

# A Biomechanical Analysis of Cervical Spine Posture using Geometric Morphometrics

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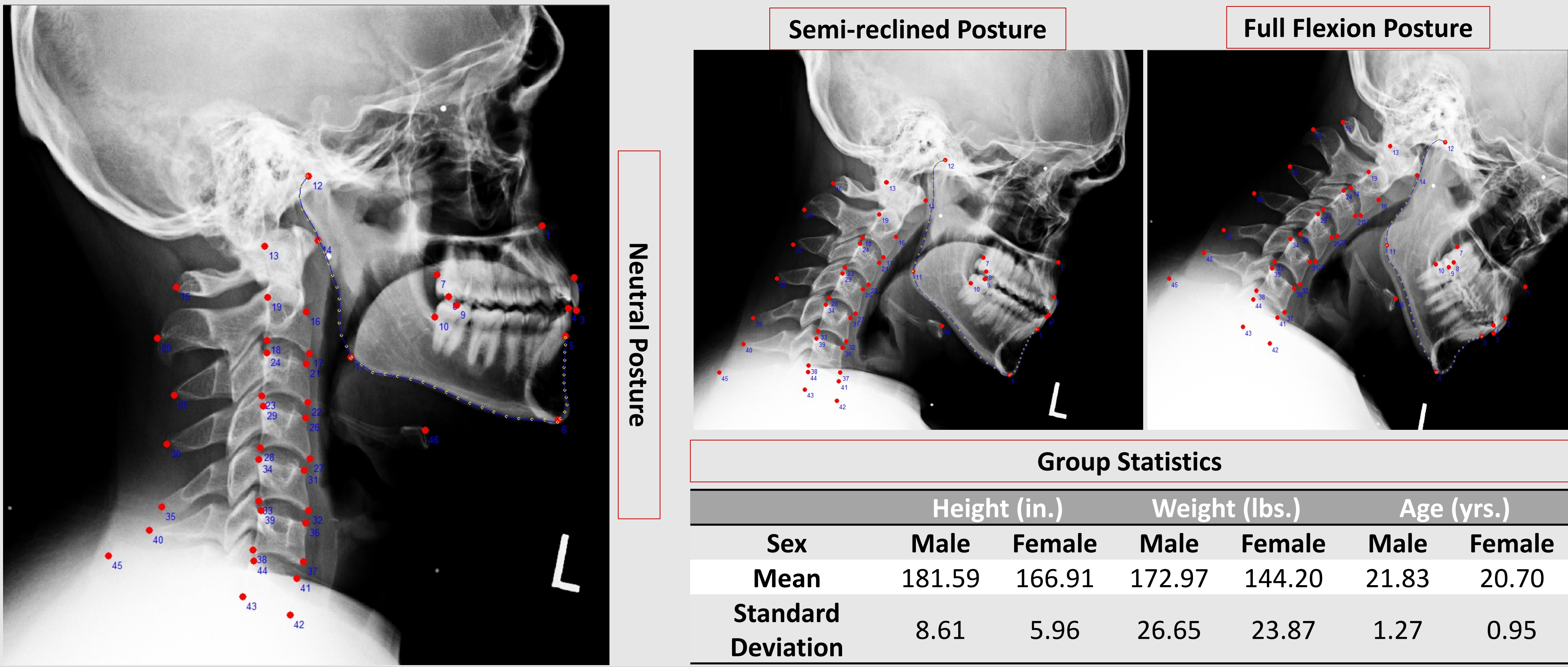
Tablet ownership in the United States has increased rapidly in the past decade. With this increase in tablet use comes increased levels of neck flexion compared to using a desktop or laptop. These neck postures have been linked to increases in neck pain. Importantly, tablet viewing postures can be achieved in multiple ways and could be determined by either the morphology of the individual or other 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 postures may be related to other factors, such as sex and height of the subject. We utilize geometric morphometric methods 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 seated in 5 neck postures: neutral, maximum neck flexion, upright seated tablet viewing, semi-reclined tablet viewing, and reclined tablet 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 TMD, stiffness). 87 two-dimensional landmarks were placed on the cervical spine and skull on each radiograph signifying osteological features of the face, positions of the posterior-most occlusal molars, the mandible, and the morphology of the cervical vertebrae. Variation among positions and subjects was visualized using principal components analysis and thin-plate spline analysis. A series of ANOVAs and regression models were performed to examine the relationships between morphology and other factors, such as sex, weight, and height, and the presence of symptoms related to temporomandibular joint disorder (TMD). Separate one-way ANOVAs for each neck posture indicate that every posture but neutral is achieved differently 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 rates of TMD, given that increased neck protrusion has been linked to increased stresses 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 (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 (TSD), but the recent presentation of this phenomenon equates to a minimal amount of research on how these comorbid clinical 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 neck flexion during tablet use.**

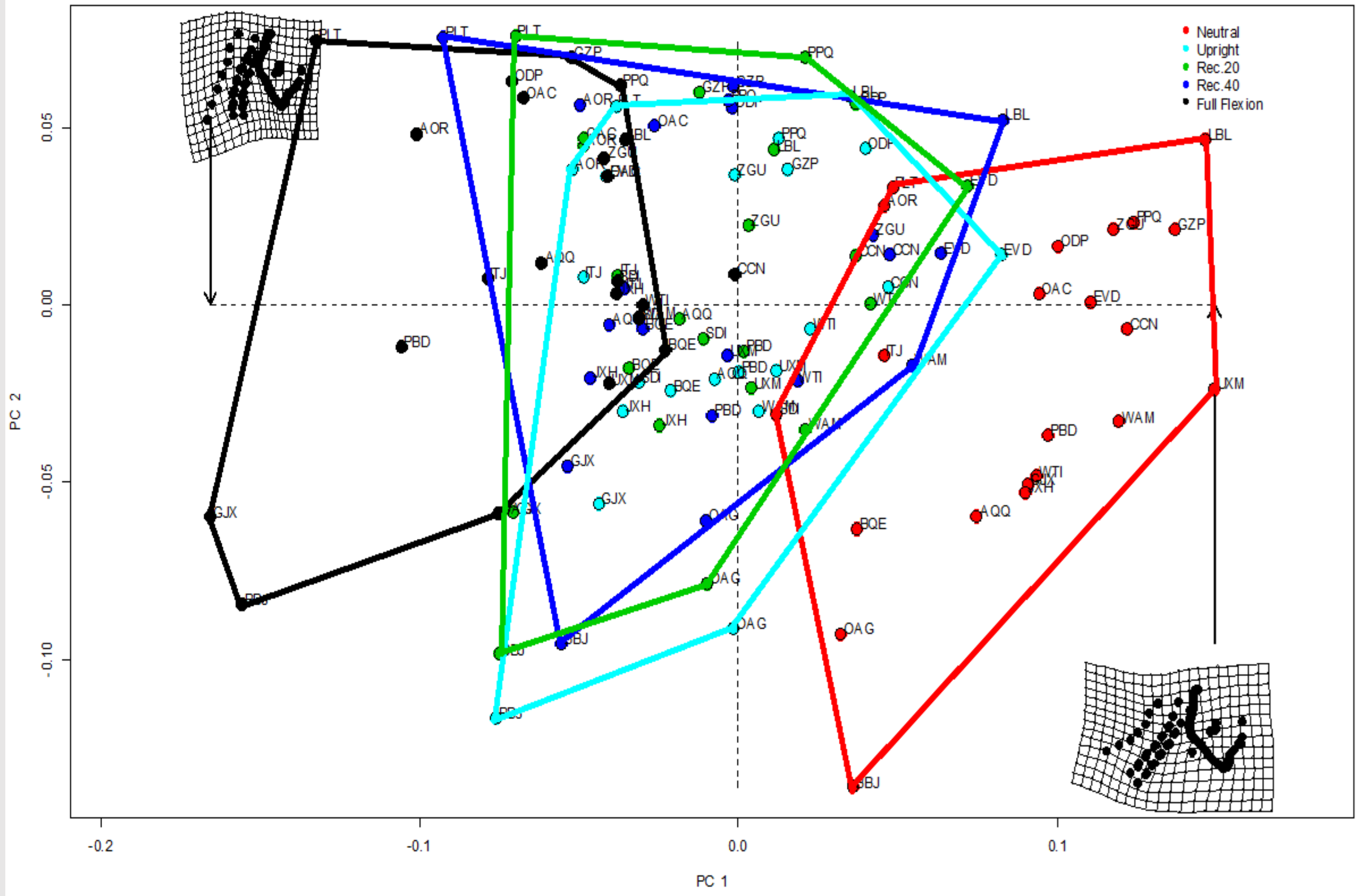
## Materials and Methods

- 12 male and 10 female college-aged subjects screened for presentation of TMD
- 5 radiographs/subject, with one in each position: neutral, full neck flexion, upright seated, semi-reclined (15°), and reclined (30°)
- 43 two-dimensional landmarks and 44 sliding semi-landmarks placed on 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



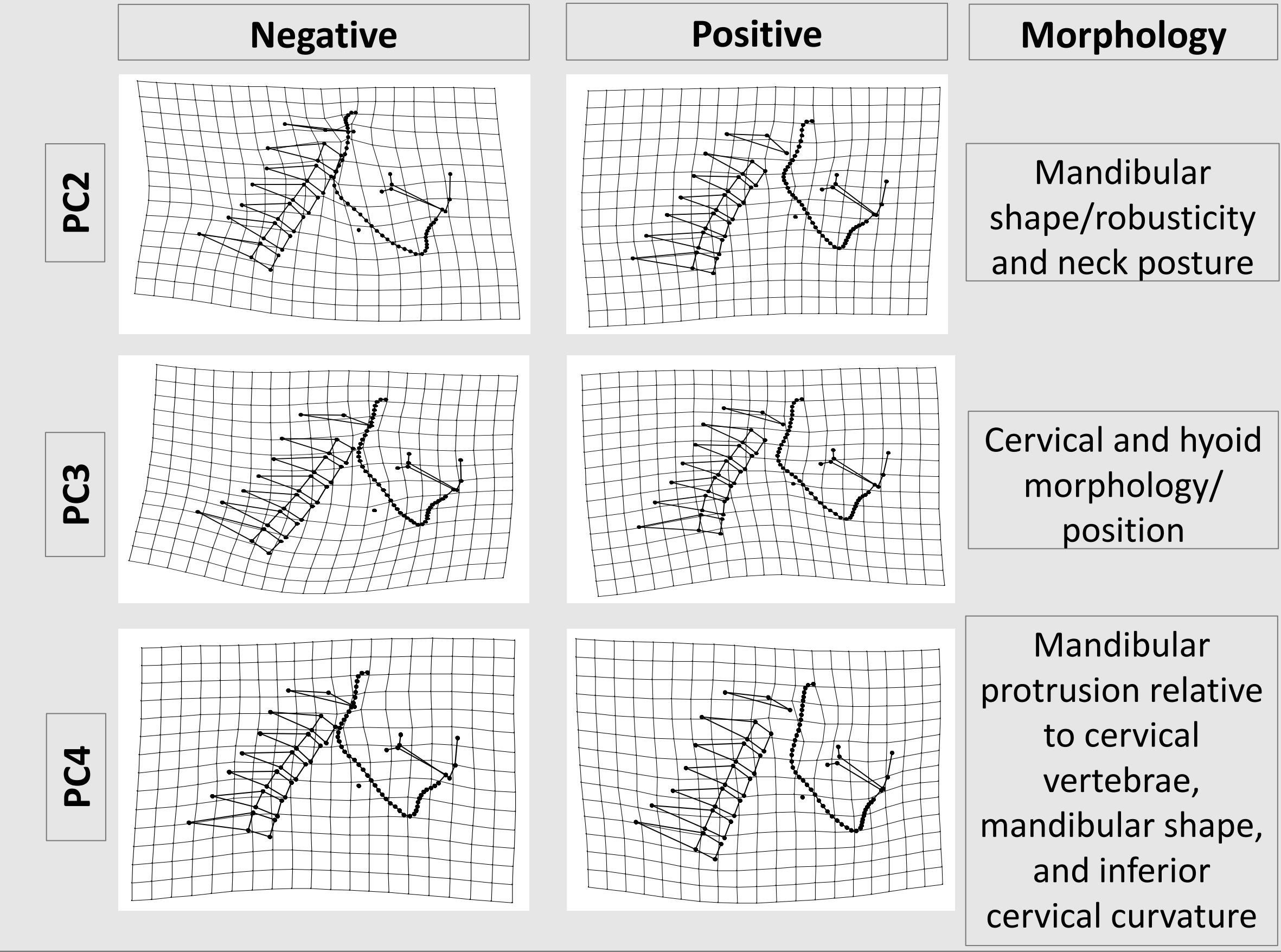
## Results

### PCA of all analyses with convex hulls and corresponding TPSAs for PC1



PC1 = 40.7%, PC2 = 21.4%, PC3 = 12.7%, PC4 = 4.4%  
PC1 represents neck flexion/posture

### TPSAs for PC2, PC3, and PC4



### Procrustes distance results; distance values in upper triangle and p-values in lower triangle

	Neutral	Upright	Semi-Reclined	Reclined	Full Flexion
Neutral	--	0.096	0.103	0.103	0.159
Upright	<0.0001	--	0.014	0.020	0.065
Semi-Reclined	<0.0001	0.977	--	0.012	0.058
Reclined	<0.0001	0.698	0.995	--	0.058
Full Flexion	<0.0001	<0.0001	0.0002	0.0001	--

- Significant differences between neutral posture and all other postures
- Significant difference between full flexion and all other postures
- Semi-reclined, reclined, and upright postures are not significantly different in shape

### P-values of ANOVAs and regressions, analyzed per posture

	ANOVA		Multivariate Regression (Shape vs.)		
	TMD	Sex	Centroid Size	Weight	Height
Neutral	0.925	0.069	0.437	0.117	0.053
Upright	0.626	0.028	0.269	0.092	0.008
Semi-Reclined	0.657	0.026	0.265	0.047	0.001
Reclined	0.770	0.002	0.297	0.092	0.001
Full Flexion	0.762	0.010	0.284	0.190	0.003

- Neutral** – variation in morphology along PC1 attributed to cervical spine length/curvature and position of mandible (relative to cervical spine)
- Upright** – variation in morphology related to sex (partially due to differences in mandibular shape) and height
- Semi-reclined** – variation in morphology related to sex, height, and weight
- Reclined** – variation in morphology related to sex and height
- Full Flexion** – variation in morphology related to sex and height

## 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 if the subject were 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 TMD presentation. Further research should include a larger number of subjects with known TMJ-related concerns, as well as individuals of both sexes with similar heights (or 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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Paolo CD et al.. 2013. Epidemiological analysis on 2375 patients with TMJ disorders: basic statistical aspects. Annali di Stomatologia IV(1): 161-169  
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