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Co-activation of Sternocleidomastoid Muscles During Maximum Clenching

G.T. CLARK, P.A. BROWNE¹, M. NAKANO², and Q. YANG

UCLA Dental Research Institute, School of Dentistry, 73-017 Center for Health Sciences, 10833 Le Conte Avenue, Los Angeles, California 90024-1668; ¹Division of Physical Therapy, Chapman University, Orange, California 92666; ²Tokushima University, School of Dentistry, Department of Fixed Prosthetics, Tokushima 770, Japan

In an attempt to determine the degree of co-activation present in selected cervical muscles during clenching, we instructed 12 male subjects to produce four brief maximum voluntary contraction (MVC) efforts (clenching) in a position of maximum intercuspation. Surface EMG activity was recorded bilaterally from the masseter and sternocleidomastoid (SCM) muscles. The contraction level for the SCM during clenching was reported as a percentage of the SCM's maximum activity achieved during maximum neck flexion against resistance. All EMG signals for the masseter and SCM were converted to a true RMS voltage signal and digitized at a 100-Hz sampling rate. Mean peak EMG voltage levels were determined for the activity recorded during each brief MVC task. All subjects demonstrated co-activation of the SCM during strong abrupt clenching efforts. The mean levels (\pm S.D.) of SCM activity were $11.8 \pm 9.6\%$ (right) and $14.2 \pm 9.4\%$ (left) of the MVC capacity. Fifty percent of masseter activity was required to achieve 5% activity of the SCM bilaterally, and there was a progressive development of the SCM co-activation which paralleled the masseter activation.

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Introduction.

The position and stability of the unsupported head are dependent on the structure and function of the cervical muscles and joints, and the maxilla is held steady during almost all mandibular functions. It is reasonable, therefore, to conjecture that there would be a coupling between the mandibular motor system (*i.e.*, trigeminal nerve) and cervical motor systems (*i.e.*, spinal accessory and upper cervical nerves). Indeed, there are several reports of neuro-anatomical, developmental, neurophysiological, and functional coupling between these two systems. Neuro-anatomical studies of animals have established that the trigeminal spinal tract and nucleus extend into the upper cervical segments (Brown, 1956; Kruger *et al.*, 1961; Kerr, 1970; Rustioni *et al.*, 1971). Convergence of trigeminal and cervical input volleys has been reported on single units located in the cervical dorsal horn (Kerr and Olafson, 1961; Kerr, 1972; Abrahams *et al.*, 1979). The functional consequences of this convergence have been demonstrated in several studies investigating the influence of trigeminal input on neck muscles. Developmental studies of human and rat fetuses have demonstrated that perioral stimuli elicit head movements along with oral responses (Humphrey, 1964; Narayanan *et al.*, 1986). Sternocleidomastoid and trapezius contraction can be elicited by direct stimulation of the Gasserian ganglion of the adult cat (Green *et al.*, 1957). Intracellular responses have

been elicited in splenius and trapezius motoneurons following stimulation of both V1 (supra-orbital nerve) and V2 (infra-orbital nerve) (Rose and Sprott, 1979). These experimental findings represent examples of the structural and functional intimacy of these two anatomical areas.

Thompson and Brodie (1942) and Brodie (1950) postulated that isometric clenching of the teeth in humans must be balanced by activity in the cervical muscles when the head is erect. Halbert (1958) provided the first electromyographic (EMG) documentation of cervical muscle activity during jaw function. He recorded activity in the neck extensor and infra-hyoid muscles during clenching. Davies (1979) also reported EMG activity of the sternocleidomastoid (SCM) muscle during jaw opening, protrusion, laterotrusion, and retrusion. Yoshida (1988) and Kohno *et al.* (1988) confirmed Davies' (1979) observation that EMG activity could be recorded from the SCM muscle during clenching. None of these investigators quantified the level of the cervical muscle activity relative to maximum voluntary contraction (MVC) ability of the individual muscles.

Further elucidation of the nature and degree of coupling between the cervical and masticatory systems is necessary, because cervicogenic pain is frequently reported in patients with temporomandibular disorders. This suggests a connectivity between the two systems when they are in dysfunction (Alanen and Kirveskari, 1984; Clark *et al.*, 1987).

The SCM attaches to the mastoid process and the occiput and is one of the primary controllers of head position. It is innervated by cervical segments of the spinal accessory nerve (XI) and by the cervical segments (C2, C3, and C4) directly. It has been implicated in various clinical pathologies, including headache (Braaf and Rosner, 1975; Edeling, 1982), vertigo (Ryan and Cope, 1955; Travell, 1955; Weeks and Travell, 1955; Jongkees, 1969), torticollis (Xinkang, 1981; Goor, 1984; Webb, 1987), and myofascial pain dysfunction (Butler *et al.*, 1975; Curtis, 1980).

The purpose of this study was to quantify the level of EMG activity of the SCM during maximum jaw clenching by healthy subjects and to relate this level to that achieved during maximum voluntary activity of the SCM. A brief communication regarding these results has been published previously (Browne *et al.*, 1987).

Materials and methods.

Twelve healthy adult male subjects were selected from a pool of individuals with normal jaw and cervical function. The average age was 36 years, with a range from 21 to 49 years. All subjects were UCLA students, staff, or faculty. A questionnaire and brief TMJ and cervical screening examination were used to ensure that the subjects did not have any overt temporomandibular or cervical dysfunction. Examination of the subject's jaw function involved an evaluation of jaw motion and palpation of the temporomandibular

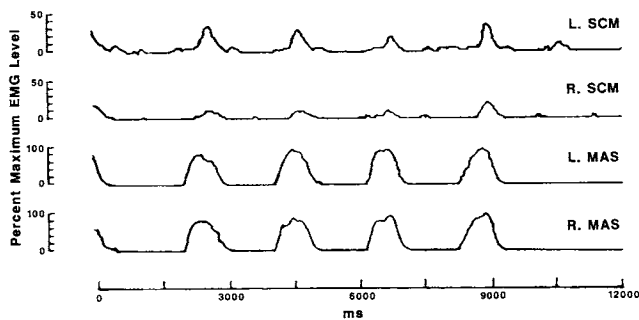


Fig. 1—EMG data (RMS converted) acquired from four bipolar surface electrodes placed centrally on the right and left SCM and superficial masseter muscles during four brief maximum voluntary tooth-clenching efforts. Each clenching effort lasted approximately 1-2 s from onset to offset.

joints. Two masticatory muscles (*i.e.*, the masseter and temporalis) and selected cervical muscles (*i.e.*, the SCM, splenius capitis, and upper trapezius) were also palpated for overt tenderness, and the subject's range of craniocervical motion was evaluated. A brief clinical, dental, and intra-oral soft-tissue visual examination was also performed. No subject was missing more than one tooth *per* quadrant (excluding third molars) or had overt TMJ or cervical movement restrictions, joint noises, or joint or muscle tenderness on palpation. All subjects read and signed an informed consent form which had been approved by the UCLA Human Subjects Protection Committee.

Surface electromyography.—Electrical activity was recorded from the SCM and superficial masseter muscles bilaterally by means of bipolar surface electrodes. Electrodes were positioned centrally, 15 mm apart, over the body of each muscle parallel to the direction of the muscle fibers. Bipolar electrode resistance was measured before the experiment and determined to be less than 10 kohm.

TABLE
PERCENT OF SCM MUSCLE MAXIMUM VOLUNTARY CONTRACTION LEVEL DURING A MAXIMUM VOLUNTARY TOOTH-CLENCHING TASK

Subject	L-SCM (% MVC)	R-SCM (% MVC)
1	13.2	11.8
2	15.9	10.6
3	4.2	4.8
4	2.8	5.7
5	1.5	5.9
6	19.7	12.9
7	25.7	5.8
8	5.4	2.4
9	16.2	22.6
10	24.3	31.7
11	12.5	2.6
12	29.5	24.8
Mean \pm S.D.	14.2 \pm 9.4	11.8 \pm 9.6

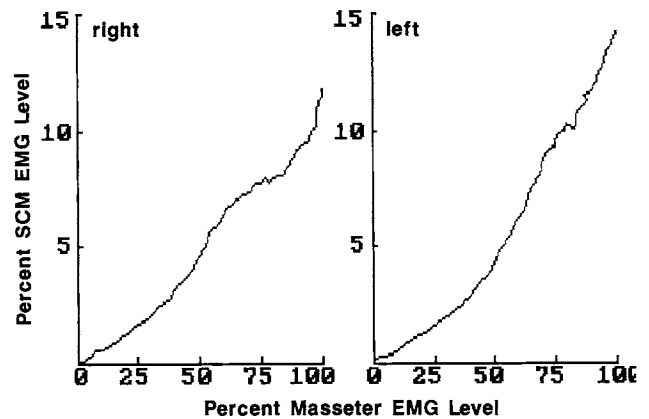


Fig. 2—Mean percent MVC in the right and left SCM muscles (*y*-axis) plotted as a function of the percent MVC in the masseter muscles (*x*-axis) during a maximum voluntary tooth-clenching task ($n = 12$).

Myopotentials were amplified with a custom-built amplifier using a gain of 1000 and filtered with an 8-Hz high-pass filter. The mean voltage level was determined during a 30-second representative baseline period. During this time, subjects were instructed to "keep your teeth slightly separated and your jaw and neck as relaxed as possible". The maximum voluntary contraction level for the SCM muscle was then recorded during resisted neck flexion effort. Finally, the MVC level for the masseter muscle was obtained during clenching. There were four repetitions of the maximum contraction efforts. Each maximum effort involved an abrupt onset and offset and was no more than 3 s long. To ensure a full effort, visual feedback of masseter muscle EMG activity was provided *via* an oscilloscope (Tektronix), and subjects performed several practice contractions to familiarize themselves with the experimental paradigm. A rest period was provided between the practice efforts and the experiment. All clenching was performed by the subjects in the position of maximum intercuspation.

Because head position is known to affect and be affected by the cervical muscles, an attempt was made to control for this variable without hindering the subject's neck mobility. Subjects were seated in a straight-backed chair (knees and hips flexed at 90 degrees) with an adjustable lumbar support. This sitting position is optimal for establishing the upright head position. Subjects were instructed not to move their heads voluntarily during the experiment and were visually monitored for compliance during the experiment.

All EMG data were stored on a multi-channel tape recorder (Vetter Model B) for subsequent playback and computer analysis. During the experiment, a taped verbal record and a written record were made describing the conditions under which the data were collected.

The EMG data were played back through the tape recorder. The data were visually inspected on a multi-channel storage oscilloscope, converted to a true RMS signal, and digitized directly onto the hard disk of an IBM 286 XT by analog-to-digital data acquisition hardware and software (RC electronics ISC-16 software and computerscope board). Signal acquisition involved sampling at a 100/s rate. The measurement of SCM muscle activation levels involved determination of the mean peak EMG voltage levels (minus baseline EMG level) during

the brief maximum voluntary contraction tasks. The software program calculated the mean voltage level measured between two cursors positioned 100 ms on each side of the center of the EMG peak during each brief maximum contraction effort. SCM activity levels were expressed as a percentage of the maximum contraction level obtained during the voluntary maximum activation of the muscle. This percent of SCM activation, relative to the level of masseter activation during a brief maximum voluntary clenching task, was determined by conversion of the raw EMG data to a true RMS signal. A data file was then acquired onto a computer which represented activity from onset to peak at a 100/s sample rate. All muscle data files were normalized to be of equal length, averaged across subjects, and the masseter *vs.* SCM activity was plotted.

Results.

Spontaneous SCM EMG activity from 12 healthy male subjects was determined during maximum voluntary isometric clenching in maximum intercuspation (Fig. 1). Among all subjects, a clear co-activation of the SCM was present in 93% of the four repeated MVC trials. Two types of responses were observed. Subjects demonstrated SCM activity either with every maximum clench or during at least three of the four clenching efforts. There was also moderate variability in the percent of activity elicited in the SCM among subjects. The combination of these factors is reflected in the variability of mean percentage of activity among subjects and in the range of the means from 1.5% to 29.5% for the left SCM and from 2.4% to 31.7% for the right (Table). In most cases, co-activation was variable, but when present, it was bilateral.

The percent of right or left SCM activity was plotted against the percent of the ipsilateral masseter activity during a brief and abrupt masseter contraction effort (Fig. 2). These plots revealed that co-activation of the SCM appeared to develop in concert with the masseter activity. Fifty percent of masseter activity was required to achieve 5% activity of the SCM bilaterally. There was a slight plateau of the SCM activity at 75% to 80% and a steeper slope of co-activation bilaterally at greater than 80%.

Discussion.

The findings of this study are consistent with those of other investigators who have reported that certain cervical muscles become active during various mandibular maneuvers (Halbert, 1958; Davies, 1979; Kohno *et al.*, 1988). We demonstrated two findings by converting the level of muscle activity to the maximum level for the respective muscles, one being that there was SCM co-activation during masseter MVC efforts. This SCM activity was highly variable and generally less than 30% of the SCM's maximum. In six subjects, there was between a 5% and a 10% difference between the right and left SCMs' co-activation levels, but there was no consistency in which side had the greater activity. The second finding was a progressive development of the SCM co-activation which paralleled the masseter activation. It seems clear that the SCM level of activation was a function of the masseter level. The above findings could be explained by the necessity of the cervical muscles to provide a stable position of the maxilla for clenching. It is conceivable that this co-

activation is purely a mechanical response, that central commands co-activate both systems, or that there is a reflex connectivity between the trigeminal and cervical systems. The present study was not designed to explore whether this connection was reflexive or mechanical. Single motor unit studies and analysis of latencies would be required to address this question.

In order to appreciate the possible functional significance of these findings, one should consider reports of EMG activity in other systems. In a study of co-activation of forearm muscles, Tyler and Hutton (1986) reported that, during maximum co-activation, the flexor muscles achieved an activity level less than 50% of maximum. This would support the concept that less than 30% co-activation of SCM during strong clenching may have functional significance.

Other questions of interest would include the degree of coupling between the masseter and other cervical muscles (*e.g.*, trapezius or splenius capitus), in situations other than maximum intercuspation clenching (*e.g.*, in an eccentric jaw position), or in situations other than a relaxed upright craniocervical posture. Additionally, the degree of craniocervical activity during mandibular parafunction (*e.g.*, nocturnal bruxism) or in subjects with abnormal cervical structure or with concurrent musculoskeletal dysfunction would be clinically useful to document. The levels of SCM activity established by this experiment provide a baseline for comparison with these other situations.

In summary, this study confirmed that there is a functional connection between the masticatory and cervical motor systems. Our results indicate that when healthy subjects who had normal jaw function were sitting in an upright position and clenching maximally, the SCM was activated at or below 30% of its maximum capacity. Future research should focus testing on whether higher levels of cervical co-activation are seen during mandibular parafunction or in the presence of dysfunction or abnormal structure of the cervical or masticatory system.

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