Neuromuscular Interaction of Jaw and Neck Muscles During Jaw Clenching

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Aims: *To test the hypothesis that jaw muscles and specific neck muscles, ie, levator scapulae, trapezius, sternocleidomastoideus, and splenius capitis, co-contract at the different submaximum bite forces usually generated during jaw clenching and tooth grinding, and for different bite force directions.* ***Methods:*** *Bite-force transducers that measured all three spatial force components were incorporated in 11 healthy subjects. The test persons developed feedback-controlled submaximum bite forces in a variety of bite-force directions. The electromyographic (EMG) activity of the levator scapulae, splenius capitis, and trapezius muscles was recorded, at the level of the fifth cervical vertebra, by use of intramuscular wire electrodes. The activity of the sternocleidomastoideus and masseter muscles was recorded by surface electrodes. For normalization of the EMG data, maximum-effort tasks of the neck muscles were conducted in eight different loading directions by means of a special force-transducer system. Differences between neck-muscle activity during chewing, maximum biting in intercuspation, and the force-controlled motor tasks were compared with the baseline activity of the various muscles by one-way repeated-measures analysis of variance.* ***Results:*** *The results confirmed the hypothesis. Co-contractions of the neck muscles in the range of 3% to 10% of maximum voluntary contraction were observed. Significant (*P *< .05) activity differences were recorded as a result of the different force levels and force directions exerted by the jaw muscles. Long-lasting action potential trains of single motor units triggered by jaw clenching tasks were also detected.* ***Conclusion:*** *The findings support the assumption of a relationship between jaw clenching and the neck muscle activity investigated. The low level of co-contraction activity, however, requires further study to elucidate possible pathophysiological interactions at the level of single motor units.* J OROFAC PAIN 2013;27:61–71. doi: 10.11607/jop.915

Key words: bruxism, electromyography, masticatory muscles, neck muscles

Masticatory muscles and neck muscles have a close functional connection, conforming to the fundamental principle that coordination of all body segments is a prerequisite for the neuromuscular interactions concerning static and dynamic physical motor activity. Like the masticatory musculature, the neck muscles are characterized by complex anatomy. More than 20 pairs of muscles are directly involved in the control of head position.[1] These muscles can be divided into anterolateral and posterior neck muscles. The posterior neck muscles are the trapezius, semispinalis capitis, semispinalis cervicis, splenius capitis, levator scapulae, and posterior paravertebral muscles. The infrahyoid muscle complex, sternocleidomastoideus, platysma, scaleni, and anterior prevertebral muscles are the anterolateral neck muscles. Little is known about consistent neuromuscular control strategies used for the appropriate muscle co-contractions during specific motor tasks. Preferred directions for activation of the neck muscles have been reported,[2–6] although large variations in muscle activation between subjects have been observed, especially for the splenius capitis,[7] scalenus medius,[3] and semispinalis capitis.[8]

In contrast to the neck muscles, probably because of better accessibility for electromyographic (EMG) recordings, co-contractions of masticatory muscles have been well studied under static and dynamic conditions[9–18] and control strategies have been assessed by biomechanical modeling.[13,19–25]

The functional link between both muscle groups has been well documented in numerous experimental studies. In particular, the head has to be stabilized against the shoulder girdle during forceful kinetic motor tasks, for example, during mastication. Kinematic and EMG recordings have shown that coactivation of neck and jaw muscles can be observed during jaw movement and during isometric contractions of masticatory muscles.[26,27] Jaw opening and the temporally related head extension in human subjects reveal the close association of head and neck movements.[28] Likewise, there is evidence that modification of the occlusal support changes the activity pattern of the neck musculature[29,30] or alters head posture.[31,32] Animal studies have revealed that input from orofacial structures can affect or initiate head-neck movements.[33] Neurophysiologic connections between the trigeminal systems, and neuromuscular control of the neck, have been verified by the "trigeminal neck reflex," which can be induced in humans and in animal models.[33,34] Kinematic interactions of both muscle groups are, furthermore, substantiated by biomechanical modeling.[35]

Epidemiologic surveys reveal a high comorbidity of masticatory-muscle and neck-muscle pain.[36,37] A close functional coupling of these muscle groups may be involved in the multifactorial etiology of craniocervical myofascial pain conditions.[38] In particular, it is assumed that muscular chain reactions, in the sense of masticatory muscle activity during bruxing which presumably triggers robust co-contractions of the neck muscles, might elicit myofascial pain by overloading these muscles in predisposed subjects. However, interactions between the masticatory system and the adjacent neck muscles under loading of the jaw muscles in the range of bite forces generated during bruxism have not yet been investigated.

The main objective of this study was to test the hypothesis that jaw muscles and specific neck muscles, ie, levator scapulae, trapezius, sternocleidomastoideus, and splenius capitis, co-contract at the different submaximum bite forces usually generated during jaw clenching and tooth grinding, and for different bite force directions. Maximum neck muscle strength in different horizontal force directions was also examined.

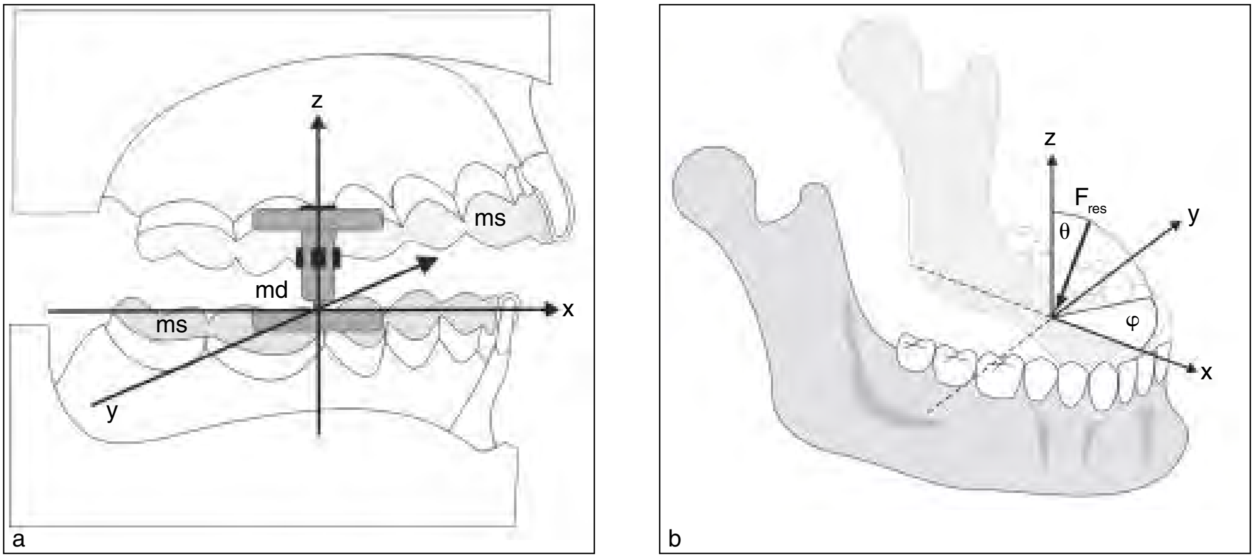
Materials and Methods

Subjects

Eleven healthy subjects (three female, eight male; average age 24 ± 2.3 years) participated in the experiments. Exclusion criteria were skeletal anomalies (eg, short-faced or long-faced as clinically assessed on the basis of soft tissue landmarks) or malocclusions (eg, in skeletal Class II or III), or history of injury or painful dysfunction of the craniocervical region. The study was approved by the Ethics Committee of the University Medical Centre, Heidelberg (S-213/2008). All participating subjects gave their informed written consent to the experiments. All experimental procedures were conducted in accordance to the declaration of Helsinki.

Intraoral Force Simulation and Force Measurement

For individual fabrication and adjustment of the force-measurement device, casts of the subjects' maxilla and mandible in maximum intercuspation were mounted in an articulator. Jaw separation at the incisors was adjusted to 5 mm. Bite force was transmitted by an intraoral "bearing pin device" equipped with strain gauges and mounted parallel to the occlusal plane of the mandible on a metal splint[39]; this device was based on the principles of the bite-force transducer described by Osborn and Mao.[40] Intraoral gothic-arch recordings with the inserted device located midway between the mandibular first molars were obtained to determine the centric jaw relation of the contact plate, which was placed on the mandible. A perforation drilled in the contact plate 0.5 mm anterior of the top of the gothic-arch tracing determined the position of the tip of the pin for force transmission in centric jaw relation. For force measurement, the cylindrical profile of the pin was equipped at half its height with four strain gauges (3/120 LY 11; Hottinger Baldwin Messtechnik), offset at 90 degrees to each other. The base plate was equipped with a fifth strain gauge (6/120 LY 11) mounted at the center of the underside. The transducer measured forces in three orthogonal directions (anteroposterior = x axis, left-right = y axis,



Figs 1a and 1b Schematic diagrams of the incorporated force transducer (md) and its orientation in the Cartesian x, y, z-coordinate system. ms, metal splint; angles θ; and φ in the spherical coordinate system used; F_{res}, resultant force.

vertical = z axis) relative to the occlusal plane (Fig 1a). Before the experiments, the force transducers were calibrated in a laboratory setup by increasing the loading stepwise (10-N steps) in the z, x, and y directions. The signals were amplified by use of a measuring amplifier (MGCplus ML55B; Hottinger Baldwin Messtechnik) and displayed on a monitor. The signals were also digitized (sampling rate 1,500 Hz) and recorded simultaneously with the EMG signals.

Feedback

The intraorally measured force vector was displayed to the subjects on a monitor.[41] The target values were marked on the display. The angle φ (angle between the x axis and the projection of the force vector on to the x-y plane) and the angle θ (angle between the z-axis and the force vector) of the spatial force vector generated by the subjects (Fig 1b) were displayed in a planar coordinate system as a vector. The angles φ and θ were plotted in the circumferential and radial directions, respectively. A pure vertical force corresponds, therefore, to θ = 0 degrees, and a pure horizontal force to θ = 90 degrees. The amount of force was shown on the display as an additional vertical bar incorporating a scale.

Measurement of the Strength of the Neck Muscles

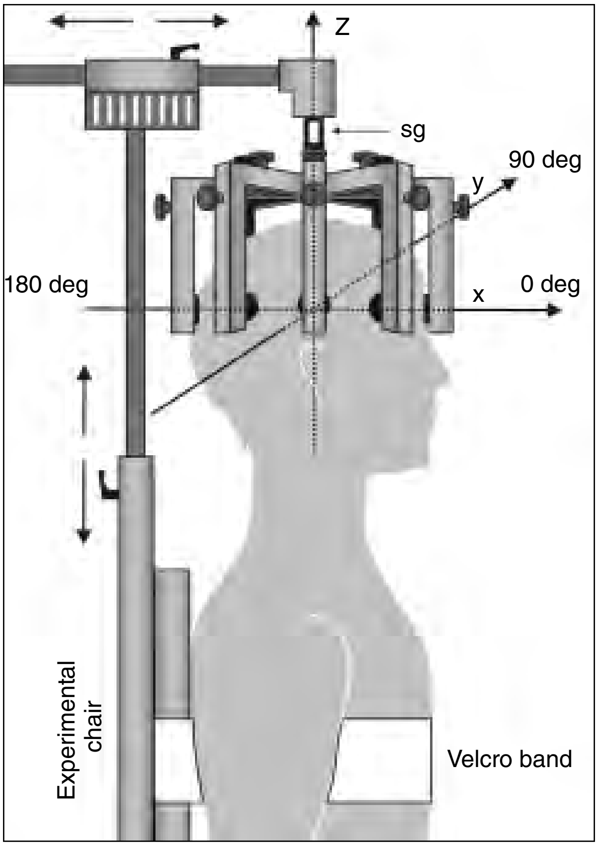


Fig 2 Measurement device for recording of maximum-effort tasks of the neck muscles. sg, strain gauges.

A special measurement device was developed (Fig 2) to record the EMG activity during maximum-effort tasks of the neck muscles, as recording of maximum electrical muscle activity is a prerequisite for normalization of submaximum EMG activity (measured during force-controlled motor tasks).[3]

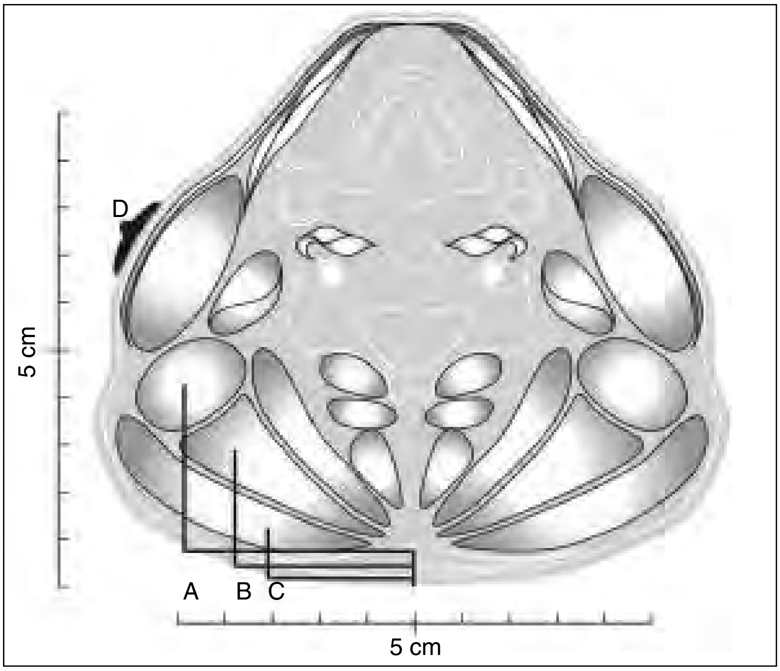


Fig 3 Schematic diagram of MRI scans used to determine the insertion region, penetration depth, and angulation of the needle with the wire electrodes. D, surface electrode over sternocleidomastoideus. Intramuscular position of the wire electrodes in the levator scapulae (A), splenius capitis (B), and trapezius (C).

Maximum strength and corresponding maximum EMG activity are usually developed in the loading direction with the optimum biomechanical advantage for the individual muscle. The device consisted of eight vertical rods in a circular arrangement, separated by 45-degree angles, concentrically connected, by horizontal bars, to a bending beam in the middle of the apparatus. The beam was equipped with four strain gauges (6/120 LY 11; Hottinger Baldwin Messtechnik) for two-dimensional force measurement. Prior to the experiments, the force transducer was calibrated in a laboratory setup. During the experiments, the test subject sat on a chair with the subject's upper part of the body fixed to the back of the chair by means of a Velcro band. The force-measurement apparatus, which was connected to the chair, could individually be adapted to the anatomical geometry of the subject so that all the vertical rods were in gentle contact with the head on a horizontal plane intersecting the middle of the forehead (Fig 2). In this position, the subjects were able to load the neck muscles in eight directions with maximum effort by firmly pressing the head in the direction of a particular vertical rod.

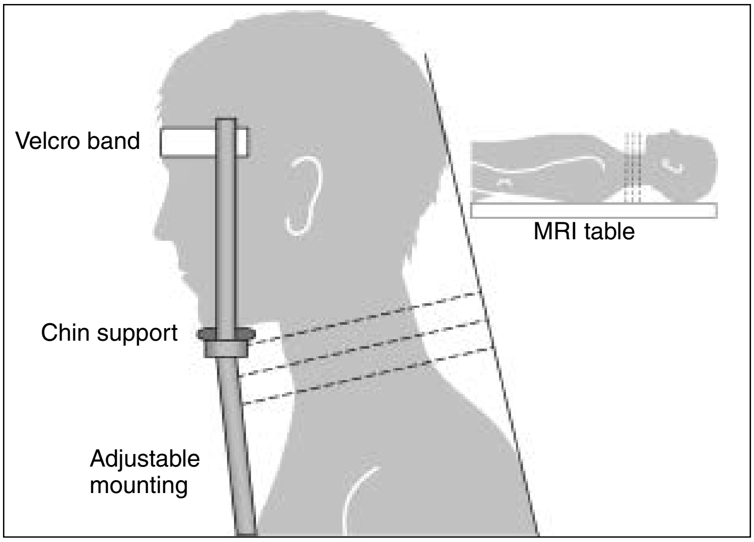
EMG Recordings

Bipolar surface electrodes measured bilaterally the electrical activity of the masseter muscle and the upper third of the sternocleidomastoideus muscle on a horizontal level, as is described later for the indwelling electrodes. The muscle bulk was located by palpation. Ag/AgCl electrodes with 14-mm conducting surface diameter, and 20-mm distance from center to center of the two electrodes (Noraxon Dual Electrodes, Noraxon), were placed parallel to the longitudinal axis of the muscle. Before electrode application, the skin was carefully cleaned with 70% ethanol. A single surface electrode placed over the 7th vertebra served as the common electrode.

Bilateral bipolar wire electrodes recorded the electrical muscle activity of the levator scapulae, splenius capitis, and trapezius muscles. Each electrode consisted of two Teflon-coated 0.08-mm stainless-steel wires (California Fine Wire) with de-insulated ends (1.5 mm) that were bent to a hook. The distance between the ends was approximately 3 mm. The electrodes were inserted by use of 0.4 × 40 or 0.6 × 50-mm disposable needles.

Penetration data for each subject were inferred from an axial T1-weighted 3D VIBE-sequence (Volume interpolated breathhold examination) of the neck at a 3-Tesla magnetic resonance imaging (MRI) system (Magnetom Trio; Siemens AG) with a voxel resolution of 0.5 × 0.5 × 1.0 mm. For a better delineation of the muscles to the surrounding fat tissue and fascia, the MRI sequence was performed out of phase with an echo time of 3.72 ms. Axial images at the level of the 5th cervical vertebra, perpendicular to an axis given by the points of contact of the back of the head and the upper back with the table of the MRI system, were used to determine insertion region and penetration depth (Fig 3). A modified adjustable head and chin rest (NovaVision AG) was used during insertion of the wire electrodes to reproduce the anatomical geometry of the neck

Fig 4 Schematic diagram of the device used to position a subject's neck corresponding to the neck posture on the MRI-scanner table.



as depicted in the MRI scans. This device enabled positioning of a subject's head and upper back in positions corresponding to those on the MRI table (Fig 4). Verification of the correct placement of the wires was accomplished for three test subjects by using 3D susceptibility weighted images (SWI) with an isotropic resolution of 0.8 mm. Because of the potential increase of temperature during examination in high-field MRI, these images were performed at a field strength of 1.5 Tesla (Magnetom Avanto; Siemens AG) and 0.05-mm polyurethane-coated platinum–iridium wires (Highways International). In contrast to steel wires, the polyurethane-coated platinum–iridium wires enabled a more accurate reconstruction of the position of the wires in the neck without interfering artifacts. The increase in temperature during the MRI scan was within the permitted physiological limits.

Before insertion of the wire, the level of insertion was located by palpation of the vertebrae. The landmarks determined by means of MRI were then transferred to the skin with a sterile pencil. Thereafter, the penetration area was disinfected with Cutasept F (Bode Chemie). The shortened security cap of the disposable needle was used as a penetration stop for the specified needle length. All needles were inserted perpendicular to the craniocaudal neck surface and parallel to the sagittal plane. The EMG signals were differentially amplified (MP100, Acquire 3.9.1 software; Biopac), bandpass-filtered (1 to 5,000 Hz), recorded at a sampling rate of 1,500 Hz, and saved on a computer.

Experimental Procedure

After placement of the electrodes in the manner described above, the subjects were strapped in the experimental chair. Initially, resting EMG activity was recorded for 10 seconds, followed by recording of EMG activity during three maximum-effort bites in intercuspation. The head device was then adjusted and the subjects developed maximum force against each vertical rod for approximately 3 seconds clockwise in each of the eight different directions. Two sequences of maximum force exertions were separated by a rest period of 10 seconds. All subjects received repeated vocal encouragement to achieve maximum force.

Subsequently, the intraoral force transducer was mounted on the maxilla and a metal splint with a plate on the mandible. The subjects generated 20 different force vectors in the central jaw position. Resultant force vectors were produced in orderly sequence with F = 50, 100, 200, and 300 N, each time with different angles φ (vertically, anteriorly 0 degrees, left 60 degrees, posteriorly 180 degrees, right 300 degrees) and a constant value of angle θ (60 degrees), except for the pure vertical direction, for which θ was 0 degrees (see Fig 1b). The angles φ = 300 degrees and 60 degrees were selected because in a previous study[42] it was found that oblique clenching activity spontaneously developed by the subjects was best generated at those angles. In an additional test, the subjects generated resultant bite force vectors of 50, 100, 200, and 300 N without a predetermined force direction. The force range was determined on the basis of previously reported nightly motor activity in normal subjects and bruxers.[43,44] To avoid muscle fatigue, the individual tests, which lasted up to 10 seconds, were separated by 1 minute. Each test was repeated three times. After completion of the bite experiments, the force transducer was removed and the subjects were instructed to chew unilaterally (right side) standardized test

Table 1 Mean Maximum Neck Muscle Forces and Standard Deviations (SD) in the Different Radial Force Directions

	Direction (deg)							
	0	45	90	135	180	225	270	315
Neck force (N)								
Mean	122	107	105	124	168	123	93	110
SD	42	44	46	57	83	60	39	37

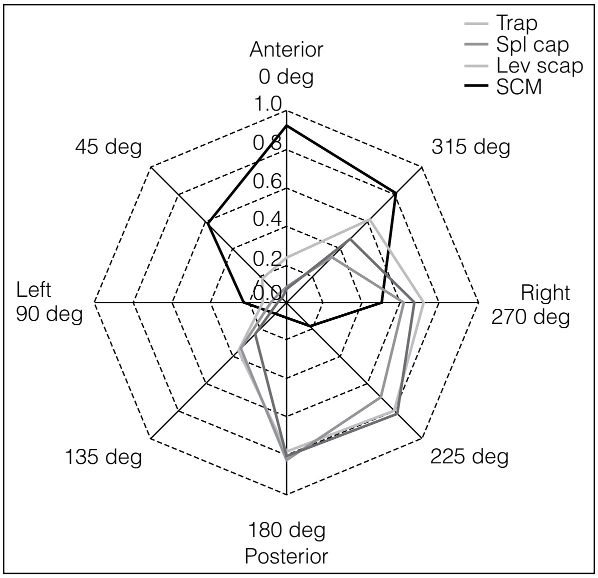


Fig 5 Maximum EMG activity of the right neck muscles in the predetermined horizontal directions during maximum-effort tasks. Trap, trapezius; Spl cap, splenius capitis; Lev scap, levator scapulae; SCM, sternocleidomastoideus.

food (17 silicon cubes, 5.6-mm edge length) with 15 chewing cycles as described in earlier experiments with three repetitions.[45] The chewing test provided comparative physiologic values for the submaximum clenching tasks.

Data Analysis

Specially developed software was used to determine the time at which the subject was closest to the given intraoral force vector, ie, the time at which the error

$$e = \left|\vec{F}_{\text{measured}} - \vec{F}_{\text{target}}\right| \Big/ \left|\vec{F}_{\text{target}}\right|$$

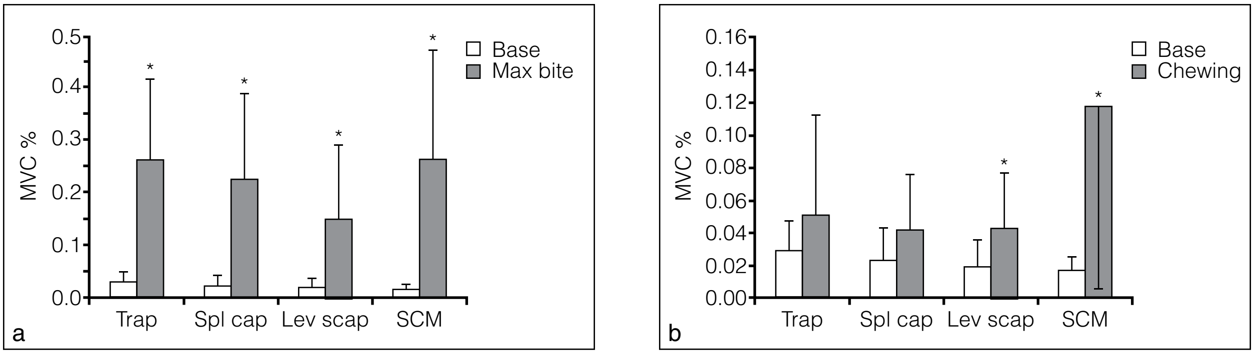
was minimum. An interval of 400 ms around this point was used for analysis of the activity of the neck muscles. The EMG data obtained for individual subjects were rectified with the root-mean-square algorithm (RMS) and normalized to the maximum EMG activity found during the maximum-effort tests for the respective muscle. Maximum neck strength was reported as mean and standard deviation (SD) of the two-dimensional force vectors. The inter-individual distribution of EMG activity for the various bite-force directions was reported as the mean values and SDs of the normalized data for the neck muscles. Neck muscle activity during the chewing tasks was averaged over the 15 chewing cycles, taking the mean for a 400-ms interval around the peak EMG activity of each cycle.

Statistical Analysis

The intra-individual scatter of the EMG values for the same tasks was clarified by use of the coefficient of variation (cv). The mean deviation of the measured force vectors from the target force vectors was determined for all subjects and all tests. The values were averaged over the 11 subjects and reported as a percentage (%). Maximum-effort tasks of the neck in the different loading directions were investigated by one-way repeated-measures analysis of variance (ANOVA). Differences between neck-muscle activity during chewing, maximum biting in intercuspation, and the force-controlled motor tasks were compared with the baseline activity of the various muscles by one-way repeated-measures ANOVA. The effect of force direction (six levels) and bite force (four levels) on EMG activity was examined for each muscle by two-way repeated-measures ANOVA. The activities of the left and right muscles during corresponding tasks were compared by use of two-tailed paired *t* tests. The value $\alpha = 0.05$ was selected as the level of significance.

Results

Comparison of the mean EMG activity of homonymous muscles of the left and right sides revealed no significant ($P > .05$) differences for corresponding motor tasks. It was, therefore, justified to average the activity of the individual muscles of both sides. The mean intra-individual variability (cv) of the EMG data for three replicate measurements was 17 ± 6%.



Figs 6a and 6b Neck muscle activity during maximum biting in intercuspation *(a)* and during chewing *(b)* compared with baseline activity. MVC %, normalized EMG activity (y axis: 1 = 100% MVC); Base, baseline; Max bite, maximum biting in intercuspation; Trap, trapezius; Spl cap, splenius capitis; Lev scap, levator scapulae; SCM, sternocleidomastoideus. *$P < .05$.

The mean deviation of the intraorally measured force vectors from the target force vectors was 12 ± 5%.

Table 1 shows the mean values of the maximum forces generated from the neck muscles studied in the different load directions. The mean force values in the eight force directions ranged from 93 ± 39 to 168 ± 83 N. Figure 5 depicts the EMG activity of the investigated muscles of the right side during maximum-effort tasks. One-way ANOVA revealed significant ($P < .05$) EMG and corresponding force differences for the different loading directions of the neck. Splenius capitis, trapezius, and levator scapulae generated the most activity on the ipsilateral side during tasks from the anterolateral to posterior direction. The EMG activity in the anterolateral direction was highest for the trapezius followed by the levator scapulae and splenius capitis. The highest activity for the splenius capitis was observed in the posterior direction. In the subsequent directions, the differences decreased and disappeared completely in the posterior direction. In contrast, the maximum EMG activity of the sternocleidomastoideus was measured in the anterior direction, followed by the anterolateral and lateral directions. Substantial contralateral co-activation during the tasks was observed for the sternocleidomastoideus only.

Figures 6a and 6b depict EMG activity of the examined neck muscles during maximum biting in intercuspation and during chewing tasks compared with baseline EMG activity. Maximum activation of the masticatory muscles caused the most significant ($P < .001$) coactivation of the neck muscles (range 15% to 25% of their maximum voluntary contraction [MVC]). Chewing tasks resulted also in significant ($P < .05$) EMG activity differences compared with baseline, but only for the levator scapulae and sternocleidomastoideus. An example of the coactivation of a neck muscle and the masseter during chewing tasks is depicted in Fig 8b.

Figure 7 illustrates the EMG response of the four neck muscles related to the intraoral force levels and force directions applied, compared with their baseline EMG activity. Baseline EMG activity of all examined neck muscles was significantly ($P < .05$) lower than that during the controlled motor tasks. The normalized EMG activity of the muscles generated by submaximum bite forces ranged between 3% and 10% of MVC. For the trapezius, in particular, exceptionally high inter-individual variability (SD) was observed. Depending on the individual muscle, two-way ANOVA revealed significant ($P < .05$) EMG activity difference between force directions (trapezius, levator scapulae), force direction and force levels (sternocleidomastoideus), or interactions between both factors (splenius capitis), ie, the force directions affected the EMG activity differently at the different force levels. The best correlation of increased EMG activity with force was observed for the sternocleidomastoideus, but correlation was also seen for the trapezius and splenius capitis. For the latter two muscles, EMG activity was greater during 50-N loads than during 100-N loads, in several force directions. This behavior could be systematically observed up to 200-N loads for the levator scapulae as well. On average, force vectors without direction control (free bite tasks) resulted in less EMG activity in the neck muscles than equal force vectors generated in specific directions.

Observations of single motor unit behavior in the neck musculature revealed that during oral motor tasks, long-term action potential trains could be triggered, outlasting the specific masticatory muscle force production. A representative case is illustrated in Figs 8a and 8b.

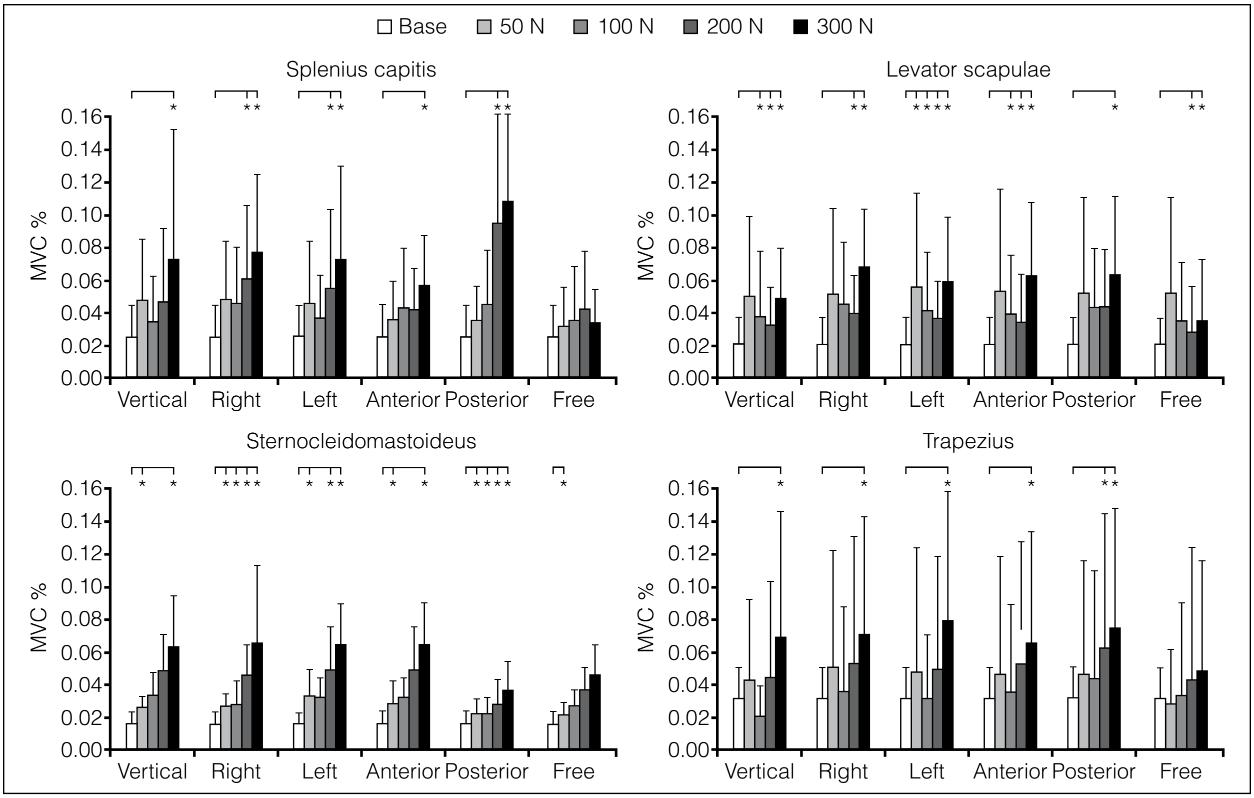


Fig 7 Dependence of the EMG response of the four neck muscles on the applied intraoral force and its direction, compared with baseline activity. MVC %, normalized EMG activity; Base, baseline. *$P < .05$ compared to baseline.

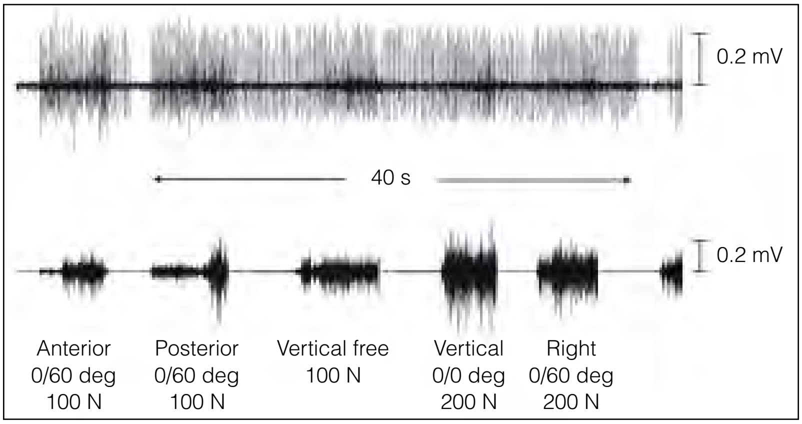


Fig 8a Representative raw EMG recordings from the left levator scapulae *(top)* during intraoral bite-force generation in different directions documented by the EMG activity of the right masseter *(bottom)*. In addition to the EMG increase during the specific motor tasks, long-lasting low-level activation of motor units can be observed throughout the duration of the different motor actions.

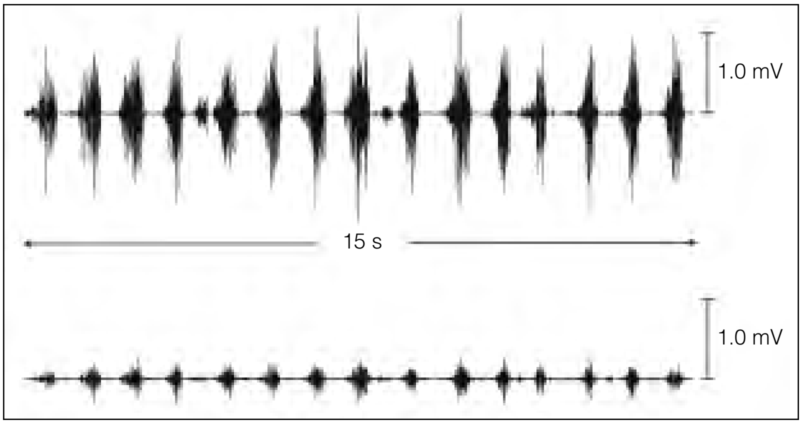


Fig 8b Co-activation of the right masseter *(top)* and the right sternocleidomastoideus *(bottom)* during chewing of artificial test food. s, seconds; mV, millivolts.

Discussion

The main result of this investigation was that during submaximum jaw clenching, weak but significant co-contractions of the neck muscles could be observed. The co-activations did not essentially exceed those observed during chewing, but differed significantly from baseline EMG activity. Activation of all neck muscles was significantly lower during chewing than during maximum biting. Under both conditions, however, significant activity differences compared with baseline could be observed. For the chewing task, only levator scapulae and sternocleidomastoideus activation reached a significant level. Differences between activation behavior in chewing and maximum biting can be ascribed to different motor-control strategies and the concomitant different force levels generated under these experimental conditions.

Previous studies of the co-contraction behavior of jaw and neck muscles under maximum activation of the masticatory muscles were restricted to the sternocleidomastoideus and trapezius muscles.[46–50] The present findings showed, for the first time, that co-contraction can also be observed under submaximum activation of the masticatory muscles, which is, presumably, in the same range of muscle activity during bruxing.[43,44] These effects were demonstrated for all the neck muscles studied. The high inter-individual variability (SD) of EMG activity observed for all the muscles investigated, and most pronounced for the trapezius, might be explained by sex differences of muscle cross-sectional area or differences between intermuscular and/or intramuscular activation patterns. Individually characterized co-contraction behavior is also a common feature of motor control between masticatory muscles.[25]

The significant co-activation during maximum-effort tasks in intercuspation supports the findings of previous studies,[46–48] but questions their predictive value for pathophysiological interactions, because jaw muscle activation during bruxing does not, by far, reach these levels of activity, as can be inferred from previous studies in which EMG activity was investigated during sleep for normal subjects and bruxers.[43,44]

It might be argued that the intraoral force-measurement device affected the contraction behavior of the jaw muscles and, in turn, that of the neck muscles. A previous study,[42] however, evaluated maximum biting in intercuspation and biting with incorporated measurement devices as used in this study. Excellent agreement of activity levels in different regions of the masseter was observed under both conditions. Significant bias, caused by the instrumentation, of neck muscle co-contraction affected by activity changes in the masseter is, therefore, unlikely, although the possibility cannot be excluded completely, because masticatory muscle length was marginally changed by the experimentally produced jaw opening of approximately 5 mm in the incisal region.

Some limitations of the study must be emphasized. As found in morphological studies, inter-individual shape and size of the neck muscles differ substantially.[51] Therefore, the cross-sectional area in which the wire electrodes had to be placed varied among subjects. Although the MRI scans available for each subject enabled optimum orientation during wire insertion, as shown by the verification study, the possibility of cross talk from adjacent muscles cannot be excluded. So the recorded EMG activity should be regarded as a measure of regional muscle activity rather than a measure of the activation of a specific muscle. Nevertheless, the maximum activity measured in this research corresponded well to that reported for the specific muscles in the corresponding directions.[3,52] Bruxism is usually associated with nightly motor activity in the supine position. All force-controlled simulations of this study were performed under static conditions with the subjects seated. A supine body posture might affect the muscle activity of the neck in a different manner. Future studies will address this issue. Furthermore, only selected dorsal neck muscles were investigated. No data from the other deep dorsal and anterior neck muscles have yet been recorded under these experimental conditions. Further studies are needed to complete the picture of neck muscle co-contraction during submaximum activation of the masticatory system.

In contrast with other studies, all muscle activity was recorded in the same anatomical plane and the normalizing procedure was accomplished in a force-direction–controlled manner. This procedure provided data for the maximum force capacity developed by healthy subjects, which are in good agreement with those of previous investigations.[3,52] The experimental method might be used in the future for comparative studies between patients and controls.

Realistically, the relatively weak contractions make it difficult to explain biomechanical overload on the basis of the individual muscles, in particular if the activity lies in the range of physiological loading, ie, during chewing, as has been shown in this study. However, in the context of actual hypotheses of pathophysiologic mechanisms of acute myofascial pain,[53] it seems conceivable that even small activity changes might trigger single motor units of type-I fibers into long-lasting activation, as has been demonstrated for the trapezius muscle in previous studies.[54,55] Further support for the concept of local muscle overload comes from a well-founded explanation of work-related upper extremity muscle disorders (with myalgias being the main symptom); it is assumed that repetitive, long-lasting, low-intensity muscle loading may selectively and continuously activate small type-I motor units (Cinderella hypothesis). Because of accumulation of Ca^{2+} in the active motor units, and other homeostatic disturbances, including impaired blood flow, single muscle fibers may become metabolically exhausted and be damaged.[53,56,57] Basically, it is possible that long-lasting motor unit activation similar to that described for the trapezius might also occur within all the neck muscles of *susceptible patients*, triggered by tooth grinding or jaw clenching. It must, however, be emphasized that bruxism is more than static activation of the jaw muscles; it also includes dynamic (grinding) muscle activity. Although bruxism can be performed during wakefulness as more or less conscious muscle activity, it can also be unconsciously performed during sleep. The possibility that co-contraction of the neck muscles is different for conscious and unconscious biting tasks cannot, therefore, be excluded. Nevertheless, the long-term activation of the neck muscles, outlasting the specific masticatory muscle force production, found in this study might be an indicator of such interrelation. However, to support this hypothesis, further studies are needed to investigate co-contractions of neck muscles at the level of single motor units.

Acknowledgments

The first and second authors made equal contributions to this investigation. This investigation was supported by the Deutsche Forschungsgemeinschaft grants RA 1737/2-1 and SCHW 307/25-1. The authors declare no conflict of interest.

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