Despite their widespread use across age and BMI spectrums, very few studies have looked at the biomechanics of these exercises. Of existing studies, most have focused on younger, normal weight, populations. The influence of obesity on the performance of squat and lunge has not been documented [2]. Despite the potential for biomechanical differences from normal weight subjects, there are no published data showing that clinicians make different recommendations when prescribing exercises for obese individuals. The purpose of this study was to analyze and compare the biomechanics of obese and normal weight individuals, as measured by hip and knee moments, while performing common physical therapy rehabilitation exercises. Taking the biomechanical stresses and strategies into consideration during common exercises may help to inform rehabilitation approaches used for obese individuals.

METHODS

Ten obese (BMI > 30 kg/m²) female subjects age 37.4 ± 3.7 years, BMI 39.2 ± 3.7 kg/m² and ten normal weight (BMI<23 kg/m²), female subjects, age matched 38.1 ±4.5 years, BMI 21.6 ±2.3 kg/m², volunteered for the study. Height, weight, waist circumference; hip circumference and tibial length were recorded. Infrared emitting markers were applied to the lower limbs, pelvis, and trunk segments. Anatomical landmarks were digitized, relative to segment local coordinate systems, to create a link-based model. Three-dimensional motion analysis system (Optotrak, NDI) and force plates (Kistler) were used to collect kinematic and kinetic data. Testing sessions included two trials: squatting down, feet shoulder width apart with right foot on force plate and held for 3 seconds at 3 different knee angles: 60, 70, and 80 degrees (full knee extension being 0 degree). Real time feedback was used to achieve the desired knee angle. Forward lunging, held for 3 seconds, with the right lead foot, on the force plate at, 3 different distances between feet- heel to toe: 1, 1.1, 1.2 times subject’s tibial length.

DATA ANALYSIS

Visual 3D software (C-Motion) was used for processing. Mean values, over 3 s while holding the positions, were calculated for lower limb joint moments and support moments (summation of the lower limb extensor moments). The moments were normalized to body mass. A group (obese vs normal weight) by level of difficulty ANOVA was used to find differences in hip, knee and ankle moments across three levels of difficulty for the squat and lunge. Regression analysis was performed to find relationships between BMI or other anthropometric measures and extensor moments. SPSS 21.0 was used for analysis with p-value < 0.05.

RESULTS AND DISCUSSION

For the squat, hip and knee extensor moments in obese subjects were not different than normal weight subjects for all three levels of squat. However, ankle extensor moments were higher in obese subjects (Table 1). The support moment was higher in obese subjects, as compared to the normal weight subjects, for squat 70 (p = 0.03) and squat 80 (p= 0.01), but not different for squat 60 (p= 0.07). Increased support moment across the three lower limb joints points to the possibility of an overall higher kinetic joint stress in obese subjects during squatting.
For the lunge, hip extensor moments were greater in obese than normal weight control subjects for level 1, 1.1 and 1.2 (p-values: 0.004, 0.003 and 0.007 respectively). Knee and ankle extensor moments were not different (Table1). Support moments showed an overall group effect between obese and normal weight subjects (p=0.01).

Recent study looked at the effect of adding external load on the biomechanics of the lunge and showed an increase in hip extensor moments with little change in the knee contributions [3]. It could be argued that the external weight simulates the excess adipose tissue in obese subjects, causing a similar increase in hip moment.

Although there was no linear relationship, non-linear polynomial fit showed a moderate relationship between hip moments and BMI (Figure 2). Similar relationships were seen for squat 70 (r-square = 0.42) and squat 80 (r-square = 0.39). This points to the possibility of a ceiling effect in subjects with higher BMI’s. A similar ceiling effect has been postulated for gait in obese females with BMI greater than 30 kg/m^2 [4].

Table 1: Mean (standard deviation) hip, knee, ankle extensor and support moment for different levels of squat and lunge exercises. The measures highlighted in grey color showed significant differences (p<0.05).

<table>
<thead>
<tr>
<th>Moment(Nm/kg)</th>
<th>Squat 60</th>
<th>Squat 70</th>
<th>Squat 80</th>
<th>Lunge 1</th>
<th>Lunge 1.1</th>
<th>Lunge 1.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip</td>
<td>Obese</td>
<td>0.22 (.24)</td>
<td>0.29 (.28)</td>
<td>0.37 (.30)</td>
<td>1.32 (.27)</td>
<td>1.41 (.28)</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>0.12 (.17)</td>
<td>0.17 (.18)</td>
<td>0.24 (.18)</td>
<td>0.96 (.39)</td>
<td>1.07 (.38)</td>
</tr>
<tr>
<td>Knee</td>
<td>Obese</td>
<td>0.67 (.10)</td>
<td>0.73 (.12)</td>
<td>0.82 (.12)</td>
<td>0.53 (.15)</td>
<td>0.53 (.16)</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>0.59 (.22)</td>
<td>0.66 (.23)</td>
<td>0.75 (.26)</td>
<td>0.64 (.30)</td>
<td>0.56 (.29)</td>
</tr>
<tr>
<td>Ankle</td>
<td>Obese</td>
<td>0.28 (.16)</td>
<td>0.31 (.19)</td>
<td>0.34 (.19)</td>
<td>0.42 (.20)</td>
<td>0.43 (.20)</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>0.19 (.10)</td>
<td>0.20 (.13)</td>
<td>0.20 (.11)</td>
<td>0.45 (.26)</td>
<td>0.42 (.25)</td>
</tr>
<tr>
<td>Support</td>
<td>Obese</td>
<td>1.18 (.25)</td>
<td>1.33 (.32)</td>
<td>1.53 (.36)</td>
<td>2.33 (.36)</td>
<td>2.44 (.42)</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>0.92 (.27)</td>
<td>1.03 (.30)</td>
<td>1.18 (.34)</td>
<td>2.07 (.65)</td>
<td>2.05 (.64)</td>
</tr>
</tbody>
</table>

Figure 1: For the lunge, hip extensor moments were greater in obese than normal weight control subjects for level 1, 1.1 and 1.2 (p-values: 0.004, 0.003 and 0.007 respectively). Knee and ankle extensor moments were not different (Table1). Support moments showed an overall group effect between obese and normal weight subjects (p=0.01).

Figure 2: Non-Linear relationship between hip extensor moment for obese and normal weight subjects for squat 60.

CONCLUSIONS

The results suggest that obese individuals experience higher biomechanical stress than normal weight subjects while performing squat and lunge exercises. Non-linear associations were uncovered between anthropometric measures and kinetic measures, which makes the assessment of how best to approach exercise in this population even more challenging. Thus, while this study advocates for the need to consider obesity as a factor in exercise prescription, it acknowledges the apparent complexity that inhibits the understanding of issues that bias the kinetic measures.

REFERENCES