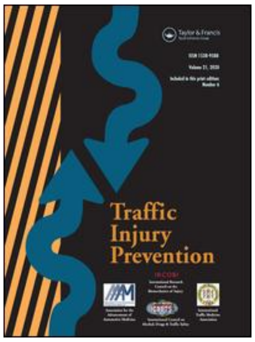

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Isometric, concentric, and eccentric neck strength in the sagittal and coronal planes of motion for adult females

Yadetsie Zaragoza-Rivera, John Bolte & Laura Boucher

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Isometric, concentric, and eccentric neck strength in the sagittal and coronal planes of motion for adult females

Yadetsie Zaragoza-Rivera, John Bolte, and Laura Boucher

Injury Biomechanics Research Center, Ohio State University, Columbus, Ohio

ABSTRACT

Objective: Assess strength in adult females using multiple positions, motions, and contraction types, to better understand strength production of young and non-symptomatic of adult female subjects to help assess and improve the biofidelity of anthropomorphic test devices and human body models.

Methods: Fifteen adult females (25.4 ± 6.3 years) were recruited for this study. Strength measurements were collected for the sagittal and coronal planes during isometric, concentric, and eccentric muscle contractions in neutral and mid-range of motion anatomical positions.

Results: For both planes, subjects were strongest during eccentric muscle contractions and weakest in concentric muscle activations. In the sagittal plane, subjects were stronger in extension for all muscle activation types and anatomical positions. In the coronal plane, there were no side differences in isometric nor concentric strength.

Conclusions: Neck strength of adult females depends on muscle activation type and anatomical positions. Future computational models should account for muscle activation type when quantifying responses of female subjects.

KEYWORDS
Cervical spine; cervical spine strength; neck strength; adult females; muscle contractions

Introduction

Adult females are more likely to suffer whiplash injuries during vehicle crashes than male occupants (Hoy et al. 2010). The increased vulnerability to severe injuries and mortality of female occupants can be attributed to a lack of female focused safety systems (Yoganandan et al. 2017). A need for the understanding of the unique biomechanical characteristics caused by the physical and physiological dimorphism between males and females are needed. There is a need to better understand the specific strength characteristics of the female cervical spine in a variety of engagements to further assess the biomechanical response of this population. The present study characterizes neck strength in isometric, concentric, and eccentric muscle activations in the sagittal and coronal planes for a variety of anatomical positions in non-symptomatic adult females.

Methods

This study was reviewed and approved by the Institutional Review Board (IRB) at the Ohio State University, Columbus OH (Project #2016H0300). Fifteen adult females aged 25.4 ± 6.3 years (range: 20–40 years) were recruited for this study. Exclusion criteria were injury to the neck within the last year, neck surgery within their lifetime, excessive kyphosis, allergies to adhesive tape, and head girth $\leq$ 56 cm. Peak strength (Nm) was defined as the maximum measurement for each muscle contraction at each anatomical position.

Isometric strength

Strength measurements were recorded using a Biodex Isokinetic Dynamometer (Biodex Medical Systems Inc., Shirley, New York) (Figure 1). The Biodex was fit to each participant such that the fulcrum of the rotation for each test occurred at the palpated C7 protrusion of each subject (Figure 2). Measurements were recorded for neutral anatomical position (0° of axial deviation) and at mid-range of motion (30° of neck bending) in the sagittal and coronal planes. In the sagittal plane, subjects performed flexion and extension isometric strength measurements (Figure 3a). In the coronal plane, subjects preformed left and right lateral bending (Figure 3b). For each measurement subjects completed three, 5 second isometric contractions, with 5 seconds of rest between repetitions.

Dynamic strength

Concentric and eccentric strength were evaluated during a dynamic testing protocol, with the Biodex moving at a rate of 30°/s through each motion (Figure 3c and d). Concentric strength was measured as peak strength when subjects were engaging toward the same direction as the Biodex was moving. Eccentric strength was the peak strength value when subjects engaged against the motion of the Biodex. Subjects moved through a 60° arc of total motion, and 30° in each direction for flexion-extension and left-right lateral bending. Dynamic strength was stratified per the subjects' effort and anatomical position.

CONTACT Yadetsie Zaragoza-Rivera zaragoza-rivera.1@osu.edu Injury Biomechanics Research Center, Ohio State University, Columbus, Ohio.

Statistical analysis

Statistical analyses were performed using JMP 14 (SAS Institute Inc., Cary NC). Descriptive statistics were used to compare overall cohort means and standard deviations (SD). Statistical analyses were conducted at an α-level of 0.05. Student's t-test were performed using Wilcoxon/Kruskal-Wallis statistics.

Results

Isometric strength

In the sagittal plane, isometric flexion strength significantly varied based on anatomical position. Flexion at mid-range of motion when flexed was significantly greater than at neutral ($p < .0001$) and while extended ($p = 0.043$). Flexion at neutral was significantly greater than when extended. In extension, strength at mid-range when extended was significantly greater than in neutral ($p = 0.002$) and when flexed ($p < .0001$). Subjects were always stronger in extension regardless of neck position. In the coronal plane, isometric strength measurements toward the right side of lateral bending did not significantly vary with location and all right side measurements were within 3 Nm of each other. Isometric strength toward the left side had significant differences based on location, with bending toward the left being stronger than neutral ($p = 0.037$) and bending toward the right ($p = 0.002$). Subjects were always stronger at mid-range of motion when laterally bent to the same side of engagement.

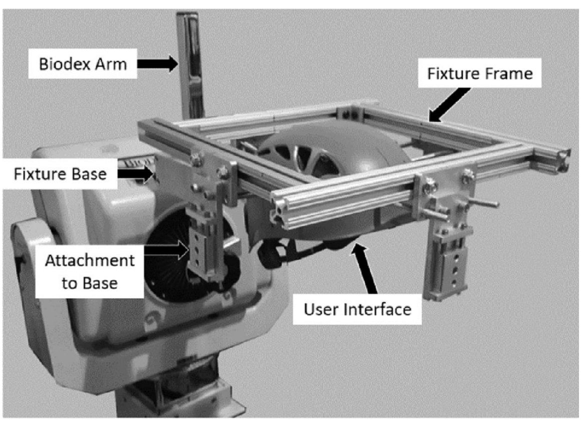

Figure 1. Custom head fixture retrofitted on a Biodex Isokinetic Dynamometer.

Dynamic strength

In the sagittal plane, subjects were stronger in the same direction they were flexed regardless of type of concentric or eccentric contraction (Table 1). When comparing flexion and extension, subjects were always stronger in extension for both concentric and eccentric muscle contractions. Subjects were stronger eccentrically regardless of anatomical position. In the coronal plane, there were no significant differences in concentric strength between the sides when subjects were engaging toward the same side they were laterally bent or when they were engaging to the opposite side they were laterally bent. Concentrically, subjects were significantly stronger when pushing toward the side they were laterally flexed. Right eccentric lateral bending was significantly stronger than the left side (Table 2).

Discussion

This study assessed neck strength in isometric, concentric, and eccentric contractions of asymptomatic adult females both for the sagittal and coronal planes. Overall subjects were always stronger at mid-range of motion and with

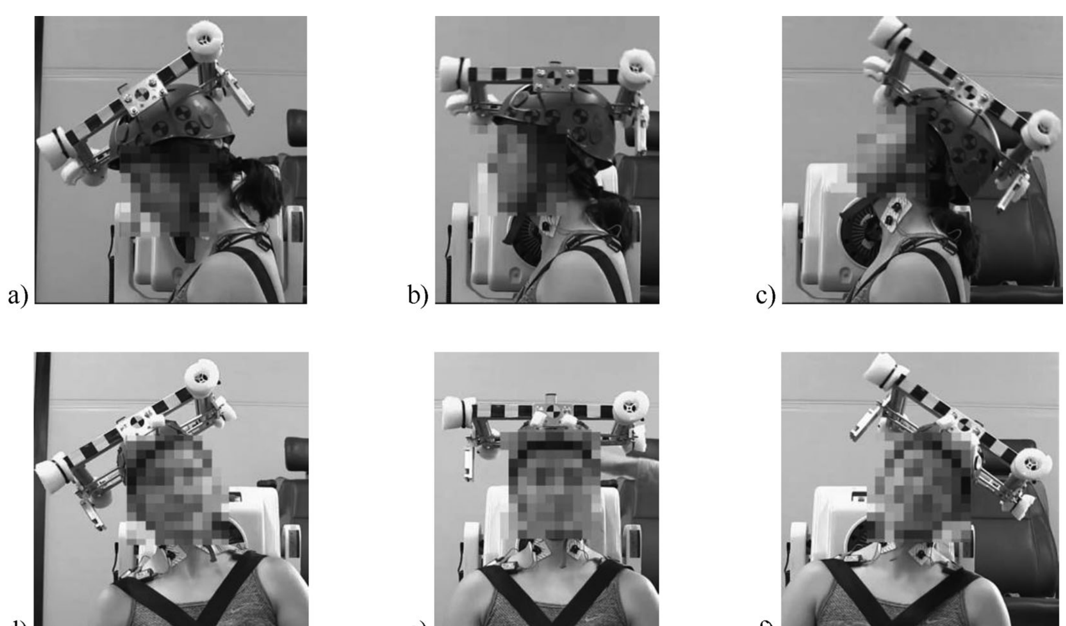

Figure 2. Subject in the testing equipment. Top: Sagittal plane engagement. Bottom: Coronal plane engagement. A-C) Subject in mid-range flexion, neutral, and mid-range extension positions. D-F) Subject in right lateral bending, neutral, and left lateral bending positions.

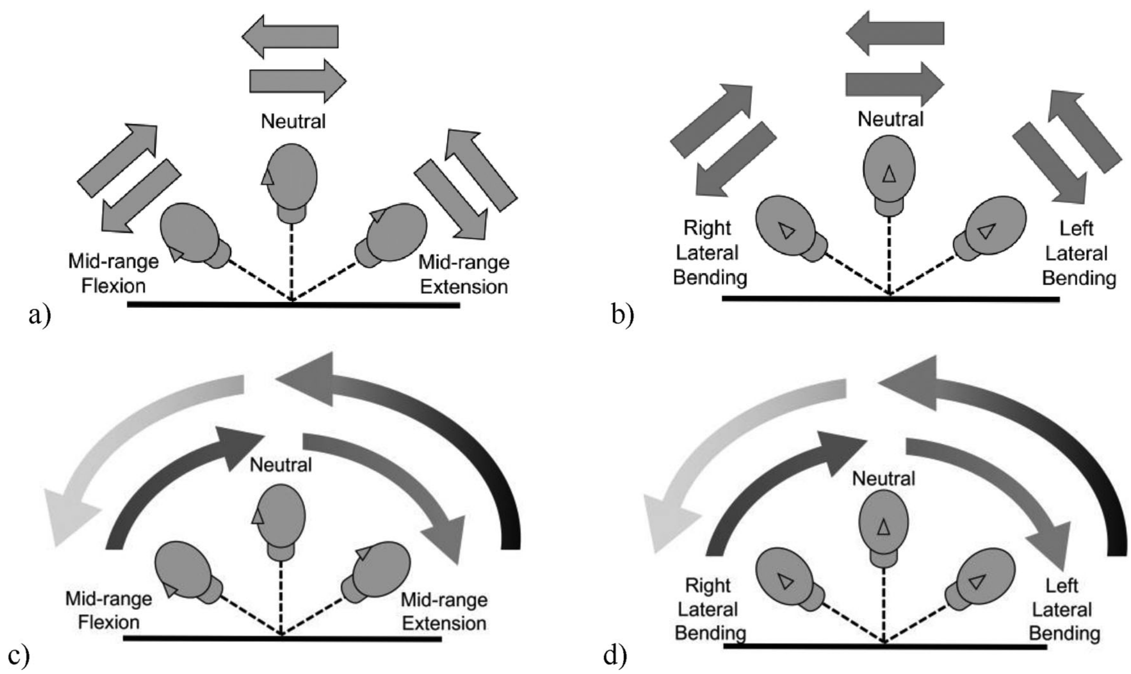

Figure 3. Schematics of the testing setup. Top: Subject's efforts (represented by arrows) during the isometric testing condition at neutral and mid-range of axial deviation. Bottom: Subject's motion (represented by curved arrows) during dynamic testing; where concentric or eccentric engagement was achieved with engagement with or against the motion, respectively. A, C) Sagittal plane engagement. B, D) Coronal plane engagement.

Table 1. Strength by muscle engagement in Nm (SD) for the sagittal plane.

	Mid-Range Flexed		Neutral		Mid-Range Extended	
Engagement Type	Flexion	Extension	Flexion	Extension	Flexion	Extension
Isometric	13.85 (2.53)	15.26 (3.78)	7.75 (1.76)	17.88 (3.93)	4.08 (1.78)	21.77 (3.85)
Concentric	10.33 (2.10)	11.93 (4.13)			2.80 (1.96)	15.94 (4.01)
Eccentric	10.95 (2.98)	15.55 (6.58)			8.24 (2.79)	19.60 (5.78)

Table 2. Strength by muscle engagement in Nm (SD) for the coronal plane.

	Mid-Range Right		Neutral		Mid-Range Left	
Engagement Type	Right	Left	Right	Left	Right	Left
Isometric	15.74 (2.60)	10.67 (4.41)	12.82 (3.06)	12.26 (3.34)	12.12 (3.75)	15.86 (2.49)
Concentric	13.05 (2.93)	8.58 (3.18)			8.95 (3.88)	12.35 (2.21)
Eccentric	14.69 (3.73)	10.97 (4.41)			14.03 (4.26)	13.42 (4.30)

contraction to the same side they were flexed. In the sagittal plane, subjects were always stronger in extension. This trend in strength production has been reported in literature and it is believed to be related to the increased sized and amount of musculature working in extension compared to flexion (Salo et al. 2006). In the coronal plane, strength did not vary by side in isometric and concentric muscle contractions. However eccentrically, subjects were stronger on the right side. We hypothesized that this difference in strength may be related to subjects' natural side preference, as all subjects self-identified as right handed. While this study has a small sample size, it offers a comprehensive assessment of neck strength in a variety of anatomical positions and muscle contractions for healthy adult females. Strength of adult depend on type of muscle contractions. Subjects were weakest with concentric contractions and strongest in eccentric contractions. These data may help the future development of anthropomorphic test devices and computational models to better assess the kinetic and kinematic responses of female vehicle occupants.

ORCID

Yadetsie Zaragoza-Rivera http://orcid.org/0000-0002-2674-0280
John Bolte http://orcid.org/0000-0001-8301-5547
Laura Boucher http://orcid.org/0000-0002-4770-9522

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