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Jaw tremor as a physiological biomarker of bruxism

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HIGHLIGHTS

- Patients with sleep bruxism show abnormal tremor of the jaw during a visually-guided bite force task.
- The magnitude of ~8 Hz jaw tremor and its modulation by dynamic bite force production separated patients from controls.
- The spectral characteristics of force tremor and masseter EMG activity suggest that bruxism is marked by abnormal or mishandled periodontal feedback.

ABSTRACT

Objective: To determine if sleep bruxism is associated with abnormal physiological tremor of the jaw during a visually-guided bite force control task.
Methods: Healthy participants and patients with sleep bruxism were given visual feedback of their bite force and asked to trace triangular target trajectories (duration = 20 s, peak force <35% maximum voluntary force). Bite force control was quantified in terms of the power spectra of force fluctuations, masseter EMG activity, and force-to-EMG coherence.
Results: Patients had greater jaw force tremor at ~8 Hz relative to controls, along with increased masseter EMG activity and force-to-EMG coherence in the same frequency range. Patients also showed lower force-to-EMG coherence at low frequencies (<3 Hz), but greater coherence at high frequencies (20–40 Hz). Finally, patients had greater 6–10 Hz force tremor during periods of descending vs. ascending force, while controls showed no difference in tremor with respect to force dynamics.
Conclusion: Patients with bruxism have abnormal jaw tremor when engaged in a visually-guided bite force task.
Significance: Measurement of jaw tremor may aid in the detection/evaluation of bruxism. In light of previous literature, our results also suggest that bruxism is marked by abnormal or mishandled peripheral feedback from the teeth.

1. Introduction

Bruxism is a relatively common disorder in which unconscious jaw clenching can lead to pain, headaches, and severe damage to the teeth (reviewed in Shetty et al., 2010; Manfredini et al., 2013). The neurophysiological origin of the condition is not known and appears to be multifactorial. Early theories relating bruxism to improper dental contact are no longer considered valid (Rugh et al., 1984; Clark et al., 1999; Manfredini et al., 2013), however, the condition may still be marked by dysfunction in the acquisition or handling of afferent feedback from the teeth and jaw. For example, patients with bruxism overestimate the level of bite force required for a precise task, indicating a sensorimotor deficit related to the control of jaw force (Mäntyvaara et al., 1999). Further, it has been shown that patients with bruxism have lower interocclusal tactile thresholds (i.e., the minimum thickness of foil that can be detected

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between the teeth) compared with healthy individuals, which may indicate hypersensitive periodontal mechanoreceptors (Suganuma et al., 2007). Although a clear link between bite force perception and tooth grinding has not been established, periodontal mechanoreceptors do provide positive feedback to masseter motor neurons, and play an important role in chewing (Türker 2002, 2007).

Periodontal mechanoreceptor feedback also appears to generate a jaw tremor of ~8 Hz in healthy participants which can be observed during bite force tracking (Sowman et al., 2006, 2007, 2008), and is eliminated by periodontal anesthetization (Sowman et al., 2006, 2007). Non-neural sources of physiological tremor, such as mechanical resonance, have been largely ruled out with respect to the jaw-muscle system (Junge et al., 1998). If periodontal sensation is altered in bruxism (Mäntyvaara et al., 1999; Suganuma et al., 2007), then it is likely that abnormal jaw tremor may mark bruxism as well. In healthy participants, 8 Hz jaw tremor is of greater magnitude during descending (isometric) force ramps relative to ascending force ramps (Sowman et al., 2008). The dynamics of force production can influence motor neuron behavior through afferent feedback (Semmler et al., 2002), or through the intrinsic properties of motor neurons themselves (Gorassini et al., 2002; Revill and Fuglevand, 2011; Vandenberk and Kalmar, 2014). Intrinsic properties are not known to be altered in bruxism, at least in terms of overall firing rates and the activation of persistent inward currents during voluntary bite force production (D'Amico et al., 2013). However, it is possible that in bruxism, where afferent feedback may be abnormal or mishandled (Mäntyvaara et al., 1999; Suganuma et al., 2007), the normal relationship between tremor magnitude and force dynamics could be altered as well.

In this investigation, we tested two main hypotheses. First, we predicted that patients would have increased 8 Hz jaw tremor compared to controls during a force tracking task, assuming hypersensitivity of periodontal mechanoreceptors is sufficient to increase 8 Hz tremor (as hyposensitivity decreases 8 Hz jaw tremor). Second, we predicted that the difference in 8 Hz jaw tremor between ascending and descending ramp contractions would be larger in patients relative to controls, since overactive periodontal mechanoreceptors may be hyperresponsive to different force dynamics. If patients with bruxism show abnormal jaw tremor, then its measurement might provide insight into the physiology of the condition, and perhaps serve as a clinically useful biomarker. To our knowledge, there has been no previous exploration of jaw tremor as a potential biomarker of bruxism.

2. Methods

All procedures were approved by the Human Ethics Committee of Ege University and were conducted in accordance with the Declaration of Helsinki. Participants gave informed consent prior to testing. The recordings utilized in the present investigation have also been described in the study of D'Amico et al., 2013, in which a separate set of measurements (single motor unit activation properties) were analyzed. Overall, data were collected from 9 (2 male, age range 24–35 years) healthy participants and 13 patients (5 male, age range 19–29 years) with sleep bruxism. Control participants had a mean age of 26 (3.7 SD) and the bruxism patients had a mean age of 22 (3.1 SD). Symptom severity was assessed by a clinician on the basis of stiff/painful jaw muscles and a dental examination. The symptom level of each patient was graded a scale of 1–5, with level 1 indicating no obvious pain or tooth abrasion and level 5 representing continuous bruxing. The cohort analyzed in the present study included patients with level 2 (light jaw pain and no tooth abrasion), level 3 (mild pain and light tooth abrasion), and level 4 (severe joint pain and significant tooth abrasion) symptoms.

2.1. Data recording

Bite force was measured using a custom apparatus in which a force transducer (Kyowa (KFG-5-120-C1-11) strain gauge) was fitted to a bite-bar. The bite plates were coated with dental impression material (3M Express, 3M ESPE, St. Paul, MN, USA) to ensure a comfortable fit and to ensure consistent contact forces and jaw positions across participants. Surface EMG electrodes were placed over the right masseter muscle in a bipolar configuration grounded at the lip. Force and EMG signals were amplified using CED 1902 amplifiers and acquired at 2000 Hz using a CED power 1401 data acquisition board along with Spike 2 software (Cambridge Electronic Design, Cambridge, UK). Data analysis was conducted offline using custom Matlab (The MathWorks, Inc, Natick, MA, USA) scripts.

2.2. Experimental task

Participants sat upright in a dental chair facing a feedback monitor. A stable but relaxed position for the neck and jaw was ensured through the use of a head restraint and an adjustable arm which held the bite-bar. In each trial, participants were instructed to track a 20 s triangular target trajectory displayed on the computer screen using visual feedback of their bite force. Five trials were recorded from each participant. The peak forces (occurring at 10 s) were variable across trials, as required by the protocol of a separate study in which single motor unit activity was analyzed (D'Amico et al., 2013). Although variable, we confirmed that no statistical differences in bite force existed between patient and control trials prior to further analysis (see Section 2.7). For the present analysis, only trials with peak forces between 5 and 35% Maximum Voluntary Contraction (MVC) strength were used. Each target trajectory spanned the height (35 cm) of the 56 cm computer monitor, which was placed 1.5 m from the subject, at eye level. Visual gain therefore varied from 0.38 DVA (degrees of visual angle) per 1% MVC to 2.67 DVA per 1% MVC. Our exclusion criteria resulted in a final data set consisting of 33 trials collected from 8 control participants and 53 trials from 11 patients. Neither peak forces nor visual gains varied significantly between patient and control trials ($p > 0.1$ for both measures, unequal variance t-test). An example of an individual force/EMG recording is shown in Fig. 1.

2.3. Force analysis

Raw force signals were normalized to each participant's MVC strength, which was established from the average of 3 maximum-force bites. The force traces were then band-pass filtered (1–50 Hz) to remove the target 'triangle', leaving only force tremor and error corrections. The filtered traces were then used for all subsequent spectral analyses of force. We chose to focus on activity under 50 Hz for all analyses since this covers the full range of frequencies typically associated with neural drive to muscles. Although greatly attenuated within the force spectrum, the higher frequency components of neural drive are still detectable in measures of EMG activity and force-to-EMG coherence.

Power spectra were estimated with Welch's modified periodogram method, using 2 s, Gaussian-windowed time segments, with 50% overlap between segments. This yielded power spectra with a frequency resolution of ~0.5 Hz. The absolute power and relative power (expressed as % of total power between 1 and 50 Hz) were evaluated at each frequency. Spectra were then smoothed in the frequency domain using a 1 Hz moving window (3 frequency samples, equal weighting). We focused primarily on relative power (vs. absolute power), as it is ideal for assessing differences in the