INTRODUCTION:
Knee osteoarthritis (OA) is associated with a number of biomechanical and neurological impairments, such as joint laxity and proprioceptive deficits, which contribute to functional limitations and disability [1]. These impairments may lead to further progression of the disease, by reducing joint stability and causing abnormal loading on the articular cartilage. Increased joint laxity (decreased stiffness) potentially places a greater burden on the musculoskeletal system to maintain joint stability and prevent harmful loading. In this context, enhancing proprioception may aid in developing a motor control strategy to compensate for changes in joint mechanics. Yet, as proprioception relies on sensory feedback from receptors in muscle, ligament, and skin [2], it is possible that the disease-related changes in joint stiffness also contribute to proprioceptive deficits. Understanding the association between proprioception and joint mechanics may help to guide interventions aimed at reducing pain and improving function in knee OA.

Previous attempts to correlate these two metrics may have been confounded by an experimental paradigm which likely targeted different joint tissues in the assessment of each quantity (i.e. sagittal plane proprioception and frontal plane joint laxity) [3]. Thus, this study sought to assess proprioceptive acuity and joint stiffness in the frontal plane in people with and without knee OA. We hypothesized that both metrics would be reduced in knee OA participants. Further, we hypothesized that there will be a negative correlation between proprioceptive acuity and passive frontal plane stiffness, reflecting a reduction in the mechanical input to sensory afferents. If this is the case, future interventions may aim to enhance sensory inflow during neuromuscular training to reduce the rate of progression of the disease.

METHODS:
All experimental procedures were approved by the IRB. Thirteen persons with moderate unilateral or bilateral tibio-femoral knee OA (7 males, 6 females) and 14 age- and gender-matched healthy control subjects (7 males, 7 females) with no pain or symptoms of knee OA participated in the study after providing informed consent. The more affected limb of knee OA subjects and the right leg of control subjects were tested. Subjects were seated in an experimental chair with the knee of the affected limb of knee OA subjects and the right leg of control subjects participating in the study after providing informed consent. The more affected limb of knee OA subjects and the right leg of control subjects were tested. Subjects were seated in an experimental chair with the knee at neutral flexion/extension. The ankle was placed in an aircast connected by a rigid cantilever beam to a servomotor actuator.

To determine frontal plane stiffness, the joint was stretched at a constant velocity (3°/s) up to 7° in varus and valgus. Joint stiffness was estimated as the slope of the resulting frontal plane torque-angle relationship at 5° of varus and valgus excursion (terminal stiffness) as well as between -1° and 1° of rotation (neutral stiffness). Stiffness was normalized by the product of subject mass (kg) and height (m) prior to analysis [4] to account for anthropometric differences.

Proprioceptive acuity was assessed using the threshold to detection of passive movement (TDPM). The servomotor rotated the knee at 1°/s and subjects were instructed to press a handheld button as soon as the movement was detected. TDPM was defined as the position difference of movement. Larger TDPM values indicate worse acuity. At least five trials were performed in varus and valgus in a randomized order and the average TDPM in each direction was used in further analysis.

Two-factor (gender and study group) analyses of variance (ANOVA) were performed for joint stiffness and TDPM estimates in varus and valgus. Post-hoc Tukey-Kramer multiple comparisons were used when a significant main effect was found. Linear regression analyses were performed between TDPM and the corresponding stiffness estimates to explore the association between these metrics. The sample size afforded sufficient power to detect correlations of r ≥ 0.6.

RESULTS:
Passive stiffness and TDPM results are presented in Figure 1. A significant effect (P<0.05) of gender and subject group was noted for neutral stiffness as female OA subjects had significantly decreased stiffness compared to OA males and control females. In valgus, a main effect of study group but not gender was found, as the OA group had decreased joint stiffness compared to the control group. In varus, a significant effect of gender but not group was found with OA females demonstrating decreased stiffness compared to OA males. TDPM in varus and valgus was found to be increased in the knee OA group compared to the control group, indicating reduced proprioceptive acuity. However, no significant differences were found between genders.

A significant negative correlation was observed between terminal varus stiffness and TDPM in the OA group (see Table 1). However, results of the linear regression analysis indicated insignificant correlation between the remaining pairs.

Table 1. Correlation coefficients, r, (and P-values) between stiffness estimates (N·m/°·kg-m) and TDPM (*)

<table>
<thead>
<tr>
<th>Stiffness</th>
<th>Valgus</th>
<th>Varus</th>
<th>Terminal stiffness</th>
<th>Valgus</th>
<th>Varus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OA</td>
<td>Control</td>
<td>OA</td>
<td>Control</td>
<td></td>
</tr>
<tr>
<td>Varus Valgus</td>
<td>Valgus Varus</td>
<td></td>
<td>OA</td>
<td>Control</td>
<td></td>
</tr>
<tr>
<td>Neutral</td>
<td>-0.40 (0.18)</td>
<td>-0.36 (0.22)</td>
<td>-0.10 (0.74)</td>
<td>-0.65 (0.01)*</td>
<td></td>
</tr>
<tr>
<td>Terminal</td>
<td>0.02 (0.95)</td>
<td>-0.29 (0.3)</td>
<td>-0.11 (0.70)</td>
<td>-0.27 (0.36)</td>
<td></td>
</tr>
</tbody>
</table>

* Significant correlation (P<0.05)

DISCUSSION:
To our knowledge, this is the first examination of proprioceptive acuity and passive joint stiffness within the frontal plane of movement in knee OA. Measuring both metrics in the same plane of movement allows for a more direct assessment of the association between proprioception and the intrinsic mechanics of the joint. Our results indicate that passive valgus and neutral joint stiffness as well as proprioceptive acuity were decreased in the OA population compared to the healthy control subjects. While negative correlations were observed between stiffness and TDPM, the majority of associations were insignificant and the magnitude of the correlation coefficients was relatively low. This suggests that the changes in frontal plane joint stiffness contribute to, but cannot entirely explain, proprioceptive deficits in knee OA. Other neurological factors, such as a reduction in the density of mechanoreceptors, or changes in central sensitivity may be the primary contributors to proprioceptive deficits in knee OA. Based on these preliminary results, future neuromuscular training paradigms may seek to focus on enhancing higher order processing rather than local sensory feedback.

REFERENCES: