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Modulation of neck muscle activity induced by intra-oral stimulation in humans

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HIGHLIGHTS

- The effect of intra-oral electrical stimulation on the dorsal neck muscle activity was investigated in healthy volunteers.
- The electromyographic (EMG) activity was reduced around 50 ms after the painful intra-oral electrical stimulation on average 80% compared to baseline level in all subjects.
- Local anesthesia of the stimulus site resulted in smaller inhibition of the dorsal neck EMG activities and disappearance of the painful sensation evoked by the stimulation.

ABSTRACT

Objective: To investigate the effect of painful electrical stimuli applied to intra-oral tissues around the teeth on the neck muscle activity in healthy humans.
Methods: Electromyographic (EMG) responses of the dorsal neck muscles evoked by intra-oral electrical stimulation were recorded before and after local anesthesia to the stimulus site in 17 healthy volunteers.
Results: Inhibition of dorsal neck muscle EMG activities on average 80% compared to baseline level was observed with a latency around 50 ms after the electrical stimulation before anesthesia, and the EMG activity inhibition decreased after anesthesia of the intra-oral stimulus site. The perceived intensity of the electrical stimuli as scored on a visual analogue scale (VAS) was 6.1 ± 0.4 cm before anesthesia and 1.5 ± 0.2 cm after anesthesia.
Conclusion: Intra-oral stimulation can inhibit neck muscle activity. This modulation might be attributed mainly to nociceptive afferent nerves however, non-nociceptive fibers could also be responsible.
Significance: Intra-oral information including nociceptive activity can inhibit neck muscle activity. From a clinical viewpoint, the present findings demonstrate the neural connectivity between the trigeminal region and the cervical region raising the possibility that orofacial pain conditions could influence head, neck and shoulder activity.

1. Introduction

In routine dental practice, we sometimes encounter patients suffering from chronic head, neck and shoulder pain that may be related with a dysfunction of the stomatognathic system. Temporomandibular disorders (TMD) have been reported to be accompanied by symptoms such as pain, stiffness, fatigue, and limitations in the muscle function in the head, neck, and shoulder regions (Gelb and Tarte, 1975; Sheppard and Sheppard, 1977; Schroeder et al., 1991; Luz et al., 1997). It has been suggested that dental treatment may potentially influence head, neck and shoulder symptoms of these TMD patients (Kirveskari and Alanen, 1984; Kirveskari, 1997), but the evidence is still lacking and the topic controversial.

Neural and clinical connections between the stomatognathic system and neck muscles have been reported in many papers (Svensson et al., 2004, 2005; Ge et al., 2004; Wang et al., 2004;

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Manni et al., 1975; Sumino et al., 1981; Alstermark et al., 1992; Abrahams et al., 1993; Dessem and Luo, 1999; Browne et al., 1993). Some of these reports demonstrate that an electric stimulus to the branches of the trigeminal nerve or a mechanical stimulus to the facial skin modulates neck muscle activity (Manni et al., 1975; Sumino et al., 1981; Alstermark et al., 1992; Abrahams et al., 1993). This response has been called the trigemino-cervical reflex (Lazzaro et al., 1995; Sartucci et al., 1986; Quartarone et al., 2000; Nakashima et al., 1992; Serrao et al., 2003). In addition, neural projections from deep orofacial structures, e.g. masticatory-muscle spindles (Dessem and Luo, 1999), the temporomandibular joint (TMJ) (Yu et al., 1995) and the masseter muscle (Hellström et al., 2000) to the motoneurons or circuits controlling neck muscles were also reported. Other studies report modulation of the neck muscle activity (Svensson et al., 2004), reflexes in the neck muscles (Ge et al., 2004; Wang et al., 2004) and pain characteristics of the neck region (Svensson et al., 2005) after experimental jaw muscle pain. In contrast to muscle and joint receptors, only few reports in animal studies give specific information about the connections between intra-oral receptors and neck muscle activity (Zeredo et al., 2002), or convergence of tooth pulp, facial and neck afferents onto C1 spinal neurons (Matsumoto et al., 1999; Nishikawa et al., 2004). In humans, only one study (Browne et al., 1993) was found. In this study the authors reported that inhibition of the sternocleidomastoid muscle activity could be evoked by electrical stimulation of the gingiva. Consequently, only sparse evidence has been reported regarding sensory–motor interactions between the intra-oral sensory system and neck muscle activity. The aim of the present study, therefore, was to investigate the effect of painful electrical stimulation of the gingiva on neck muscle activity in humans.

2. Materials and methods

2.1. Participants

Seventeen healthy individuals (7 women, 10 men; aged 23–33, mean 26.2) participated in this study. They were free from any signs or symptoms of craniomandibular, neck and shoulder disorders, periodontal or endodontic disease. None of the subjects took any medication at least 1 month before participation. This study was approved by the ethics committee of Nagasaki University School of Dentistry (approval No. 0959) and followed the guidelines from the Helsinki Declaration. All subjects gave their informed consent and understood that they were free to withdraw from the experiment at any time.

2.2. Recording and stimulation

A pair of fine wire electrodes 100 μm in diameter (KS211-018; Unique Medical, Japan) was used to record the electromyographic (EMG) activity from the right dorsal neck muscles. The electrodes were inserted into the hair pouch about 3 mm deep and placed 15 mm apart. The electrode-position was vertically in the upper 1/4 part of the dorsal neck between the torus occipitalis and the seventh cervical spine, and horizontally about 2 cm to the right from the midline. To secure the electrode position, retroflex movement of the neck was performed, and stable and appropriate EMG recordings were observed. A reference surface electrode was attached to the right earlobe. The EMG signals were amplified, filtered with bandpass 10 Hz–5 kHz (Neuropack four mini, Nihon Kohden, Japan), sampled at 2560 Hz, and stored from 50 ms before to 200 ms after the electrical stimulus by use of waveform analysis system (MacLab; ADInstruments, Pty Ltd) for further analysis. Forty sweeps of responses to the electric stimuli were evoked in each condition, i.e. before and after local anesthesia of the stimulus site.

A ball type electrode of 1.5 mm diameter (UL 3010-1; Unique Medical, Japan) was placed on the buccal gingiva of the right upper first premolar as a cathode, and a disc electrode of 8 mm diameter was placed on ipsilateral palatal gingiva as an anode. Both electrodes were fixed by dental resin reinforced with dental wire. That is, a resin frame with a clip-like shape, fixing the two electrodes was made on a die of the upper dental arch of each subject. Then, using the frame, the ball and disc electrodes were fixed to buccal and palatal gingiva, respectively. An electrical square-wave pulse (0.2 ms duration, 0.3 Hz) was delivered by a constant-current stimulator (Neuropack four mini, Nihon Kohden, Japan). To determine the intensity of the electrical stimulation, the sensory threshold (ST) to the electrical stimulation and the tolerance limit as the upper limit of the intensity were determined for each subject. All stimuli were delivered below the tolerance limit of each subject. Basically, the EMG response was evoked with an intensity of $8 \times$ ST, which was usually perceived as slightly to moderately painful. The perception level was scored in all subjects and the pain level in ten out of 17 subjects, using a 10 cm visual analog scale (VAS, 0 = no sensation, 10 = most pain imaginable) and (VAS, 0 = no pain, 10 = most pain imaginable). During the preliminary test recording, the lowest stimulus intensity needed to obtain a clear reflex response was determined for each subject. The intensity varied between 8 and $15.5 \times$ ST. This stimulus intensity was always within the tolerance limit and used for each subject in the two conditions.

2.3. Experimental protocols

All subjects participated in 2 recording conditions (before and after local anesthesia). The two sessions were carried out during the same experimental day with a 20 min interval. At the start of the experiment, three maximum efforts of 3 s each were performed to contract the dorsal neck muscles against resistance of the examiner's hands put on the subject's occipital region. The maximum voluntary contraction (MVC) using the rectified and integrated EMG was calculated as the maximum value of the 3 efforts. During recording of the responses to the electrical stimuli, the subjects were instructed to contract their dorsal neck with their eyes closed. The rectified and integrated EMG activity of the dorsal neck muscle was displayed on an on-line monitor, and the experimenter instructed the subjects to keep a constant EMG level around 15% MVC. The experimenter used the feedback signal to give the subject verbal instructions. A one-kg weight applied on the subject's forehead by means of a headgear, made it easier for the subjects to keep the contraction level of the dorsal neck muscles constant.

2.4. Anesthesia

Infiltration anesthesia around the roots of the right first premolar was performed with a maximum of 1.8 ml of local anesthetic (2% Xylocaine; epinephrine 1:80,000; Fujisawa–AstraZeneca Japan). Five minutes after the anesthesia, stimuli were delivered again. Before restarting the recordings, it was ensured that painful sensations evoked by poking the oral mucosa using a dental probe with a sharp tip around the anesthetized tooth had disappeared.

2.5. Data analysis

Fig. 1 shows a typical EMG responses and the data processing. Every reflex response was A/D converted at 2560 Hz using a waveform analysis system (MacLab; ADInstruments, Pty Ltd) from 50 ms before to 200 ms after the onset of electrical stimulus in order to measure the reflex response. The EMG signals of 40