DIFFERENCES IN GLENOHUMERAL BONE AND CARTILAGE MORPHOLOGY BETWEEN ADULT-ONSET AND CHILDHOOD-ONSET MANUAL WHEELCHAIR USERS: A MULTI-MODAL QUANTITATIVE IMAGING STUDY

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INTRODUCTION: Debilitating shoulder pain is prevalent among wheelchair users, and impairment due to shoulder pain is of great functional consequence because manual wheelchair users rely on their upper limbs for maintaining their independence. However, the causes of wheelchair users’ shoulder pain remain unknown. Shoulder pain is reported to be greater in individuals who began wheeling after skeletal maturity (>16 yrs adulthood-onset, AO) than in individuals who began wheeling prior to skeletal maturity (<16 yrs childhood-onset, CO). One potential explanation for this difference is functional adaptation of bone and cartilage to wheelchair use. Bone adapts to loading, especially prior to skeletal maturity. Cartilage appears to adapt to loading prior to chondral maturity (~18 yrs), however, to our knowledge, mature cartilage does not adapt to loading. It is unclear whether loads from manual wheelchair use affect glenohumeral bone and cartilage morphology.

This cross-sectional pilot study was performed to assess the feasibility of determining whether there are differences in glenohumeral bone and cartilage morphology between CO and AO wheelchair users. We assumed that the CO had an adaptational advantage over the AO because the former began wheeling prior to skeletal maturity. Based on this assumption, we hypothesized that glenohumeral volumetric bone mineral density, glenoid subchondral bone normalized cross-sectional area, and glenohumeral cartilage volume would be higher in the CO than in the AO, relative to their able-bodied matched controls.

METHODS: This study included four distinct subject groups: childhood-onset wheelchair users (CO, nCO=3) and able-bodied age- and gender-matched controls (CO controls, nCC=3), adulthood-onset wheelchair users (AO, nAO=5) and able-bodied age- and gender-matched controls (AO controls, nAC=5) (Table 1). Controls were included to account for known age-related changes in bone density. All wheelchair users had wheeled independently for at least 10 years. This study was approved by our institutional ethics board. All subjects were of legal age (>18 yrs) and gave informed, written consent.

RESULTS: Compared to the AO groups, the CO groups in our study had significantly higher (p=0.05) glenoid subchondral nCSA (Figure 1) and non-significantly higher humeral head trabecular vBMD and glenoid trabecular vBMD (Table 2). Sample size calculations predict that 22 subjects (per group) are required in a cross-sectional study that would find higher humeral head and glenoid trabecular vBMD in CO subjects.

**Figure 1: Two-way ANOVA main effect of age group on glenoid nCSA.**

**Table 1: Demographic Data for the Subject Groups**

<table>
<thead>
<tr>
<th>Subject Groups</th>
<th>Age (yrs)</th>
<th>Wheelchair Use (yrs)</th>
<th>Gender (M/F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO Controls</td>
<td>26 (2)</td>
<td>16 (6)</td>
<td>2 M, 1 F</td>
</tr>
<tr>
<td>AO Controls</td>
<td>52 (12)</td>
<td>24 (8)</td>
<td>3 M, 2 F</td>
</tr>
<tr>
<td>AO Controls</td>
<td>53 (12)</td>
<td>N/A</td>
<td>3 M, 2 F</td>
</tr>
<tr>
<td>CO Controls</td>
<td>26 (2)</td>
<td>N/A</td>
<td>2 M, 1 F</td>
</tr>
<tr>
<td>AO Controls</td>
<td>79 (29)</td>
<td>173 (56)</td>
<td>653 (120)</td>
</tr>
</tbody>
</table>

**Table 2: Mean (SD) bone and cartilage measurements in childhood-onset (CO) and adulthood-onset (AO) wheelchair users and controls.**

**DISCUSSION:** The difference in nCSA between the wheelchair users and their matched controls was greater for the CO groups than for the AO groups, which suggests that the higher nCSA in the CO wheelchair users is related to adaptation and not to age. The difference in vBMD between the wheelchair users and their matched controls was similar for both CO and AO groups, suggesting that the non-significantly higher vBMD in the CO groups is due to known-age related changes in bone density rather than to differences in the functional adaptation of bone to wheelchair use. Small effect sizes and large variances in humeral and glenoid cartilage volumes suggest that further study of these parameters would not provide insight into wheelchair users’ shoulder pain.

In addition to our novel combination of qCT and qMRI to quantify glenohumeral bone and cartilage morphology, this is the first assessment of glenohumeral cartilage at 3T MRI. Gaining a better understanding of how glenohumeral bone and cartilage adapt to wheelchair use is a step towards mitigation and prevention of shoulder pain in wheelchair users, with implications for wheelchair design and rehabilitation protocols.


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