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Revisited relationships between probable sleep bruxism and clinical muscle symptoms

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ABSTRACT

Objectives: Sleep bruxism (SB), characterized by repetitive jaw-muscle activity during sleep, is often suggested as a cause of temporomandibular disorders (TMD), orofacial pain, and headache. This study aimed to challenge the relationship between jaw-muscle electromyographic (EMG) activity during sleep and jaw muscle symptoms including pain by modulation of the levels of EMG activity. Contingent electrical stimulation (CES) using a portable single-channel EMG device was applied at different stimulus intensities to inhibit jaw muscle activity.
Materials and methods: Sixty probable sleep-bruxers, screened and confirmed by a 2-week use of a portable EMG device, were randomly allocated into one of 3 groups (High/Low/Placebo CES). At baseline and after 2 weeks CES intervention, the participants were asked to score pain intensity, as well as unpleasantness, fatigue, tension, soreness and stiffness in their jaw muscles, on 0–10 numerical rating scales (NRS).
Results: Only in the High CES group, the number of EMG events/hour was significantly decreased ($P = 0.024$). Although the NRS scores of pain did not change, interestingly the NRS scores of unpleasantness ($P = 0.037$), tension ($P < 0.001$) and soreness ($P = 0.004$) in the High CES group and tiredness ($P = 0.002$) and soreness ($P = 0.006$) in the Low CES group were significantly decreased after the CES intervention compared to baseline.
Conclusion: High intensity CES demonstrated inhibitory effect on masticatory muscle EMG activity during sleep and was associated with significant decreases in jaw muscle symptoms (unpleasantness/tiredness/soreness) but not pain responses. These findings challenge the traditional concept that probable sleep bruxism is directly related to pain but appears related to more unspecific muscle symptoms.

1. Introduction

Bruxism is characterized by repetitive jaw-muscle activity during awake or sleep periods that can be present as clenching or grinding of the teeth and/or by bracing or thrusting of the mandible [1]. Sleep bruxism (SB) is believed to cause dental problems such as tooth wear, damage or fractures of tooth structures or dental restorations, pain in the orofacial region, and tension-type headache, which can be associated with impaired quality of life for patients [2,3]. SB is, indeed, often suggested as a cause of orofacial pain, such as temporomandibular disorders (TMD), and headache [4–7]. Despite extensive research efforts, the relation between SB and many adverse clinical symptoms and signs still remains unclear. Furthermore, the factors causing SB and the physiological mechanisms behind SB are still being discussed [3].

As an option to monitor SB, ambulatory single-channel EMG recording devices have been used to characterize the frequency of repeated grinding or clenching episodes which have been termed Rhythmic Masticatory Muscle Activity (RMMA) [7,8]. In addition to be able to monitor SB, a new treatment option to inhibit or reduce jaw muscle activity during sleep with the use of contingent stimulation has been researched using different types of stimuli e.g. auditory [9], electrical [10], vibratory [11], and taste [12]. Surface EMG electrodes and single-channel EMG devices can be employed not only to assess EMG jaw muscle activity during sleep [7] but also to deliver “contingent electrical stimulation (CES)” [13]. The use of CES on the temporalis muscle has been shown to induce a reduction of 54–55% jaw muscle EMG events/hour of sleep [14]. Furthermore, this reduction in EMG events may last for some days, even when the CES has been terminated [10,13]. Importantly, this type of inhibitory non-painful CES does not cause major sleep arousal responses [10,13]. Nevertheless, it is

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not known how different intensities of CES may affect the efficacy to induce an inhibition of EMG activity during sleep.

The main aim of this study was to test the efficacy of different intensities of CES to inhibit EMG activity during sleep. The secondary aim was to compare the potential inhibitory effect on EMG activity during sleep to changes in self-reported muscle symptoms.

2. Materials and methods

2.1. Participants

Adult individuals (> 18 years old) with "probable SB" [1] were included from the clinic of the Department of Dentistry and Oral Health, Faculty of Health, Aarhus University. Also, advertisements were posted inside the campus of Aarhus University and on the webpage (www.forsoegsperson.dk). Inclusion criteria were "probable SB": self-reported SB or reported by sleep-partner of tooth-grinding noises, and at least one or more of the following clinical signs: wear facets (grade > 1), hypertrophy of the masseter muscle, evidence of wear on oral splint, hyperkeratosis of cheek mucosa (linea alba), teeth impressions on the tongue, lips or tooth, tooth or tooth restorations fractures due to bite forces, or sign or symptoms of traumatic occlusal contacts. Exclusion criteria were: use of pacemaker, reported allergies to nickel or rubber, simultaneous participation in another trial with medicine, or in trials of medical devices. In case an individual wore an oral appliance, they were asked to discontinue the use of the device during his/her participation in the study. The study was approved by the local ethics committee (approval No. 1-10-72-192-14, Aarhus County, Denmark) and conducted in accordance with the Helsinki Declaration II. Also, this study was managed by Good Clinical Practice. Prior to participation, informed consent was obtained from all the patients. Initially, 149 individuals with a self-report of bruxism were assessed for eligibility to participate in this study. In total, 93 probable bruxers were included, 66 probable bruxers participated and, finally, 60 probable bruxers completed the study (Fig. 1).

2.2. EMG recordings

EMG activity of the temporalis muscles was recorded with a portable EMG device (GC4-DL Prototype device; hereafter GC4-β, Sunstar Suisse SA) during sleep at home. GC4-β has a single-electrode assembly with three electrode contacts. The electrode was placed at the anterior temporalis muscles which provide the same information as EMG recording from the masseter muscles during sleep (Koyano et al. [29]).

Recorded EMG data extracted from GC4-β using a custom made Matlab algorithm was filtered by the following two criteria: 1) Duration: Recordings should be longer than 4 h/night, as per the protocol, 2) Missing data in a recording session due to technical errors. The main EMG parameters extracted were total duration of recording and total number of EMG events detected by GC4-β using a built-in algorithm, which is characterized by a comparison of EMG amplitude to the estimated background level (moving average) and applying the rules for detection of RMMA activity as described by Lavigne and collaborators [15,16].

2.3. Assessment of jaw muscle symptoms

Each participant was asked to score the intensity of clinical symptoms in their jaw muscles, defined as pain, unpleasantness, fatigue, tension, soreness and stiffness, on 0–10 NRS at baseline and after 2 weeks with CES. Care was taken to explain the different symptoms. For example, regarding pain, 0 on the NRS indicated 'no pain at all' and 10 on the NRS indicated 'the worst pain imaginable'.

2.4. Assessment of jaw muscle sensitivity

Mechanical muscle sensitivity was assessed with a standardized palpation device (Butler® Palpeter®, Sunstar Suisse SA, 1.0 kg, 2 s) applied to the following sites: the masseter muscle (the most prominent point during contraction, approximately 2 cm superior of the mandibular border) and the temporalis muscle (the most prominent point during contraction in the anterior area of the muscle). Each participant was asked to score the mechanical muscle sensitivity with 0-50-100 NRS where 0 indicated 'no sensation at all', 50 indicated 'the pain threshold, i.e. when the applied force was perceived as barely painful' and 100 indicated 'the most painful sensation imaginable' [17].

2.5. Study design

The study was designed as a single-blinded placebo-controlled study with 3 arms: a group with high CES intensity, a group with low CES and a group without CES stimulation (placebo). First of all, after having been assessed for eligibility in this study, "probable bruxers" were examined clinically using the diagnostic criteria for temporomandibular disorders (DC/TMD). Furthermore, the participants were also clinically examined for the above-mentioned clinical signs or symptoms related to

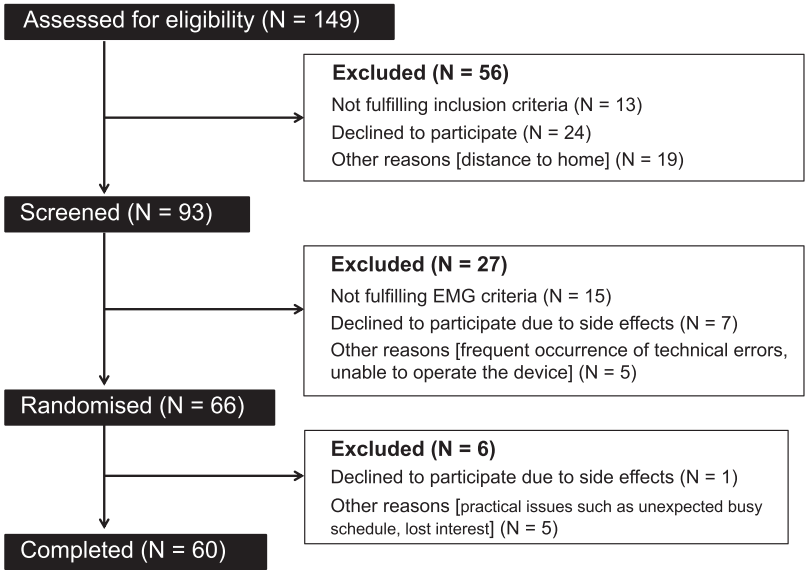

Fig. 1. Flow diagram of participants. Illustration of the selection of participants enrolled in this study. Possible bruxers (N = 149) were inspected in a clinical examination for either wear of facets (grade > 1), hypertrophy of the masseter muscle, evidence of wear on oral splint, hyperkeratosis of cheek mucosa (linea alba), teeth impressions on the tongue, lips or tooth, tooth or tooth restorations fractures due to bite forces, or sign or symptoms of traumatic occlusal contacts. A total of 93 possible bruxers (N = 93) were confirmed to be probable bruxers, meeting the inclusion criteria and screened with GC4-β. From this group, 66 probable bruxers with high number of EMG events/h were randomized and assigned into 3 groups with different CES levels. Finally, 60 probable bruxers completed the whole experiment.

SB: 93 possible bruxers were included in Session 1 where they were screened for bruxism with a 2-week use of the ambulatory EMG device without CES stimulation.

Based on the result from Session 1, each participant was defined in this study to be a possible bruxer or not. The inclusion criteria for Session 2 based on this objective EMG assessment of bruxism were 1) at least 4 recordings/week for 4 h, 2) having more than 8 recordings showing more than half of sleeping hours with over 15 times/h EMG events [7]. Participants who in this way were confirmed to be probable bruxers by the EMG recording in Session 1 continued to participate in Session 2, where they were randomly allocated into one of the 3 different groups depending on the intensity of CES: High CES group, Low CES group and Placebo. The High CES group received intervention of active CES at a very clear, distinct needle-like pin-prick, but tolerable level. The Low CES group received intervention of active CES at a just barely noticeable level like light mechanical tactile sensation. The Placebo group received the same intervention as the High CES group but CES was active only for the first 20 min of each recording [10].

2.6. Statistics

Statistical analyses were performed using STATISTICA (version 5.1; Stat Soft, Inc., Tulsa, OK, USA). All data were checked for normality distribution and are presented as means ± SEM.

Due to lack of a complete EMG data set caused by technical issues, there were 15 participants who were excluded for the further analysis of EMG.

For comparison of the clinical variables between groups, a chi-square test was performed.

A paired *t*-test was performed to compare number of EMG events/hour at baseline versus after intervention. One-way ANOVA was used for comparison of number of EMG events/hour and average recorded sleep duration between groups.

For comparison of baseline NRS scores of clinical symptoms (pain, unpleasantness, fatigue, tension, soreness and stiffness) in all participants, a one-way ANOVA was used. For each clinical symptom, a one-way ANOVA was also used to compare baseline NRS scores between groups. A paired *t*-test was performed to compare relative change (normalized to baseline) in the NRS scores of the clinical symptoms between sessions in each group. Levels of P less than 0.05 were considered statistically significant.

3. Results

3.1. Baseline characteristics

The average number of EMG events/hour for all participants confirmed as probable bruxers in this study was 58.3 ± 5.7. There were no significant differences between groups at baseline in terms of number of EMG events ($P = 0.057$). The average recorded sleep duration for all participants at baseline was 7.4 ± 0.1 h with no significant differences between groups ($P = 0.882$).

Means ± SEM of NRS scores of the clinical symptoms at baseline for all participants are shown in Table 1. NRS scores of pain were significantly lower than those of tiredness ($P = 0.006$), tension ($P = 0.001$), and soreness ($P = 0.014$). NRS scores of stiffness were significantly lower than those of tension ($P = 0.011$). Only NRS scores of tension showed a minor but significant difference between groups with higher NRS scores in the High CES group compared to the Low CES group.

The number of participants with specific subtypes of TMD conditions in accordance with the DC/TMD was not significantly different between groups ($P = 0.201$) (Table 1).

3.2. Effects of CES on EMG activity

The average number of EMG events/hour during the two weeks of applying placebo CES was 50.1 ± 5.9 which compared to 46.9 ± 6.2 EMG events/hour at baseline, not was significantly different ($P = 0.655$). The Low CES group had an average of 59.8 ± 9.6 EMG events/hour compared to the 51.6 ± 7.7 EMG events/hour at baseline ($P = 0.736$). In the High CES group, the average EMG events/hour were 47.8 ± 4.8 during CES intervention compared to 76.4 ± 12.9 at baseline ($P = 0.049$) (Fig. 2).

Compared to baseline, the High CES group exhibited a relative decrease of 24.3 ± 6.2% EMG events/hour during intervention, whereas the placebo and Low CES groups both exhibited a relative increase in EMG events/hour of 38.4 ± 23.0% and 16.4 ± 9.1%, respectively. Noteworthy, the number of participants in each group that experienced a relative decrease in EMG events/hour of at least 5% or more were 6 out of 15 (40%) in the placebo group, 7 out of 15 (46.7%) in the Low CES group, and 12 out of 15 (80%) in the High CES group.

There was no difference between the three groups for average recorded sleep duration during CES intervention (Placebo: 7.6 ± 0.4 h; Low CES: 7.6 ± 0.3 h; High CES: 7.7 ± 0.2 h) ($P = 0.909$), nor any difference between average recorded sleep duration during baseline and CES in each group ($P = 0.354$, $P = 0.941$, $P = 0.185$).

3.3. Jaw muscle symptoms

Regarding the relative change in NRS scores after two weeks of CES intervention, High CES was associated with a significant decrease in the NRS scores of fatigue ($P = 0.037$), tension ($P < 0.001$), and soreness ($P = 0.004$). In the Low CES group, the NRS scores of tension ($P = 0.002$) and soreness ($P = 0.006$) were significantly decreased. In the placebo group, no significant changes in the NRS scores were observed between baseline and after placebo CES (Fig. 3).

Finally, mechanical muscle sensitivity on the 0-100 NRS did not show any significant difference in any of four jaw muscles examined between baseline and CES intervention in the three groups (High CES: $P > 0.557$, Low CES: $P > 0.248$, Placebo: $P > 0.251$) (data not shown).

4. Discussion

The current study revealed that high intensity of CES could decrease the number of EMG events/hour sleep in individuals who fulfill all current proposals (self-reports, clinical examination and EMG supported sleep recordings) to have a consistent behavior of probable sleep bruxism. Notably there were no reductions in EMG events/hour of sleep in the group with Low CES or placebo. The last finding that there were significant decreases in NRS scores of jaw muscle unpleasantness, tension and soreness in the High CES group, as well as tiredness and soreness in the low CES group, strongly suggests the dissociation between sleep-related jaw muscle activity and painful muscle symptoms. Rather the latter findings promote the view that non-painful jaw muscle symptoms may be associated with sleep-related jaw muscle activity. A number of issues will be discussed in addition to the potential implications of these novel findings.

The effect of CES on probable sleep bruxism has been shown in previous studies [10,13,14,18]. Recording of EMG activity in the temporalis muscles during sleep with portable EMG devices has been done based on a signal recognition (SR) algorithm [10,19]. An important aspect in the present study was the use of a different EMG algorithm which evaluates deviation in background EMG activity based on a moving average algorithm. The SR and moving average algorithms have previously been compared [16], but it was not known if CES would demonstrate similar decreases in EMG events/hour when based on the new moving average algorithm. This was convincingly demonstrated in the present study with the use of High CES, but not Low CES

Table 1
Summary of Baseline Characteristics.

	Total N = 60	High N = 20	Low N = 20	Placebo N = 20	Between groups
0–10 NRS of clinical symptoms					
Pain	1.4 ± 0.3	2.6 ± 0.7	0.8 ± 0.6	1.3 ± 0.5	NS
Unpleasantness	2.6 ± 0.3	3.0 ± 0.7	2.2 ± 0.6	2.6 ± 0.6	NS
Fatigue	3.0 ± 0.3*	3.8 ± 0.5	2.6 ± 0.6	2.8 ± 0.6	NS
Tension	3.8 ± 0.3*	5.0 ± 0.6	2.9 ± 0.6	3.5 ± 0.6	0.042
Soreness	2.9 ± 0.3*	4.0 ± 0.6	2.4 ± 0.6	2.5 ± 0.6	NS
Stiffness	2.2 ± 0.3§	2.7 ± 0.7	1.9 ± 0.5	2.2 ± 0.4	NS
DC/TMD diagnosis					
None		6	8	11	NS
Myalgia		10	5	5	NS
Arthralgia		4	3	3	NS
Headache attributed to TMD		7	2	0	NS
Disc displacement with reduction		4	4	3	NS
without limited opening		2	5	1	NS
Disc displacement without reduction with limited opening		0	1	1	NS
Degenerative joint disease		0	0	1	NS

* Indicates a significant difference compared to pain.
§ Indicates a significant difference compared to tension.

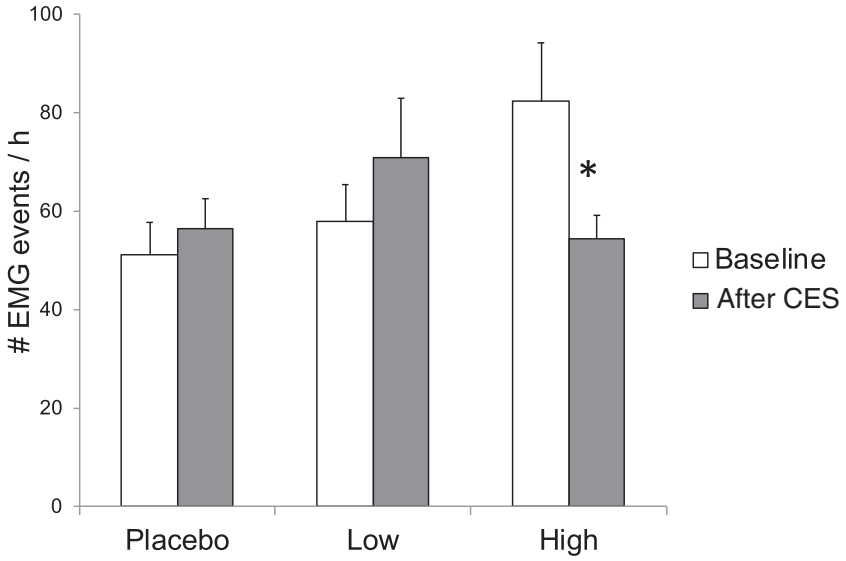

Fig. 2. CES effect on EMG events. The mean number of EMG events/hour (± SEM) in the 3 experimental groups. * Indicates a significant difference ($P < 0.05$). Each group contains 15 participants. CES = contingent electrical stimulation.

or placebo.

Clinically, the CES is adjusted to the highest possible intensity without being painful or cause interference with sleep [19]. The present study demonstrated that low intensity CES set at a barely perceivable level of a faint touch may be too low to trigger any inhibitory EMG responses in the contracting jaw closing muscles during sleep. This is in agreement with laboratory studies showing a clear relationship between stimulus intensity and the magnitude of the inhibition in exteroceptive suppression periods in the masseter and temporalis muscles [19–24]. The important point is that the exteroceptive suppression periods 1 and 2 are not considered nociceptive reflex responses because they occur at sub-pain threshold level [23,25]. This is indeed a prerequisite for the clinical use of CES but the current study also showed that the too low intensity can be applied without clear cut effects on EMG activity during sleep in the jaw closing muscles.

There is little evidence of a strong and direct association between sleep bruxism and pain despite decades of discussions and debates [4,6]. In accordance with this, probable sleep bruxers in this study did not report high NRS pain scores and it was a deliberate choice not only to include individuals with a painful TMD diagnosis. In this light it may not be a surprise that the NRS pain scores did not decrease following the CES intervention because of possible floor effects on the pain ratings. However, it was a striking finding that most individuals reported non-painful jaw muscle symptoms such as tension, stiffness, fatigue, unpleasantness etc. (Table 1). This is also consistent with the recent findings that self-report of non-painful orofacial symptoms such as stiffness, fatigue, pressure, soreness and ache can predict first onset of TMD pain [26]. In fact, the non-painful orofacial symptoms appear to be ranked as the second most important risk factor for first onset of painful TMDs [26]. This could suggest that more diffuse jaw muscle symptoms may play an important role in the development of or transition to manifest TMD pain and that probable sleep bruxism therefore indirectly could be a contributing factor to TMD pain. It should also be noted that high CES in this study was associated with significant decreases in NRS scores of tension and soreness, yet again not NRS scores of pain, possibly suggesting the clinical value to control jaw muscle activity during sleep at lower levels. It is important to emphasize that in a study in patients with fibromyalgia and assessment of their perceived muscle tension and EMG activity during flexions of the shoulder, there were no significant correlations between self-reports of tension,

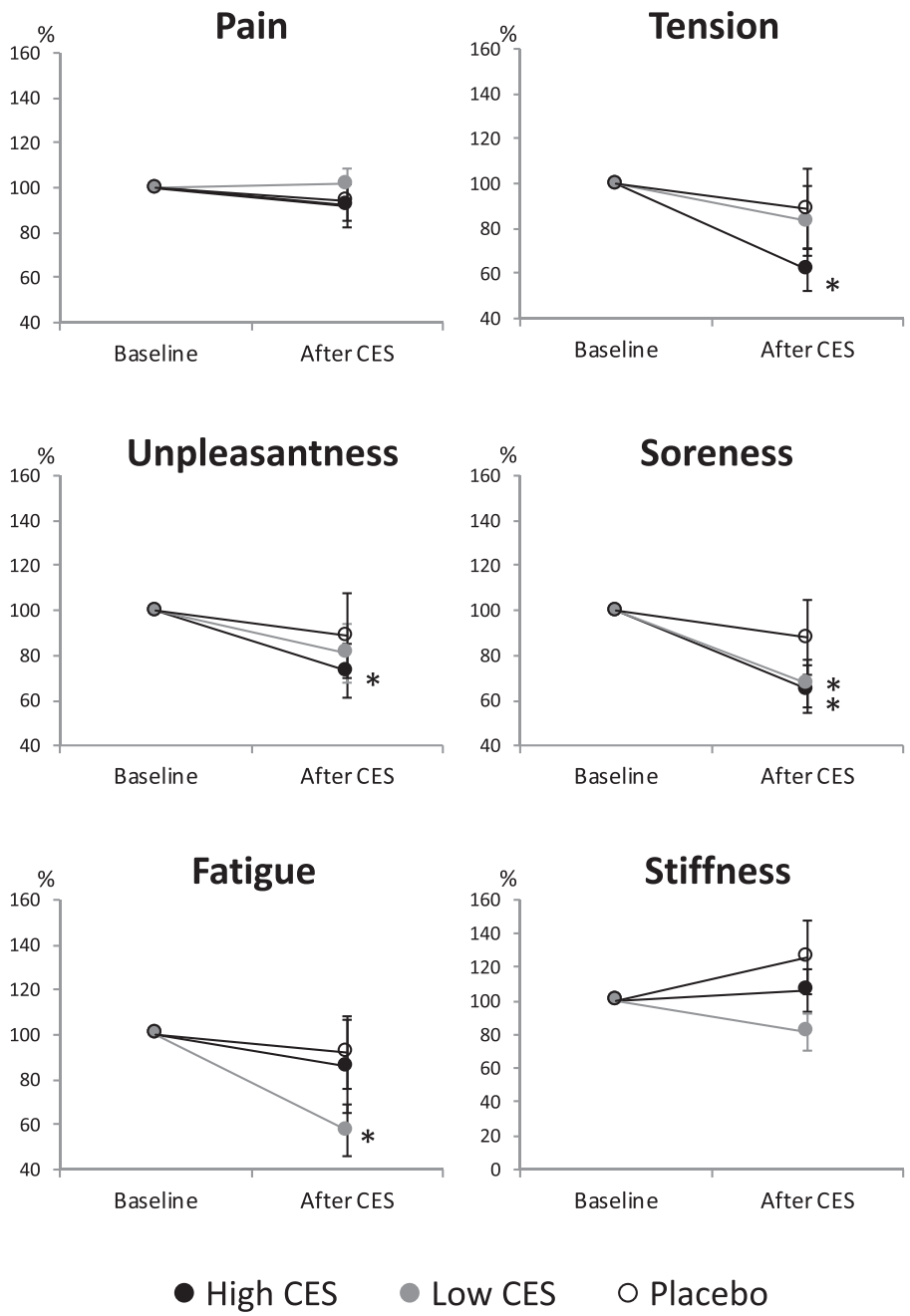

Fig. 3. CES effect on clinical symptoms. Relative change (%) in mean NRS (numerical rating scale) scores (± SEM) of pain, unpleasantness, fatigue, tension, soreness, and stiffness at baseline and after CES (contingent electrical stimulation) intervention in the 3 experimental groups. Each group contains 20 participants. * Indicates a significant difference between baseline and after CES intervention.

personality traits of muscular tension and EMG muscle activity [27]. This clearly illustrates the dissociation between self-reports of muscle tension and actual EMG activity and should be further explored in patients with self-reports of probable sleep bruxism and TMD pain.

It should also be acknowledged that there are a number of methodological limitations in the present study. First, there are some inherent problems in single-channel EMG recordings. Previously, it has been claimed that single-channel EMG devices detect an excessive number of "true" events of RMMA [28] and, due to lack of audio-video input, it may overestimate the assessment by up to 25% [29]. However, these problems have been addressed with the more recent developments of moving average EMG algorithms that provide outcomes that are more comparable to classical PSG recordings [16]. Obviously, it would have been an advantage to perform studies like this with full PSG montages but also unrealistic in terms of time and costs. Additional measures to the number of EMG events/hour should also be included in future studies but there is a technical caveat with area under the EMG curve measures as the current device is also used for CES, i.e., the recording electrodes are also used as electrodes for stimulation and will be distorted if included in the EMG recordings. The advantage of the current ambulatory single-channel EMG device is that it could be used for extended periods of time with relatively little efforts for the participants. It also should be noted that the NRS scores in the clinical symptoms at baseline between groups were not identical. This likely reflects the combination of a spectrum of bruxism and the randomization of a relatively limited number of patients.

In conclusion, high intensity CES demonstrated inhibitory effects on jaw muscle EMG activity during sleep and was associated with

significant decreases in jaw muscle symptoms (fatigue/tension/soreness) but not pain responses. These findings challenge the traditional concept that probable sleep bruxism is directly related to pain but appears related to more unspecific muscle symptoms. The current findings may have implications for both assessment of non-painful jaw muscle symptoms and future management of sleep-related bruxism.

Conflict of interest statement

The authors report the following potential conflicts of interest: P. Svensson was a paid consultant for Sunstar Suisse SA and A. Shimada's post-doctoral fellowship was partially funded by the company. None of these authors has stocks in Sunstar Suisse SA.

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