INTRODUCTION

Chronic neck pain affects millions of Americans and is associated with significant healthcare expenditures, yet remains poorly understood. The long term goal of this project is to develop subject-specific biomechanical models informed by dynamic imaging and electromyographic (EMG) data to understand why specific regions of the neck muscles are vulnerable to local injury and to abnormal stretching during activities of daily living, and whether such injuries can cause biomechanical changes that perpetuate asymmetric loading of the neck muscles.

Our research group has been investigating the pathogenesis and pathophysiologival mechanisms of myofascial trigger points (MTrPs) in the upper trapezius muscle. MTrPs appear as firm tender nodules on palpation and have been associated with myofascial pain syndrome [1]. In order to understand the mechanical causes and consequences of MTrPs, we design experiments to collect kinematic, muscle EMG, ultrasound imaging, and clinical data from controlled subjects and patients with neck pain who have symptomatic MTrPs. We develop subject-specific musculoskeletal models based on the acquired data which can predict muscle and joint forces during various movements. Through computational simulation and quantitative analysis, we can then investigate whether there is difference (1) in muscle activities, (2) muscle actions, and (3) joint loads between two groups of subjects and whether there is any correlation between these parameters and asymmetric cervical range of motion observed from neck pain patients. In the following, we present some preliminary results from a pilot study on collecting kinematic and EMG data which are used to build biomechanical simulation and further analysis.

METHODS

Data Acquisition

The subject sat in a chair in an upright neutral position with shoulder relaxed and hands positioned on the laps. Two Optotrac® Certus™ position sensors from which 3D real-time motion data was captured at 100Hz were positioned in front of the subject. Three Optotrak markers were placed on the shoulders and the chest to calibrate each subject’s kinematics and to monitor potential shoulder motion. Smart marker rigid body consisting of three pre-calibrated markers was placed on the subject’s forehead using a headband, which tracked 3DOF of the head. Two Delsys surface EMG sensors were affixed to the posterior surface of the neck at approximately C7 level. Each sensor made a 35° angle to the midline of the body to measure the activity of the upper trapezius muscle. EMG data was acquired at 1000Hz using the Delsys Myomonitor® IV EMG system, synchronized with the Optotrak motion capture system through an external trigger signal.

The subject was instructed to exert maximum voluntary efforts in attempted neck side bending and cervical rotation without moving the shoulders. The subject completed five repetitions of each target movement. Each repetition lasted for 10 seconds and a 5-second pause was taken between two repetitions.

Biomechanical Model

A computational musculoskeletal model of the neck [2] was used and slightly modified for dynamic simulation and analysis in OpenSim [3]. Wrapping surfaces were applied to realistically model the curved upper trapezius muscle paths during movement.

RESULTS AND DISCUSSION

Fig. 1 shows kinematic and EMG data of two representative trials, one side bending and one
cervical rotation, both to the right hand side of the subject. The shoulder markers confirmed that there was little shoulder motion thus contraction of the upper traps muscles primarily contributed to cervical rotation. Three cervical rotation angles (flexion/extension, side bending, and cervical rotation) relative to the torso were computed and plotted, simplifying the neck joint as a 3DOF joint consistent with the biomechanical model [2]. Coupling between side bending and cervical rotation is known and was observed in our data. Bilateral upper trapezius muscle electrical activities were plotted on the second and third rows in each subfigure. During right side bending, the ipsilateral upper trapezius muscle was recruited while the contralateral upper trapezius muscle was inactive. During right cervical rotation, bilateral trapezius muscle coactivation was observed. The contralateral upper trapezius muscle had earlier onset and greater activation magnitude than the ipsilateral muscle, showing its recruitment as the agonist.

Snapshots of the simulated model were shown at the corresponding time frames. Combined with the measured EMG data in Fig. 1, eccentric and concentric contraction of the upper trapezius muscle during ipsilateral and contralateral movement can be further studied.

The captured kinematic data was loaded in the OpenSim neck model to analyze muscle deformation and actions through inverse dynamics simulation. Fig. 2 demonstrates simulation of the motions in Fig. 1. Musculotendon strains of the sternocleidomastoid muscle and the upper trapezius muscle, two major muscles involved in side bending and cervical rotation, were plotted over time.

We demonstrate a data-driven neck biomechanics analysis framework through a pilot study. In future work, we plan to incorporate synchronized ultrasound imaging data acquired at various locations on the upper trapezius muscle. Longitudinal muscle strains will be estimated from these images. We will model upper trapezius muscle as connected compartments associated with realistic anatomical and physiological parameters. Image-based local muscle strains will be used to drive and evaluate the biomechanical model to investigate the mechanisms of MTrPs and the neck pain syndrome in the long term.

REFERENCES