EFFECT OF CURVED MUSCLE PATHS ON NECK BIOMECHANICS

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INTRODUCTION

Most current 3D musculoskeletal models of the cervical spine use straight lines to model muscle paths. However, more accurate representations can be obtained by modeling muscle paths anatomically (1; 2). Recent studies have attempted to define anatomical muscle paths in the spine (3); but, they did not study the effect on the muscle's moment arm (MA). We propose a method that applies curvature to muscles in a 3D musculoskeletal model of the cervical spine to obtain anatomically accurate muscle paths. Our hypothesis is that incorporating curved muscle paths will significantly alter the MAs through all degrees of freedom (*dof*) in the 3D model.

METHODS

A kinematic 3D musculoskeletal model was created from magnetic resonance images (MRIs) of one subject in multiple postures - neutral, flexion, extension, protraction, retraction, axial rotation and lateral bending (3). The anatomic muscle path of the *semispinalis capitis* was defined by the centroid of the muscle on each MRI slice (Figure 1, blue circles). A straight path was defined between the first and last centroid points (Fig. 1, green line). A cylindrical wrap surface was placed such that the straight path wrapped over it (Figure 1, yellow line), toward the anatomic path. The axes of each cylindrical wrapping surface were parallel to the straight line (y) and largest perpendicular distance from a centroid to the straight line (x). For two surfaces (Fig. 1B), a *transition point* (t_p) was determined as the centroid point at which the two line segments o to t_p and t_p to i minimize the error metric (EM). **EM is the sum of the deviations of the anatomic path to the straight or curved path measured at each centroid (level).** A surface was defined for each line segment. We then incorporated a third surface using the central tangent points t_s and t_i created from the two wrapping surfaces (Figure 1C).

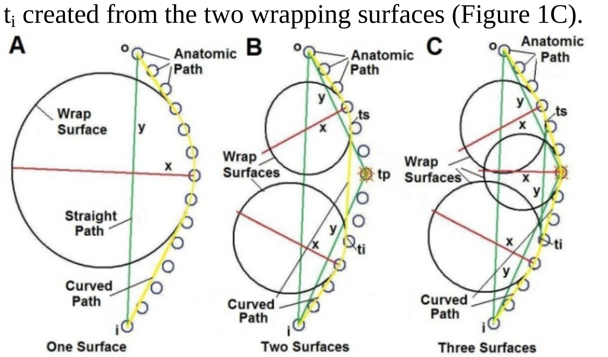

Figure 1: 2D representation of A: 1, B: 2, and C: 3 wrapping surfaces

Instantaneous centers of rotation (ICR) were determined in 2D between the neutral posture and all other postures. Static MAs were determined as the distance from the ICR axis to the closest centroid point, and were used as guidelines for MA estimations in the kinematic model. The optimal number and placement of wrap surfaces were determined by minimizing EM. MAs were calculated for straight and curved paths. Paired t-tests were used to compare MAs through all *dof* (yaw, pitch, and roll).

RESULTS AND DISCUSSION

Three wrapping surfaces resulted in the lowest average EM over all postures; 4.75 mm, a 70% decrease from the straight path (15.85 mm). One wrapping surface resulted in the second lowest; 5.45 mm, decreasing the EM by 66%.

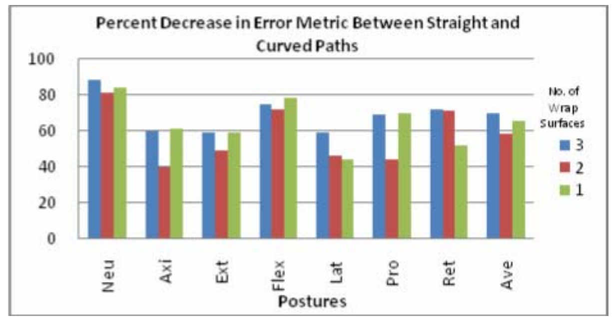

Figure 2: Percent decrease in Error Metric for all configurations

MA of the curved muscle path for 3 surfaces was significantly different ($p<0.01$) from the straight path in all *dof* (Fig. 3). MA of the curved muscle path for 3 surfaces was also significantly different from 1 in pitch and roll ($p<0.01$) and showed a trend towards significance in yaw ($p=0.09$).

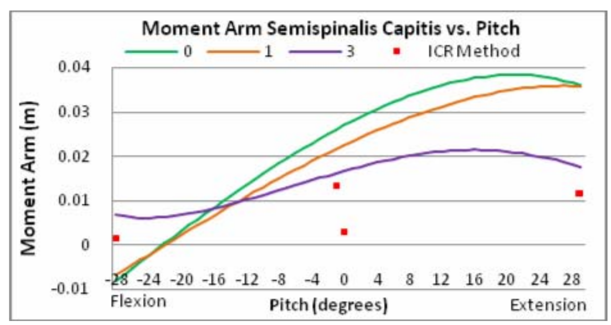

Figure 3: Moment arm of straight and curved muscles and ICR method

CONCLUSIONS

The method defined in this study decreases the error of modeled paths compared to anatomical paths. Curving muscles with this method also significantly affects MA. Although differences in EM between 1 and 3 surfaces are small, differences in MA are significant in two of three *dof* and trend towards significance in the other. MA of 3 surfaces for pitch also mimic static MAs determined with the ICR method, justifying 3 surfaces (Fig. 3). Future studies will focus on comparing MA estimations from 3D model simulations to MAs determined from tendon excursion cadaver studies.

REFERENCES

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