INTRODUCTION

Patellofemoral pain (PFP) syndrome accounts for a large fraction of knee disorders seen in sports medicine clinics [1]. A possible mechanism of pain is elevated stress at the cartilage-bone interface due to excessive lateral tracking of the patella. Delayed onset of vastus medialis (VM) activation in comparison to vastus lateralis (VL) is reported to cause lateral tracking of the patella [2], but evidence relating muscle activation delay to patellar maltracking is sparse. Broad categorization of diverse PFP subjects into a single group may be insufficient to explain the variability observed in VM onset delay [2]. The purpose of this study was to determine if precise classification of PFP subjects based on maltracking measures would lend insight into the effect of VM onset delay on maltracking of the patella. We hypothesized that two measures of patellar tracking, patellar tilt and bisect offset, correlate with VM onset delay in PFP subjects classified as maltrackers.

METHODS

We analyzed 15 (7M, 8F) healthy control subjects and 40 (21M, 19F) PFP patients with chronic pain (longer than 3 months) but no prior surgery or traumatic knee injuries. All subjects were between 18-42 years of age. The PFP subjects were diagnosed by an experienced clinician. Each subject was analyzed performing walking and jogging trials at self-selected speeds, and electromyography (EMG) recordings of the VM and VL muscles, 3D motion, and ground reaction forces were measured simultaneously in a gait lab. Anticipatory EMG activations during the swing phase prior to heel strike were evaluated (Figure 1). A muscle’s activation onset threshold was defined as the greater of 3 standard deviations (SD) of its resting value [3] and 2% of the larger of VM or VL muscles’ peak
activations; this provided a consistent method to record muscle activation onset prior to heel strike.

The PFP subjects were classified based on maltracking measures acquired from weight-bearing magnetic resonance (MR) imaging [4]. Images were obtained using a 0.5T Signa SP open-MRI scanner (GE Healthcare) fit with a backrest to stabilize a subject in an upright position (knee flexed ~5°). The scan parameters were described previously [5]. From an MR volume, an oblique-axial plane intersecting the center of the patella and the most posterior points of the femoral condyles was created to measure patellar tilt and bisect offset values. Patellar tilt is the measure of the angle formed by lines joining the posterior femoral condyles and the maximum width of the patella; bisect offset describes the percentage of the patella lateral to the midline of the femur [4]. Due to the non-Gaussian distribution of the data, a standard two-parameter Weibull distribution was fit to gender-specific tilt and bisect offset values and associated 75% confidence intervals were defined as maltracking thresholds; a PFP subject was classified as a maltracker if his/her tilt or bisect offset values were in the highest quartiles of the measured data.

RESULTS AND DISCUSSION

The thresholds for abnormal patellar tracking were 11.0° (tilt) and 68.1% (bisect offset) for males, and 15.3° (tilt) and 72.3% (bisect offset) for females. Approximately 38% (15/40) of PFP subjects were classified as maltrackers. Eight (4M, 4F) subjects had both abnormal tilt and abnormal bisect offset. Only maltracking PFP subjects with both abnormal tilt and abnormal bisect offset displayed significant relationships with VM onset delay; R² = 0.89 (p < 0.01) with tilt for walking (Figure 2, Table 1), and R² = 0.75 (p = 0.01) with bisect offset for jogging (not shown). Vastus medialis onset delays varied substantially among subjects. For walking trials, mean (SD) delays were 18 (57) ms and 9 (39) ms for the control and PFP groups, respectively, with no statistically significant difference between the means of the groups (p = 0.52).

CONCLUSIONS

The results demonstrate significant relationships between VM onset delay and patellar tracking only in maltracking subjects with both abnormal tilt and abnormal bisect offset. The other subject groups demonstrated large ranges of onset delays and maltracking values, but with no significant relationship between the two measures. A possible explanation is that VM onset delay is one of several factors affecting patellar tracking. Trochlear geometry and tension of the surrounding soft-tissue structure may also affect patella tracking. Further, differences in VM onset between studies [2] may be due to selection of PFP subjects; a study with a large number of subjects with high tilt and bisect offset values would likely measure significant delay in mean VM onset compared to healthy subjects.

A clinical intervention such as VM retraining may be effective in only a subset of PFP subjects, those with excessive tilt and excessive bisect offset measures. The results highlight the importance of appropriate classification of PFP subjects prior to selection of a clinical intervention.

REFERENCES


ACKNOWLEDGEMENTS

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Table 1: Relationship between VM onset delay and patella maltracking measures for walking trials.

<table>
<thead>
<tr>
<th>Group</th>
<th># of subjects</th>
<th>Tilt R²</th>
<th>Tilt p-value</th>
<th>Bisect Offset (BO) R²</th>
<th>Bisect Offset (BO) p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>15</td>
<td>&lt; 0.01</td>
<td>0.86</td>
<td>0.01</td>
<td>0.74</td>
</tr>
<tr>
<td>PFP</td>
<td>40</td>
<td>0.02</td>
<td>0.33</td>
<td>0.02</td>
<td>0.36</td>
</tr>
<tr>
<td>NonMaltrackers-PFP</td>
<td>25</td>
<td>0.02</td>
<td>0.50</td>
<td>0.08</td>
<td>0.17</td>
</tr>
<tr>
<td>Maltrackers-PFP (Tilt or BO)</td>
<td>7</td>
<td>0.12</td>
<td>0.45</td>
<td>0.37</td>
<td>0.14</td>
</tr>
<tr>
<td>Maltrackers-PFP (Tilt &amp; BO)</td>
<td>8</td>
<td>0.89</td>
<td>&lt; 0.01</td>
<td>0.43</td>
<td>0.08</td>
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