A Biomechanical Analysis of Cervical Spine Posture using Geometric Morphometrics

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Tablet ownership in the United States has increased rapidly in the past decade. With this increase in tablet use comes increased levels of neck flexion compared to using a desktop or laptop. These neck postures have been linked to increased neck pain. Importantly, tablet viewing postures can be achieved in multiple ways and could be determined by either the morphology of the individual or extraneous factors. In this study, we aim to preliminarily evaluate how neck postures vary among individuals with the goal of further examining how neck morphology and posture related to other factors may influence tablet use posture. We utilize geometric morphometric approaches to evaluate the biomechanics of the cervical spine and skull in various neck postures; this technique is excellent for evaluating shape variation and has not been extensively applied in the biomechanical literature. Lateral-view radiographs of 22 college-aged subjects (10 female, 12 male) were taken in 5 neck postures: neutral, maximum neck flexion, upright seated, semi-reclined seated viewing, and reclined seated viewing. In addition to the radiographs, a participant survey was completed to indicate the presence or absence of discomfort and/or abnormalities of the neck and mandible (e.g., pain, clicking/popping at the TMJ, stiffness). 87 two-dimensional landmarks were placed on the cervical spine and skull on each radiograph, to allow for shape variations related to age, sex, weight, and height, and the presence of symptoms related to temporomandibular joint disorder (TMD). Separate one-way ANOVAs were performed for each neck posture to indicate that every posture but neutral is achieved differentially by sex, with males tending to flex more at the atlanto-occipital joint than females, and females showing greater protrusion in the neck than males. We further observed a significant relationship between neck flexion and height, suggesting that neck length may influence how subjects adopt specific postures. Though we did not observe a significant relationship between neck morphology or postures and the presence of TMD, these findings may provide some insight into why females experience higher levels of TMD, given that increased neck protrusion has been linked to increased stress on the TMJ and jaw. This study establishes a framework for future research that focuses on evaluating how neck postures vary in relation to TMD.

Introduction

With the increase of handheld device use (i.e., tablet) usage, there has been a correlating increase in neck flexion. This increased flexion has led to a greater prevalence of neck pain, a common manifestation of cervical spine disorder (CSD). Previous studies (Ribeiro et al. 2015, Paolo et al. 2013) have demonstrated a relationship between CSD and temporomandibular joint disorder (TMJD), but the recent manifestation of this phenomenon equates to a minimal amount of research on how these two conditions are influenced by neck posture while using this type of device. The goal of the research presented here was to evaluate variation in cervical spine morphology and examine factors (e.g., sex and/or height) that may influence patterns of flexion during tablet use.

Materials and Methods

- 12 male and 10 female college-aged subjects screened for presentation of TMD
- 5 radiographs per subject, with one in each position: neutral, full neck flexion, upright seated, semi-reclined (35\(^\circ\)), and reclined (30\(^\circ\))
- 43 two-dimensional landmarks and 44 sliding semi-dimensional landmarks measured during each X-ray using tpsDig
- Geometric morphometric techniques were used to examine variation among subjects and between neck postures- this included generalized Procrustes, principal components, and thin-plate spline analyses
- ANOVA and multivariate regression were used to examine the correlation between morphology and other factors

Table: TPSAs for PC2, PC3, and PC4

<table>
<thead>
<tr>
<th>Posture</th>
<th>TPSA Values</th>
<th>Morphology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral</td>
<td>0.85</td>
<td>Negative</td>
</tr>
<tr>
<td>Upright</td>
<td>0.87</td>
<td>Positive</td>
</tr>
<tr>
<td>Semi-Reclined</td>
<td>0.90</td>
<td>Mandibular shape/robusticity and neck posture</td>
</tr>
<tr>
<td>Reclined</td>
<td>0.92</td>
<td>Mandibular shape, mandibular shape, and inferior cervical curvature</td>
</tr>
<tr>
<td>Full Flexion</td>
<td>0.94</td>
<td>Cervical and hyoid morphology/position</td>
</tr>
</tbody>
</table>

Discussion and Conclusion

These data show trends in cervical spine posture as related to subject sex and height. Analyses of shape changes related to varying degrees of neck flexion (as would be experienced by the subject using a tablet) indicate that the amount of flexion at the atlanto-occipital joint (AOJ) vs. neck protrusion varies substantially across subjects. Taller individuals experience more flexion at the AOJ than shorter individuals, who instead experience increased mandibular protrusion as they flex to accommodate the postures. Notably, we observed a correlation between participant height and participant sex-males tend to be taller than females- allowing us to conclude that these factors are inter-dependent. No significant relationship was established between any of the defined variables and TMJD presentation. Further research should include a larger number of subjects with known TMJD-related concerns, as well as individuals of both sexes with similar height and/or height (taller females and shorter males). This would allow for further distinction between sex and height in terms of the mechanism of cervical flexion when using a handheld device.

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