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Original article

Diagnostic validity of self-reported measures of sleep bruxism using an ambulatory single-channel EMG device

Wataru Yachida DDS, PhD[a], *Taro Arima DDS, PhD*[b,*], *Eduardo E. Castrillon DDS, MSc, PhD*[c,d], *Lene Baad-Hansen DDS, PhD*[c,d], *Noboru Ohata DDS, PhD*[e], *Peter Svensson DDS, PhD, Dr Odont*[c,d,f]

[a] *Clinical Division of Crown and Bridge Prosthodontics Dentistry, Hokkaido University Hospital, Sapporo, Japan*
[b] *Division of International Affairs, Graduate School of Dental Medicine, Hokkaido University, Sapporo, Japan*
[c] *Section of Orofacial Pain and Jaw Function, Department of Dentistry, Aarhus University, Aarhus, Denmark*
[d] *Scandinavian Centre for Orofacial Neuroscience (SCON)*
[e] *Graduate School of Dental Medicine, Hokkaido University, Sapporo, Japan*
[f] *Department of Dental Medicine, Karolinska Institutet, Huddinge, Sweden*

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ABSTRACT

Purpose: Self-reported measures have been widely used to indicate the presence of possible and probable sleep bruxism (SB) in both research and clinical situations. However, few studies have attempted to assess the diagnostic validity of this approach. The aim of this study was to estimate the diagnostic validity of self-reported measures of SB using an ambulatory single-channel electromyographic (EMG) device.

Methods: A total of 115 participants were enrolled and examined by standardized Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) including two questions related to SB: self-reported SB and morning-jaw symptoms. An ambulatory single-channel EMG device (GrindCare3™, Medotech A/S) was used for measuring jaw–muscle EMG activity during sleep for seven consecutive nights. Cut-off values for different measures of EMG activity (average, maximum and minimum) and the coefficient of variation (CV) were selected to divide participants into two groups, with higher or lower EMG activity or CV values. The sensitivity and specificity for each question and combination of them were calculated.

Results: Self-reported SB had the highest sensitivity (compared with morning-jaw symptoms) for all measures of EMG activity and CV, although the values were low to modest (average: 76.0%, maximum: 76.9%, minimum: 77.3%, CV: 61.0%). The specificity was low for both the questions related to the different measures of EMG activity and CV (35.1–52.4%).

Conclusions: This study indicated that the diagnostic validity of self-reported measures of SB was low to modest using an ambulatory EMG device assessment as a reference. Using only

* *Corresponding author at*: Division of International Affairs, Graduate School of Dental Medicine, Hokkaido University, North 13 West 7, Kita-ku, 060-8586 Sapporo, Japan. Tel.: +81 11 706 4275; fax: +81 11 706 4276.
E-mail address: tar@den.hokudai.ac.jp (T. Arima).

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self-reported measures for the assessment of SB may not have a high validity, which should be taken into consideration in the clinical evaluation of patients.

1. Introduction

Bruxism is a repetitive jaw–muscle activity characterized by clenching or grinding of the teeth and/or bracing or thrusting of the mandible and has two distinct circadian manifestations: it can occur during sleep (indicated as sleep bruxism (SB)) or during wakefulness (indicated as awake bruxism (AB)) [1]. The diagnostic methods for bruxism have been the focus of many studies, and researchers have addressed various techniques and tools for assessment of bruxism, such as questionnaires, clinical examination (e.g. tooth wear, masseter muscle hypertrophy, hyperkeratosis of cheek/lips/tongue), and electromyographic (EMG) recordings [2–7]. A recent study has proposed a diagnostic grading system of 'possible', 'probable', and 'definite' SB or AB [1] because no widely available, cost-effective, reliable, and valid diagnostic tools have been developed. So far, self-reported measures, which may yield 'possible' bruxism diagnoses, have been widely used to indicate the presence of bruxism in both research and clinical situations, especially in epidemiological studies, because this method can be easily applied to large populations [2]. However, studies suggest that the diagnostic accuracy of self-reported bruxism is generally low because many people may not be aware of their tooth clenching/grinding habits, especially during sleep, and perhaps some patients may also have difficulties understanding the specific meaning of the questions [2,8–10]. For example, one study suggested that self-reports of SB are potentially biased by what the dentist may have told the patient [11]. However, few studies have attempted to reveal the diagnostic validity of the self-report approach. So, a better understanding of the diagnostic validity of self-reported measures of SB would be needed.

The aim of this study was to investigate the diagnostic validity of self-reported measures of SB when using an ambulatory single-channel EMG device during sleep. Grindcare (Grindcare3™, Medotech A/S, Herlev, Denmark), which is an ambulatory single-channel EMG recording device, was used in this study for estimation of jaw–muscle activity during sleep. The validity of SB activity with this type of EMG device was recently described in comparison with polysomnographic (PSG) recordings and demonstrated acceptable correlations between the ambulatory EMG measurements and the golden standard method (PSG) [5,12–16].

2. Materials and methods

2.1. Participants

The present study used the same sample of participants as in the study by Yachida et al. [17]. The data from a total of 115 participants; 39 men (mean age ± SD: 36.8 ± 14.0 years) and 76 women (32.8 ± 10.2 years) were used for analysis in this study. All participants were more than 18 years old. Exclusion criteria were current illness; history of neurologic or psychiatric disorders; sleep disorders (e.g. snoring, sleep apnea, and periodic limb movement by an interview screening); use of prescription medicine or drugs; smoking, alcohol abuse and addiction to coffee; electrode gel allergy; simultaneous participation in another trial with medicine or in trials of medical devices; and user of pace maker. The study was approved by the local ethics committee in Region Midt (Denmark) and conducted in accordance with the Helsinki Declaration. Written informed consent was obtained from all participants.

The 115 participants were comprised of 30 healthy participants without self-reported SB (26.2 ± 3.9 years) who were recruited amongst students and staff at Aarhus University, Denmark; 55 self-reported SB participants (with or without pain) (39.0 ± 13.2 years) who responded to flyers and newspaper advertisement and from patients at Aarhus University, Denmark; and 30 tension-type headache (TTH) patients (with or without self-reported SB) (33.3 ± 9.6 years) from the Danish Headache Center, Glostrup Hospital, Denmark. All healthy participants were without temporomandibular disorders (TMD) in accordance with the Research Diagnostic Criteria for TMD (RDC/TMD) [18,19]. None of the healthy participants met the following criteria related to bruxism: (1) self-report or report by a bed partner of tooth-grinding or clenching habits during sleep; (2) jaw–muscle fatigue/pain upon awakening; (3) masseter muscle hypertrophy on voluntary contraction [20]; (4) moderate to severe hyperkeratosis of cheeks/lips/tongue; (5) advanced tooth wear (≥grade 1c) [21,22]; (6) loss of cuspid protection; and (7) frequent non-iatrogenic/non-material related fractures and failures of teeth/restorations/implants. Self-reported SB participants answered ''yes'' in the RDC/TMD history questionnaire 15c, which is about self-awareness of SB (''Have you been told, or do you notice that you grind your teeth or clench your jaw while sleeping at night?''). TTH patients were diagnosed as frequent or chronic TTH according to the diagnostic criteria of the second edition of the International Classification of Headache Disorders (ICHD-II) [23] using headache diaries in addition to the RDC/TMD clinical examination and questionnaire.

2.2. Study design

On the first day, all participants were examined by the Danish translation of the RDC/TMD. The RDC/TMD specifies a standardized diagnostic system for TMD supported by a well-designed history questionnaire and clinical examination [18] and has been widely used in clinical research settings around the world. The reliability of the RDC/TMD has been confirmed in several studies (e.g. Ref. [24]) and the system has been translated into many languages (http://www.rdc-tmdinternational.org). The RDC/TMD history questionnaire includes two questions

related to SB: Question (i) is: Have you been told, or do you notice that you grind your teeth or clench your jaw while sleeping at night? Question (ii) is: Does your jaw ache or feel stiff when you wake up in the morning? Question (i) is about the self-awareness and report from a bed partner of SB (Self-reported SB). Question (ii) is about the presence of morning jaw symptoms which could be caused by SB and is often used for assessment of SB (Morning jaw symptoms) [2]. All participants used an ambulatory single-channel EMG device (Grindcare3™, Medotech A/S, Herlev, Denmark) during sleep for seven consecutive nights to measure jaw–muscle activity.

2.2.1. *EMG recordings*

The Grindcare3™ was used to record the EMG activity during sleep [12]. All recordings were performed in the participant's home. The device has a single electrode assembly, with three electrode contacts. The electrode was placed on the skin over the anterior temporalis muscle. The EMG activity was amplified (800×) and filtered (250–610 Hz) in the device and further analyzed for events of EMG activity, using the signal recognition (SR) algorithm based on Fast Fourier Transformation analysis [12]. Very briefly, this EMG algorithm compares the amplitude of the EMG to a threshold level, which is set to 20% of the maximum EMG during a clench to about 60% of the maximum voluntary contraction (MVC). Setup of the threshold level is done every time the device is mounted before sleep, during which the user is required to produce a bite force to approximately 60% MVC. An EMG event is detected, counted in the log-file and registered when the amplitude of the EMG signal has been above the threshold for more than 0.1 s. To determine the individual parameters, the set-up procedures were carefully instructed by examiners and trained together with the participants. The total number of EMG events, the number of EMG events per hour and the number of measurement hours were registered. After one week of measurement was completed, the data were transferred and saved in a PC using commercial software (GrindCare Manager, Medotech A/S, Herlev, Denmark).

2.2.2. *Data and statistical analysis*

The data were presented as means ± standard deviations (SD).

The EMG data (average, maximum and minimum EMG activity) and the coefficient of variation (CV: SD/mean) from the multiple night recordings were analyzed for all participants. The CV was used to examine the night-to-night variability in EMG activity. Cut-off values of EMG and CV data were established to divide all participants into two groups: higher or lower EMG and CV data. First, the different cut-off values were selected in each question and combination of them (Questions (i) and (ii)). Then, the sensitivity (percentage of higher EMG activity/CV participants with self-reported bruxism) and specificity (percentage of lower EMG activity/CV participants without self-reported bruxism) were calculated to see how the sensitivity and specificity changed with the different cut-off values. Secondly, the EMG and CV data in healthy participants, who had no self-report and clinical signs/symptoms of bruxism, was examined to provide a specific cut-off value based on normative values; descriptive statistics were used to analyze the EMG and CV data in healthy participants. Then, the cut-off value of the EMG and CV data was selected at the upper limit of 95% confidence interval (CI). The sensitivity, specificity, positive predictive value (PPV; percentage of self-reported bruxism participants with higher EMG activity/CV) and negative predictive value (NPV; percentage of no self-reported bruxism participants with lower EMG activity/CV) were calculated for each question and combination of them.

3. Results

Fig. 1 shows the sensitivity and specificity at different cut-off values for the different measures of EMG activity (average, maximum and minimum) and CV data in relation to each question and combination of them (Fig. 1a, b, c, and d, respectively). The mean values of the EMG and CV data in the healthy participants were: 15.2 ± 11.6 events/h (95% CI: 10.9–19.5) for the average EMG activity; 25.0 ± 20.0 events/h (95% CI: 17.5–32.4) for the maximum EMG activity; 7.4 ± 6.4 events/h (95% CI: 5.0–9.8) for the minimum EMG activity; and 43.7 ± 20.1% (95% CI: 36.2–51.2) for the CV values. From the above data in the healthy subjects, the cut-off value was set at 19.5 events/h (average EMG activity), 32.4 events/h (maximum EMG activity), 9.8 events/h (minimum EMG activity) and 51.2% (CV).

The sensitivity, specificity, PPV and NPV at each cut-off value for each question and combination of them are shown in Table 1. Self-reported SB (Question (i)) had the highest sensitivity of the two questions for all measures of EMG activity and CV, although the values were low to modest (average: 76.0%, maximum: 76.9%, minimum: 77.3%, CV: 61.0%). The specificity was low for all the questions related to the different measures of EMG activity and CV (35.1–52.4%).

4. Discussion

Self-reported measures of SB by questionnaire/medical interview are the most frequently used methods and the most convenient technique for collecting data especially in large populations [3,25,26]. However, the reliability of the method has been considered low because of the potential inaccuracy of people's report as well as a substantial fluctuation over time of bruxism behaviors [9,27,28]. In a recent consensus statement, an expert group proposed a diagnostic grading system for the diagnosis of bruxism and suggested that the self-report by means of questionnaires/the anamnestic part of a clinical examination could be graded as 'possible' bruxism behaviors, which was the lowest diagnostic level: indeed, the diagnostic validity of the self-report method seems to be low [1]. In this study, the diagnostic validity of self-reported measures of SB was examined using ambulatory EMG recordings. The results showed that the diagnostic validity of self-reported measures of SB was low to modest, which is consistent with the recent consensus paper. Further, a study showed that 53% of a study population with complaints of SB in questionnaires had no diagnosis of SB according to a PSG examination, which is regarded as the gold standard measurement for the diagnosis of SB, and the authors concluded that questionnaires may overestimate the diagnosis of SB [10]. Therefore, it seems that

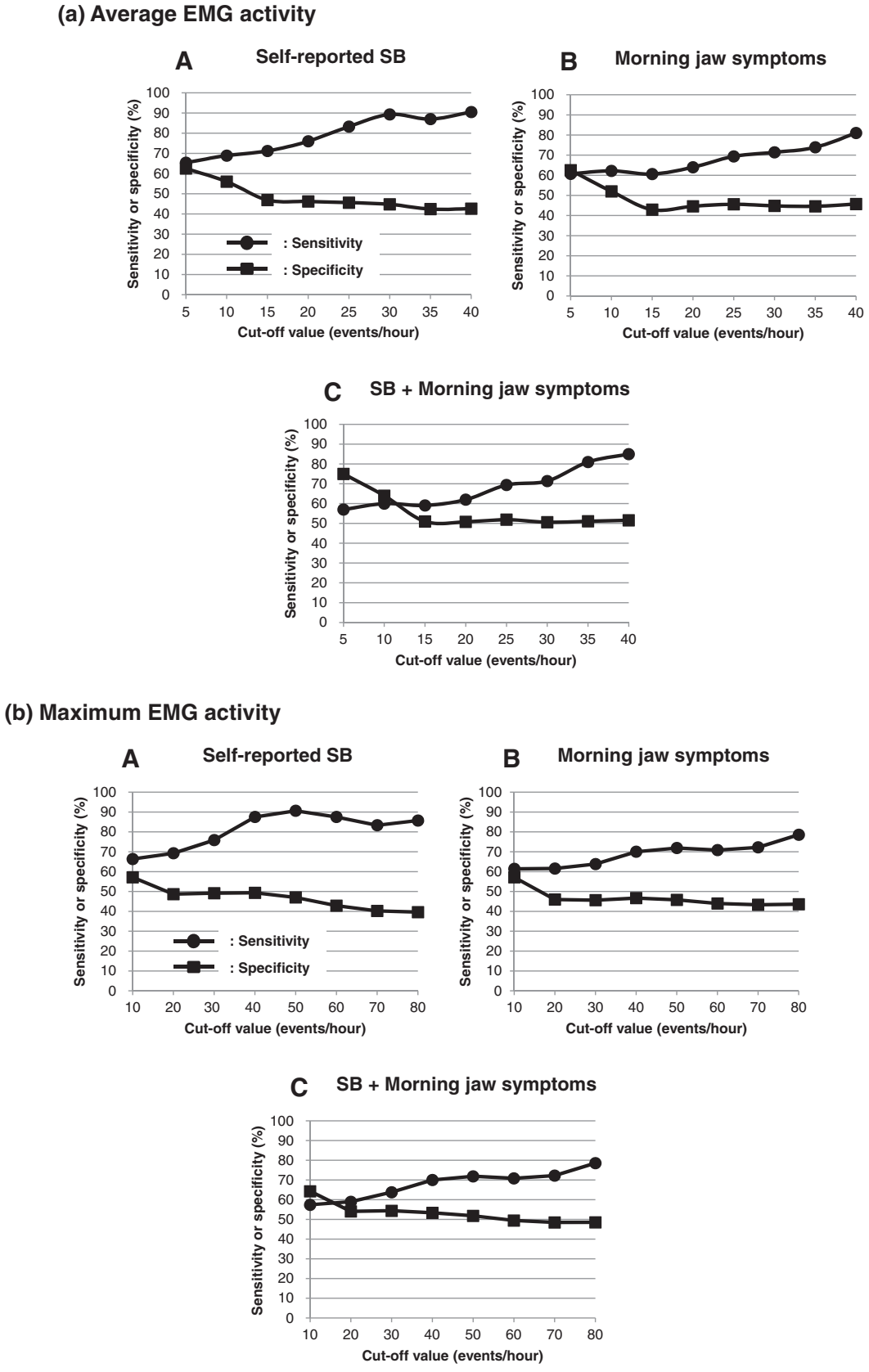

Fig. 1 – Sensitivity and specificity of self-reported bruxism questions at different cut-off values for average EMG activity, maximum EMG activity, minimum EMG activity, and coefficient of variation (CV) of EMG activity. SB = sleep bruxism.

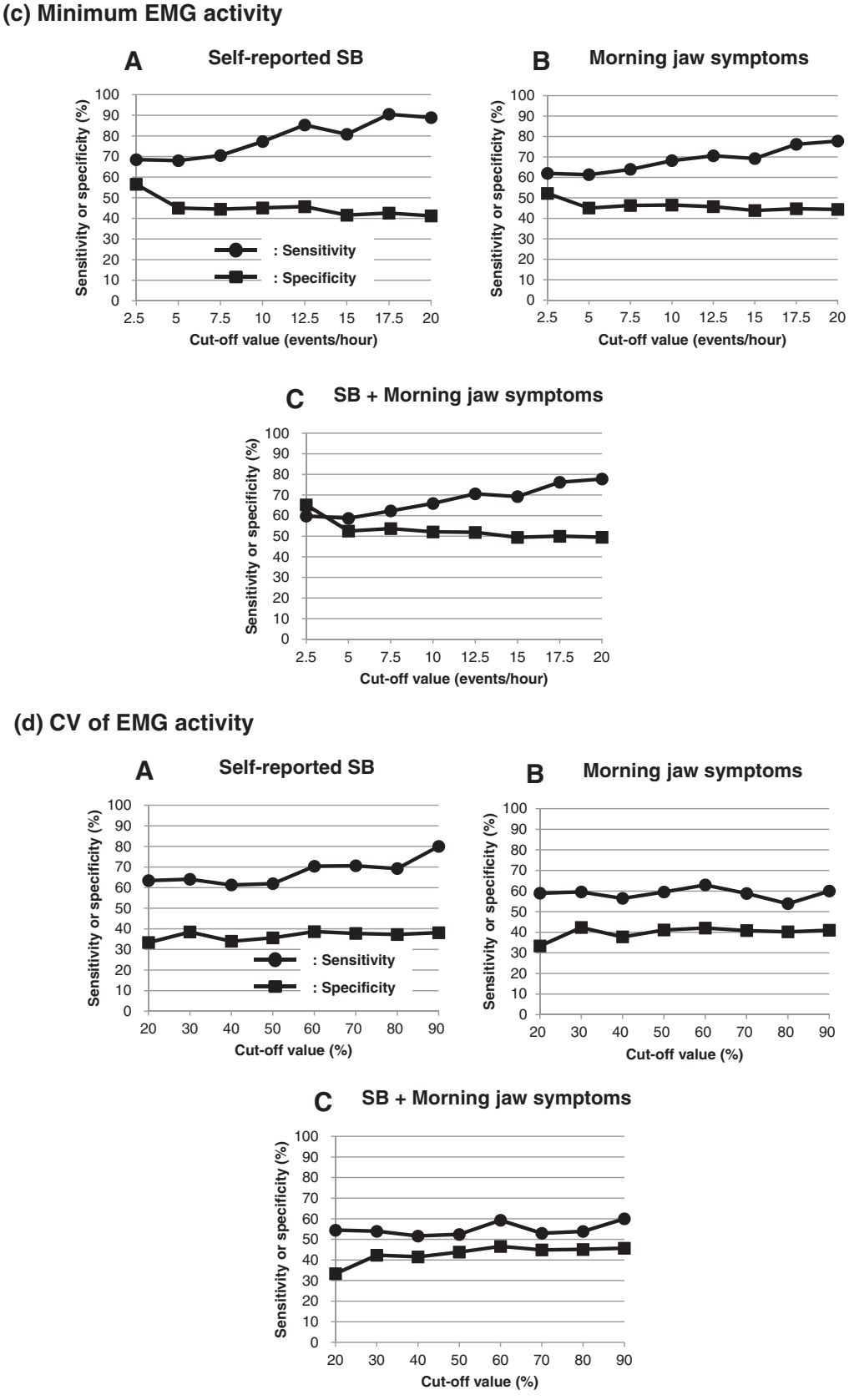

Fig. 1. (Continued).

Table 1 – Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of self-reported bruxism questions in relation to average EMG activity, maximum EMG activity, minimum EMG activity and coefficient of variation (CV) of EMG activity.

Questionnaire	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Average EMG activity				
(1) Self-reported SB	76.0	46.2	52.1	71.4
(2) Morning-jaw symptoms	64.0	44.6	47.1	61.7
(1) + (2)	62.0	50.8	49.2	63.5
Maximum EMG activity				
(1) Self-reported SB	76.9	47.6	54.8	71.4
(2) Morning-jaw symptoms	63.5	44.4	48.5	59.6
(1) + (2)	63.5	52.4	52.4	63.5
Minimum EMG activity				
(1) Self-reported SB	77.3	45.1	46.6	76.2
(2) Morning-jaw symptoms	68.2	46.5	44.1	70.2
(1) + (2)	65.9	52.1	46.0	71.2
CV of EMG activity				
(1) Self-reported SB	61.0	35.1	34.2	61.9
(2) Morning-jaw symptoms	58.5	40.5	35.3	63.8
(1) + (2)	51.2	43.2	33.3	61.5

caution would be needed when using only questionnaire/medical interview for the diagnosis of SB.

Researchers working with bruxism have used several types of questionnaires for evaluating the presence of SB [2,3,29]. A simple yes/no question has been widely used in many studies, such as self-reported or bed partner reported history of tooth grinding and complaints of masticatory muscle fatigue and/or pain on awakening. This study showed that the simple questions from the RDC/TMD questionnaire did not have high diagnostic sensitivity and specificity for SB. Possible reasons for this result may be: people are not aware of their SB behaviors; clenching is not accompanied by sounds, so family members are not aware of this behavior; jaw–muscle pain on awakening is difficult to differentiate between pain caused by SB and myofascial pain. However, questionnaires/medical interview are still the easiest way to apply to large-scale bruxism studies and every day clinical practice. Therefore, in future investigations, dit would be a better option to refine the questionnaire-based approach by adding some specific questions and by combining with determination of possible clinical symptoms, such as tooth wear, muscle hypertrophy and tongue indentations, a diagnostic strategy which is in line with the ''probable'' diagnosis proposed by the recently published consensus [1].

Although PSG with audio–video recording is the gold standard measurement for the diagnosis of SB, it is expensive and time consuming and participants have to sleep in the laboratory with equipment. This may cause a disturbance of their natural sleep and an adaptation night is normally required [27,30]. In this study, repeated ambulatory EMG recordings were conducted for evaluating the validity of self-reported measures of SB. The recordings can be performed in the subjects' home for continuous nights because of the simple recording equipment and it is possible to record jaw–muscle activity in the natural environment. Actually, in this study, the ambulatory single-channel EMG device was suitable for use for seven nights in the subjects' home within a large population ($n = 115$). Considering the substantial fluctuation over time for SB [27,28], multiple night recordings and the detailed analysis of the EMG activity variability (e.g. average, maximum, minimum and CV of EMG activity in the recording period) are needed. The present study suggested 19.5 EMG events/h (average EMG activity) for cut-off value which is in good accordance with a recent report, which directly compared EMG with a SR algorithm to PSG (19 EMG events/h (average EMG activity), sensitivity = 0.50 and specificity = 0.90, for continuous five nights recordings) [16].

There are some limitations of the present study that need to be discussed. First, the reliability and validity of the portable recording device for this study (Grindcare3^{TM}) is essential. This device was originally produced for electrical biofeedback system and equipped with functions for both recordings and electrical stimulation of the skin. Thus, when the device detects an EMG burst and the same tripolar electrode is used for this as for recording of the EMG signal, the EMG cannot be recorded for a period of one second after onset of the stimulus pulse train, the amplifiers are simply switched off in order not to saturate the stimulus pulses and potentially damage the amplifiers and in any case contaminate the EMG signal with a stimulus artifact. It may not be detected if more than one EMG burst appears during the one-second blanking period and it cannot be detected if EMG activities on-going when the amplifiers are turned on again belong to the same or to a new burst. This may possibly result in both underestimation (if the device turns on during a new EMG burst) and overestimation (if the device turns on during the same EMG burst) of actual EMG activity. Nevertheless, the method used in the present work has some scientific support in order to be considered as a reference able to detect bruxism activity. The validity of the algorithm of Grindcare3^{TM} has been estimated and strong correlations during jaw–muscle activity and clear discrimination of other orofacial activities, such as yawning, swallowing saliva, jaw play, reading loud, have been presented under laboratory conditions [13]. Further, one study attempted to evaluate an EMG algorithm for single-channel EMG recordings in direct comparison with the outcome from PSG recordings

[15]. This study showed no significant differences between the total number of SR grinds (the algorithm of Grindcare3™) and Rhythmic Masticatory Muscle Activity (RMMA) bursts detected with the SR algorithm and the gold standard (GS) criteria from PSG including audio–video recordings during sleep. However, caution needs to be exerted because the SR algorithm detected significantly more grinds than the GS if the data during awakening in the sleeping (recording) period was included. Therefore, for future studies it will be necessary to further develop the ambulatory single-channel EMG recording system with specific algorithms compared with PSG with audio–video recordings [7].

Second, TMD and/or TTH patients with craniofacial pain conditions were used for the analysis of the data. Although our previous study showed that there were no major differences between patients with craniofacial conditions and pain-free individuals [17], the relationship between SB and pain is still a matter of controversy and need careful considerations to further understand if a painful condition may affect EMG activity during sleep.

Third, this study used the ambulatory EMG devices for recording jaw–muscle activity during sleep and recordings were conducted in the participants' home. Therefore, it was difficult to control the set-up procedures of the device, such as the position of electrodes and pre-recording procedures of the EMG device. These differences may contribute to the night-to-night variability in the EMG recordings. Some PSG studies reported substantial night-to-night variability in SB activity [27,28]. Our previous study using ambulatory EMG devices also showed that there was a significant and substantial night-to-night variability in EMG recordings [31]. Therefore, multiple night recordings should be preferred when using an ambulatory EMG device.

Fourth, the prevalence of self-reported SB subjects in this study (55/115: 48%) was higher than in some epidemiological studies [25,32] but in the same range as other studies [5,33]. Nevertheless, there may be a sampling bias issue, which may affect the results of the diagnostic validity test. Therefore, caution is needed in the interpretation of the results of this study.

5. Conclusion

In summary, this study indicated that the diagnostic validity of self-reported measures of SB was low to modest. Using only questionnaires/medical interview for the assessment of SB cannot be recommended. It is suggested that researchers and clinicians need to consider the use of self-reported measures of SB in combination with other clinical methods, such as clinical examinations and ambulatory EMG recording systems, or to refine the questionnaire-based approach to make more accurate diagnosis of SB.

Conflict of interests

The authors report the following potential conflicts of interest: P. Svensson was a paid consultant for Medotech A/S and E. Castrillon's post-doctoral fellowship was partially funded by the company. None of these authors has stock in Medotech A/S.

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