FEMALE NECKS ARE NOT UNIFORMLY SCALED VERSIONS OF MALE NECKS

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INTRODUCTION

Females have an increased incidence of whiplash injury (Harder *et al.*, 1998) and neck pain (Mäkelä *et al.*, 1991). Biomechanical analyses of these gender differences has been limited by the lack of an accurate model of the human female neck. It is not known whether female models can be developed by simply scaling male neck geometry, or if it is necessary to develop a unique model of the female neck.

The goal of this study was to quantify differences in head and neck geometry and neck strength in male and female subjects size-matched for height and neck length. We hypothesized that women have smaller external head and neck dimensions, smaller vertebral dimensions, and lower neck strength than men. If these hypotheses are true, it will necessitate the development of a gender-specific musculoskeletal model for females.

METHODS

Fourteen pairs of men and women with differences in standing height and neck length (vertical distance from the C7 spinous process to the tragus) within ±0.5 cm were selected for paired analysis.

Lateral and anterior-posterior cervical spine radiographs were digitized to calculate vertebral dimensions. Maximum isometric flexion and extension strength were measured with the subject lying down, using a hand-held dynamometer. Neck strength measurements were corrected for the weight of the head (Clauser et al., 1969).

Because muscle moment is the product of its force (proportional to neck muscle cross-sectional area) and moment arm, we predicted that the ratio of female to male neck strength would be related to neck and vertebral dimensions in the following way:

$$\frac{NS_F}{NS_M} = \frac{[NW_F * ND_F - VW_F * VD_F] * MA_F}{[NW_M * ND_M - VW_M * VD_M] * MA_M},$$

where *NS*=neck strength, *NW*=neck width, *ND*=neck depth, *VW*=average vertebral width, *VD*=average vertebral depth, *MA*=moment arm (average distance from the posterior-inferior corner of the vertebra to the tip of the spinous process), and the subscripts *M* and *F* denote male and female.

Paired *t*-tests were used to test for differences, with a significance level of p=0.05.

RESULTS AND DISCUSSION

Head and neck anthropometric parameters (other than height and neck length) were significantly smaller in females compared to males (Table 1). Differences in neck anthropometry (9 to 16%) were larger than differences in head anthropometry (3 to 6%). Females had significantly smaller vertebrae in the anterior-posterior (AP) dimension, but not in the medial-lateral (ML) dimension. Vertebral heights were significantly smaller in females for vertebrae C3-C5, but these differences were generally

less than the differences in vertebral depths or spinous process lengths (Figure 1).

Table 1: Anthropometric dimensions in height-matched men and women (mean and S.D.). *indicates $p < 0.05$.

	Male	Female
Height (cm)	169 ± 3	169 ± 3
Weight (kg)*	74 ± 9	66 ± 9
Head circ. (cm)*	57.7 ± 1.3	56.2 ± 1.5
Head width (cm)	15.3 ± 0.8	14.8 ± 0.8
Head depth (cm)*	19.9 ± 0.8	19.0 ± 0.6
Head height (cm)*	19.7 ± 1.5	18.4 ± 0.8
Neck length (cm)	10.8 ± 0.5	10.7 ± 0.5
Neck circ. (cm)*	39.4 ± 2.2	33.1 ± 2.0
Neck width (cm)*	11.7 ± 1.1	10.6 ± 0.7
Neck depth (cm)*	12.3 ± 0.7	10.3 ± 0.5

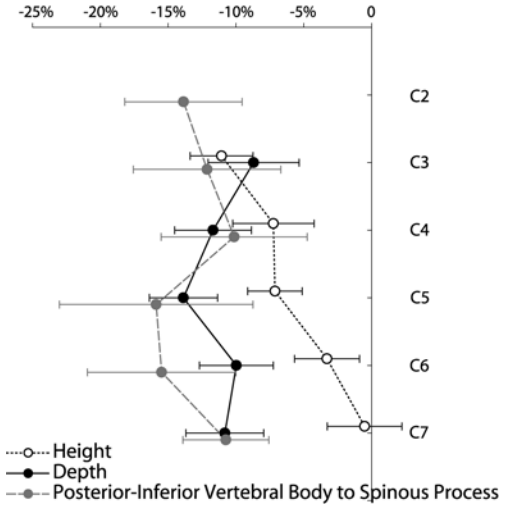

Figure 1: Percent difference (female-male)/male for cervical vertebral dimensions. Horizontal bars indicate S.E.M.

Female neck strength (corrected for head weight) was significantly lower (68 ± 25% and 80 ± 31% of male neck strength for flexion and extension respectively). Based on the anthropometry and radiology measures, the neck strength of females was predicted to be 71 ± 12% of males, which was not significantly different from the experimental neck strength ratios.

SUMMARY/CONCLUSIONS

In this sample of men and women who were matched by standing height and neck length, women had significantly smaller head and neck external dimensions, smaller vertebral size in the anterior-posterior dimension, and lower neck strength. We predicted a ratio of female to male neck strength based purely on differences in external neck and vertebral geometry, which corresponds well to the ratios measured experimentally. These findings support our hypothesis and demonstrate that male and female necks are not geometrically similar; further, geometric differences can explain much of the gender difference in neck strength.

The results of this study show that female necks are not simple scaled versions of male necks. Scaling the male neck based on one linear dimension (e.g., standing height) cannot be used to construct a model of the female neck musculoskeletal system. Therefore, female-specific models will be necessary to evaluate the biomechanical factors that lead to gender differences in neck-related disorders.

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