INTRODUCTION

Work-related chronic neck pain is a growing disorder in the United States that accounts for approximately 60% of all occupational disabling injuries [1]. Neck pain is linked to continuous and excessive activation in the upper trapezius (UT) muscle [2]. An effective treatment for chronic neck pain may be to reduce activation in the UT through an inferior shift in the muscle activity to the middle (MT) and lower trapezius (LT).

Because muscle architecture in the trapezius is complex and varied across the regions, the spatial information from high-density surface electromyography (HDsEMG) may provide a good signal on which to implement biofeedback for neck pain. Real-time EMG biofeedback using bipolar electrodes is used to assist a patient attempting to selectively activate and redistribute muscle activity [3]. Bipolar electrodes are typically used, which provide estimates of muscle activity only at the recording point. The real-time spatial distribution of the muscle activity (Fig. 1a) from HDsEMG may be particularly effective when using biofeedback to redistribute muscle activity from the UT to the MT and LT.

The objective of this investigation was to compare the redistribution of trapezius muscle activity using two different feedback interventions. We hypothesized that an HDsEMG interface would result in a more uniform and inferior distribution of trapezius muscle activity compared to traditional postural biofeedback.

METHODS

Twelve participants (5 males, 7 females) without a history of chronic neck or shoulder pain performed two, 15-minute typing tasks. Two types of feedback instruction were provided to the participants in a random order. The two types of feedback were (1) verbal feedback from the researcher prior to the typing task (NBF) and (2) verbal feedback from the researcher prior to the typing task plus visual feedback of HDsEMG signals during the typing task (BF). Verbal feedback consisted of a researcher coaching each participant how to sit at the computer with a “neutral posture.” The ideal neutral posture includes an upright trunk, tucked chin, and shoulder blades slightly depressed and adducted. Adopting this posture enacts an inferior shift in trapezius muscle activity [4]. Each participant practiced this posture for one minute with corrective manual and verbal feedback from the researcher before the typing tasks.

![Figure 1: (a) Topographical map of ARV UT activity with YCOG location (b) Electrode placement](image)

Two HDsEMG electrode arrays (composed of 64 electrodes each) were placed over the UT, MT, and LT (Fig. 1b). The superior electrode array was placed 1 cm medial to the innervation zone with the 4th electrode row placed along the C7-acromion line [5]. HDsEMG signals were sampled during both typing tasks at 2,048 Hz. Fifty-one bipolar signals were extracted from each array.

The biofeedback intervention displayed a real-time onscreen indicator of trapezius muscle activity. Real-time EMG signals from both HDsEMG arrays were bandpass filtered (4th order Butterworth, 10-500 Hz) with a 1 second time constant. The signals were summed across all electrodes in each array, and the ratio of signal amplitude (superior/inferior)
Average rectified values (ARV) of EMG signals were calculated over 0.5-s non-overlapping epochs. The distribution of trapezius muscle activity was represented by the y-component of the center of gravity ($Y_{COG}$) across both electrode arrays in the superior-inferior direction of trapezius muscle activity (Fig. 1). Homogeneity in trapezius muscle activation patterns of the UT was calculated using a measure of entropy:

$$\text{entropy} = -\sum_{i=1}^{51} p^2(i) \log_2(p^2(i))$$

where $p^2(i)$ is the square of the ARV value at electrode $i$ normalized by the summation of activity in the squares of the 51 ARV values. Higher values correspond to a more heterogeneous distribution of muscle activity across the arrays [6]. The effect of biofeedback on trapezius muscle activity was examined by comparing dependent variables across typing tasks with a one-directional paired $t$-test. Level of significance was set at $\alpha=0.05$.

RESULTS AND DISCUSSION

Three of the participants were unable to comply with the biofeedback instructions, shown by higher AR with the biofeedback interface than without (Table 1). Of the participants who were able to comply with the EMG biofeedback, the distribution of trapezius muscle activity shifted inferiorly and was spatially more homogeneous in activation patterns across the fibers of the UT muscle. However, these results were not statistically significant. AR was $10.16\pm33.31\%$ lower with biofeedback. $Y_{COG}$ was $11.38\pm11.37\%$ lower ($P=0.21$) with biofeedback. Entropy was $5.95\pm1.89\%$ lower ($P=0.12$) with biofeedback (Fig. 2). In addition, the participants who showed a larger inferior shift in $Y_{COG}$ demonstrated more homogeneous spatial distribution patterns (lower entropy).

CONCLUSIONS

HDsEMG biofeedback successful changed the distribution of UT muscle activity for 75% (9 of 12) of the participants. The three participants unable to comply demonstrated more heterogeneous trapezius muscle activation patterns. These data indicate an inability to voluntarily redistribute muscle activity to the MT and LT in some individuals. These patients often do not respond to biofeedback-based interventions. Future work will investigate the effectiveness of HDsEMG biofeedback in patients with chronic neck pain.

REFERENCES


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Table 1. Change in AR between typing tasks (* Non-Complier).