Isometric Bending Strength of the Cervical Spine Estimated from Moments Generated by Optimized Active Muscles in Flexion, Extension, and Lateral Bending

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Abstract

Little is known about the variation in isometric bending strength along the cervical spine, and less is known about the cervical muscular contribution to isometric bending strength. Electromyography (EMG) studies have only examined a fraction of the cervical muscles, and computational studies have been unable to predict volunteer strength along the cervical spine for flexors, extensors, and in lateral bending. This information is important for identifying specific muscle involvement and recruitment during activity, especially as it relates to injury risk and injury modeling.

This study used a validated computational whole cervical spinal ligamentous model, with 23 pairs of cervical muscles, to predict volunteer isometric bending strength in flexion, extension, and lateral bending. Additionally, this study examined the contribution of the hyoid muscles to flexor strength. The muscles in the cervical spinal model were optimized to maximize muscle force effort and minimize head motion while resisting external loading. The muscular activation schemes resulting from this optimization were used to calculate isometric bending strengths along the cervical spine. Three different loadings were used to generate activation schemes for isometric bending in flexion, extension, and lateral bending.

The optimized muscle activation schemes were found to predict volunteer isometric bending strengths from experimental studies to within 2 Nm. These optimized schemes included near maximal, sub-maximal, and co-activation of various flexor and extensor muscles, including active hyoid muscles. Exclusion of the hyoid muscles resulted in underestimations of volunteer flexion bending strength, with estimates of the total flexion moment being 30% to 88% lower depending on cervical level. Maximal activation (non-optimized) levels resulted in overestimations of volunteer isometric bending strength—for instance, in resisting flexion, maximal extensor activation predicted isometric bending strengths ranging from 13% to 62% higher than volunteer across cervical levels. Additionally, the optimized activation schemes and recruitment of muscles were similar to those found in volunteer EMG studies.

In conclusion, this study found that isometric bending strengths of the cervical spine are well predicted by optimized muscle activations that resist loading while maintaining posture. These results provide insight into relative bending strengths along the cervical spine, as well as into muscle activation levels and recruitment patterns.