Comparison of the occurrence of sleep bruxism under accustomed conditions at home and under polysomnography conditions in a sleep laboratory

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Abstract

Purpose: We aimed to clarify the relationship between the number of sleep bruxism (SB) bursts at home and in a laboratory equipped with polysomnography with audio-video recording (PSG-AV). We applied an identical single-channel wearable electromyography (EMG) device for both types of SB burst scorings.

Methods: The subjects were 20 healthy student volunteers (12 men and 8 women; mean age, 21.9 years) who were clinically diagnosed with bruxism based on the criteria set forth by the International Classification of Sleep Disorders (ICSD-2). We used a wearable EMG device attached to the masseteric area (the FLA-500-SD [FLA]), for scoring SB bursts at home and in the laboratory. PSG-AV was set within the laboratory environment as well. The mean interval for both sleep studies was 28.8 days. EMG bursts with amplitudes greater than twice the baseline amplitude and with durations of longer than 0.25 s were selected. EMG bursts with amplitudes ≥5% MVC (maximum voluntary contraction), ≥10% MVC, and ≥20% MVC were selected as well. A cluster of bursts was defined as an episode.

Results: In all the conditions for selecting EMG bursts specified above, the number of SB bursts and episodes recorded under laboratory conditions was statistically significantly smaller than that recorded at home. There were no statistically significant differences between the data obtained on the first and second recording days.

Conclusion: The results of this study suggest that the unfamiliar environment of a sleep laboratory equipped with PSG-AV affects the emergence of SB as compared with home conditions.

Keywords: Sleep bruxism, Wearable electromyographic device, Polysomnography, Sleep laboratory, Sleep environment

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1. Introduction

Sleep bruxism (SB) is a sleep-related movement disorder characterized by teeth grinding and clenching[1,2]. SB is a known risk factor for various dental problems, including tooth wear, tooth fracture, temporomandibular disorders, and the removal of crown restorations[3,4]. Studies have previously reported on the associations between SB and sympathetic nerve activity, the overall sleep state, and genetic factors[5–7]. However, the true state of SB and the mechanisms mediating SB genesis are not completely elucidated or understood to date.

A clinical diagnosis of SB is determined based on clinical findings including self-awareness, interviews with a sleep partner, investigations of masticatory muscle fatigue and pain awareness, and tooth wear. The objectivity and accuracy of these findings are not sufficient[8–12]. Regarding the assessment of bruxism status, an international consensus meeting recently proposed three diagnostic stages: (1) possible sleep/wake bruxism based on self-report only, (2) probable sleep/wake bruxism based on self-report in addition to clinical inspection, and (3) definite sleep bruxism based on self-report and clinical inspection combined with polysomnography (preferably combined with audio/video recordings)[1,2].

Masticatory muscle electromyography (EMG), a method objectively assessing SB, can generally be divided into two types: portable electromyography (EMG) and polysomnography (PSG). Polysomnography with audio-video recording (PSG-AV) under sleep laboratory conditions is currently considered the most reliable method for diagnosing SB[13]. In PSG-AV, sleep stages can be determined via electroencephalogram (EEG), electrooculogram (EOG), and EMG record-
ings of the mentalis muscles. Masticatory muscle activity during SB can be recorded from electrodes of the EMG system attached to the masseter and/or temporal muscle regions. Based on these biological signals, sleep-related physiological events can be measured quantitatively. Though it is possible to discriminate orofacial muscle activity other than SB by adding AV information, PSG-AV has not been frequently used for SB diagnoses in actual clinical practice due to the procedural complexity. Previous studies have suggested associations between bruxism and psychological factors.[14–18] Therefore, there is a concern that an unfamiliar environment (e.g., a sleep laboratory, the attachment of the complicated sensors in the PSG-AV system) may cause differences in the emergence of SB bursts with that of the true state of SB (i.e., accessed in a home environment).

Many studies have measured masticatory muscle activity during sleep at home using portable EMG devices or ambulatory PSG systems as an alternative to PSG-AV[19–25]. However, most of these devices are connected to the face and/or body by cords. Thus, this situation cannot be considered completely unconstrained, and there is concern about psychological influence due to discomfort. To overcome this problem, we developed a series of single-channel ultraminiature EMG devices[26–31]. These devices allow for measuring masticatory muscle activity at home without restraint as well as examining the occurrence of SB in more natural situations.

As stated above, studies have demonstrated relationships between bruxism and psychological factors, and it has been speculated that measurements in an unfamiliar environment as well as the use of complicated sensors may lead to different results as compared with the actual occurrence of SB in a home setting. However, to the best of our knowledge, no study has compared the emergence of SB bursts in a laboratory equipped with PSG-AV to that measured in an accustomed environment at home. Therefore, the effects of differences in measuring environments such as places and connected devices on the occurrence of SB have not been clarified to date.

In this study, we hypothesized that the occurrence of SB in a familiar environment at home (without restraints) and that in a sleep laboratory equipped with PSG-AV may differ substantially, even with an identical EMG measurement system used for scoring SB bursts. The aim of this study was to clarify the relationship between the number of SB bursts measured at home without PSG-AV equipment to those measured in a laboratory equipped with PSG-AV, while applying an identical single-channel wearable EMG device to both types of SB burst scorings.

2. Materials and Methods

2.1. Subjects

The subjects were 20 healthy student volunteers who were clinically diagnosed with sleep bruxism (12 men and 8 women; mean age, 21.9 years; standard deviation, 1.8 years). Diagnoses of SB were conducted based on the criteria presented in the International Classification of Sleep Disorders (ICSD-2) set forth by the American Academy of Sleep Medicine (AASM), as follows: (A) The patient reports or is aware of tooth-grinding sounds or tooth clenching during sleep, and (B) one or both of the following are present: (i) abnormal wear of the teeth and (ii) jaw muscle discomfort, fatigue, or pain and jaw lock upon awakening[32]. All subjects were healthy other than the abovementioned clinical findings associated with SB. Subjects who had 20 or more teeth, including those with restorations (i.e., resin fillings, inlays, and fixed prosthetics, that is, crowns and bridges) were included herein. Patients with removable dentures, those undergoing orthodontic treatment, those presenting with a disease that may cause SB, and/or those taking pharmaceutical drugs that may cause SB were excluded. This study was approved by the ethics committee of the Graduate School of Dental Medicine at Hokkaido University (No. 2016-1, 2018-5). All subjects provided their written informed consent prior to participation.

2.2. Recording data

Comparative measurements were performed at home and in shielded rooms in the laboratory. For recordings at the participant’s homes, we used a single-channel ultraminiature wearable EMG device, the FLA-500-SD (FLA, Furusawa Lab Appliance Co., Kawagoe, Japan) (Fig. 1). The FLA contains 12-bit central processing units (CPU), electrodes, an amplifier, an analog-to-digital (A/D) converter at a sampling frequency of 1 kHz, a 3.7-V coin-shaped lithium battery, and a micro SD memory card. The gain of the amplifier was set to 250 times[30,31].

For the home recordings, the subjects were instructed to attach the FLA device to the masseter area on the habitual chewing side (14 on the right and 6 on the left). Prior to conducting the home recording, the subjects were fully informed on how to correctly use the device and were trained on the actual handling of the device. The timing of going to bed and getting up was set according to each subjects’ personal preferences. Maximum voluntary clenching (MVC) was performed just prior to going to bed and just after waking up, and the period between these timepoints was defined as sleep time (that is, time in bed [TIB]) for scoring SB bursts at home. Drinking and taking sleeping medications were prohibited.

In the laboratory, masticeter EMGs using an FLA attached to the masseter muscle region on the same side as that in the home recordings were applied for scoring the SB burst number. In addition to the FLA, a polysomnography (PSG) instrument (Alice6, Philips Respironics, Murrysville, PA, USA) with audio-video recording was
implemented in the laboratory setting. The PSG recording variables included EEG, EOG, chin EMG, leg EMG, electrocardiogram (ECG), snoring sound, and body position readings (Fig. 2). The FLA for measuring masseteric EMG and the PSG-AV equipment were set up by a single researcher (M.M.). A bed was set up in the laboratory, and the temperature and brightness were adjusted according to the subject’s preferences. The timing of going to bed was set between 10-12 pm and the time for getting up was set to 6 am. MVC was performed prior to going to bed and after getting up. The period from turning the light off when going to bed to turning the light on when getting up the next morning (that is, the TIB) was used for scoring SB bursts in the laboratory. Drinking and taking sleeping medications were prohibited. In half the subjects, EMG recordings were performed on the first recording day using single-channel EMG at home, while the second recording day was performed in the laboratory. The order of the recording conditions was reversed in the other half of the subjects. The mean and median values of the sleep duration interval in both sleep studies were 28.8 and 21.0 days, respectively (Fig. 3).

2.3. Data analyses

For both environments, we analyzed EMG data obtained during TIB using FLA. Using dedicated software, EMG signals were high-pass filtered at 20 Hz, converted to absolute values, and smoothed by a width of 101 points (0.1 s)[29,31]. The EMG wave with the largest amplitude among the MVCs performed before and after sleep was selected as the representative MVC for each subject. The percentage of the amplitude of each EMG burst to that of the representative MVC was denoted as the %MVC value. From the obtained EMG data, EMG bursts with amplitudes greater than twice the baseline amplitude with durations of longer than 0.25 s were selected[30,31]. EMG bursts with amplitudes ≥5% MVC, ≥10% MVC, and ≥20% MVC were also selected from the EMG data[31,33]. A cluster of EMG bursts was defined as an episode. Clusters of bursts corresponding to the following three criteria were selected as episodes (EMG episodes): (1) a phasic episode consisting of three or more phasic bursts lasting 0.25 to 2.0 s, (2) a tonic episode consisting of one or more tonic bursts longer than 2.0 s, and (3) a mixed episode consisting of phasic and tonic episodes. The counts for the above-mentioned items were divided by sleep time (TIB) for each measurement, and the number of bruxism waveforms (bursts, episodes) per hour were calculated for each participant. In order to avoid differences between measurement systems with respect to the number of SB bursts under home conditions and in a laboratory equipped with PSG-AV, we did not exclude EMG bursts during the wake stage as well as those arising from oromotor activities other than SB that could be discriminated in sleep stage analyses and audio-video analyses using PSG-AV.

2.4. Statistical analyses

We compared the number of selected EMG bursts and episodes recorded at home and those recorded in the laboratory equipped with PSG-AV. The Excel add-in software Statcel3 (OMS Publishing, Tokorozawa, Japan) was used for all statistical analyses. Paired t-tests or Wilcoxon signed-rank tests were performed depending on whether the distribution of the analyzed items was normal. The statistical significance level was set at 5%.

In addition, the numbers of bursts and episodes on the first and second days of recording were compared regardless of whether the measurements were conducted at home or in the laboratory.

3. Results

3.1. Sleep scoring

The mean TIB value at the home recordings was 7.5 h, which did not differ at the level of statistical significance from the values obtained under recording conditions in the laboratory (mean TIB, 7.4 h) (Fig. 4). Additional results for sleep analyses conducted under recording conditions in the laboratory are shown in Figure 4. The sleep period time (SPT) (that is, the duration of time from sleep onset to final awakening) was 7.1 h on average. Total sleep time (TST; that is, the amount of actual sleep time in a recording, set as the time from sleep onset to final awakening excluding wake time after sleep onset [WASO]) was 6.4 h on average. The average sleep efficiency was
86.8%. The distribution of sleep stages in the laboratory was as follows: 6.4% for stage N1, 43.4% for stage N2, 32.3% for stage N3, and 17.9% for rapid eye movement (REM) sleep.

3.2. SB bursts measured at home and in the laboratory

As a typical example of EMG recordings obtained at home and in the laboratory, the data obtained for Subject 5 are shown in Figure 5 and 6, respectively. Many bursts and episodes were found in the EMG recorded at home (Fig. 5). In contrast, in the EMG recorded under laboratory conditions (with PSG-AV), considerable numbers of EMG bursts and episodes were observed; however, the numbers were much smaller than those in the EMG recorded at home (Fig. 6). This tendency was observed in most of the subjects.

Figure 7 shows the numbers of bruxism bursts with amplitudes greater than twice the baseline value as well as ≥5% MVC, ≥10% MVC, and ≥20% MVC for each subject at home and in the laboratory. For all thresholds for selecting EMG bursts, the number of SB bursts recorded under the recording conditions of single-channel EMG self-administered at home were statistically significantly greater than those recorded in the laboratory equipped with PSG-AV (p<0.05, Wilcoxon signed-rank test) (Fig. 8).

Figure 9 shows the number of bruxism episodes with amplitudes greater than twice the baseline value for each participant under recording conditions at home as well as in the laboratory equipped with PSG-AV. Similar to the tendency observed for the number of SB bursts, the number of SB episodes recorded under home recording conditions were statistically significantly greater than that obtained in the laboratory equipped with PSG-AV (p<0.05, paired t-test) (Fig. 9).

3.3. SB events on the first and second recording days

In all conditions for selecting EMG bursts and episodes, there were no statistically significant differences between the data obtained on the first and second recording days (Wilcoxon signed-rank tests were administered for SB bursts and paired t-tests were administered for SB episodes) (Figs. 10-12).

4. Discussion

To the best of our knowledge, this is the first study to quantitatively analyze and compare the number of bruxism events in a natural home environment as compared to those measured in a laboratory environment implementing PSG-AV. Our results showed that a statistically significantly larger number of bruxism events occurred in the unrestrained home environment as compared with in a laboratory equipped with PSG-AV.

In the aforementioned AASM criteria and some recent studies using PSG-AV[28,31,34], twice the baseline amplitude was used as a threshold for waveform amplitude of SB episodes, and SB episodes with amplitudes larger than twice the baseline were extracted as SB episodes. As for the number of SB bursts, a recent study demonstrated that burst number counts assessed via single-channel EMG with lower amplitude waveform thresholds (e.g., twice the baseline value
or ≥5% MVC) showed a stronger correlation with the number of SB episodes assessed using PSG-AV as compared with higher amplitude waveform thresholds[31]. In this study, in order to determine whether the influence of measurement environments differed depending on the size of the evaluated SB waveforms, ≥10% MVC and ≥20% MVC were used as thresholds of waveform amplitude for extracting SB bursts in addition to the aforementioned thresholds (i.e., defined as twice the baseline value and ≥5% MVC). Consequently, even when waveform amplitudes were large, there were differences between the SB burst numbers measured in an unrestrained environment at home and in the laboratory environment. The effects of differences in the measurement environment with respect to the occurrence of SB were not limited to SB bursts of a certain size.

A previous sleep study using PSG-AV showed that the effect of recording day (e.g., day 1 or day 2) on the determined occurrence of SB was not obvious and did not necessarily apply to all subjects[35]. In contrast, a recent study using PSG for recordings at home showed that the number of SB episodes recorded on the second or third night was greater than that recorded on the first night in mild bruxers[36]. To understand the influence of the measuring environment and the measurement date, it is necessary to measure PSG and EMG over the course of two nights each and to compare these values. Unfortunately, we could not establish this study design in the present study as this would necessitate spending a total of four nights recording each participant. As an alternative study design, measurements in the unrestrained environment at home were conducted on the first evening of each recording and measurements in the laboratory environment were conducted on the second evening of each recording.

Fig. 6. The electromyogram recorded under the condition in the laboratory with PSG-AV of the subject (Sub. 5) whose EMG record under the condition at home was shown in Figure 5. The graphs “a” to “f” show EMG bursts occurred in some parts, but the total number of EMG bursts and episodes were less. The numbers of EMG bursts/h with amplitudes larger than twice the baseline, 5% MVC, 10% MVC and 20% MVC were 26.6, 14.1, 8.1 and 3.2, respectively. The number of EMG episode/h was 4.1. These numbers of bursts and episodes were much smaller than those of the EMG record shown in Figure 5. The upper graph shows the entire sleep time period. The middle and lower graphs are displayed by enlarging the time axis of each part of the “a” to “f” of the upper graph. The upper waves of each graph are EMG signal high-pass filtered at 20Hz, while the lower waves are the signal after high-pass filter, conversion to absolute values and smoothing process. The graph of MVC shows the signal during maximum voluntary contraction that was performed during awake period before sleep. PSG-AV: polysomnography with audio-video recording.

Fig. 7. Numbers of electromyographic bursts at home and those in the laboratory. Numbers of electromyographic bursts for each subject are shown. For subjects 1-10, EMG recording on the first recording day was performed using single-channel EMG at home, while that on the second recording day was performed using PSG-AV in the laboratory. For subjects 11-20, the order of the recording condition was reversed.

Fig. 8. Comparison of numbers of EMG bursts at home and those in the laboratory. A box-and-whisker plot of data for the 20 subjects is shown. The box indicates a quartile including the median value and X indicates the mean value. The upper and lower bars indicate the maximum and minimum values, respectively. Dots on the outside of the boxes indicate statistical outliers.

EMG-burst-all/h: EMG bursts with amplitudes larger than twice the baseline amplitude
EMG-burst-5%/h: EMG bursts with amplitudes larger than 5% MVC
EMG-burst-10%/h: EMG bursts with amplitudes larger than 10% MVC
EMG-burst-20%/h: EMG bursts with amplitudes larger than 20% MVC
MVC: maximum voluntary clenching
day, whereas measurements in the laboratory PSG-AV environment were conducted on the second day for half the subjects, whereas the measurement order was reversed for the other half of the subjects; this strategy was selected in order to eliminate the influence of measurement order in the unconstrained home environment and in the laboratory PSG-AV environment to the degree possible. We found statistically significant differences between SB episode counts obtained in the different measurement environments, while no statistically significant differences were found between SB episode counts obtained on the first and second measurement days. Since the measurement environments differed on the first and second days, the results of comparing SB episodes on the first and second days do not rule out the possibility of a first night effect on SB. At least, however, it was clarified that the difference between the two measurement environments in this study was not too small to be influenced by the order of the measurement days.

It is well known that SB events tend to occur in the ascending phase from deeper sleep stage N3 to sleep stages N1 and N2 of non-REM sleep[6,37]. Therefore, one possible reason for the statistically significant differences in SB episodes between environments observed in this study may be the difference in sleep quality (for example, sleep efficiency and sleep stage distribution). In the present...
study, sleep efficiency in the laboratory was 86.3% on average, which was relatively high. The distribution of sleep stages in the laboratory PSG-AV environment was as follows: 6.4% for stage N1, 43.4% for stage N2, 32.3% for stage N3, and 17.9% for REM sleep. These figures suggest that the sleep stages under PSG conditions in this study were not shallower as compared to the results regarding sleep structure obtained in previous PSG studies.[38–41] Moreover, in a previous study using a simplified PSG device at home, sleep efficiency was measured at 89.2–90.8% and the distribution of sleep stages (N1, N2, N3, and REM) was 9.7–10.6%, 44.3–45.4%, 23.2–25.3%, and 20.1–21.9%, respectively.[36] Based on these findings, it was speculated that the sleep state as determined by in the PSG-AV environment in this study was not meaningfully different from the sleep states described in previously reported PSG environments. Regarding the sleep state at home, because only a wearable single-channel EMG device was used for measurements conducted at home, sleep efficiency and sleep stage could not be assessed in this study. Therefore, we cannot rule out the possibility that the sleep state at home differs from that in a laboratory PSG-AV environment and that this difference acts as a causal factor for the observed difference in SB occurrence. As other reasons, psychological factors may be associated with differences in SB occurrence. In previous studies, it was found that SB events were accompanied by an increase in sympathetic nerve activity.[40]. An altered activities in sympathetic nerve system due to mental stress caused by an unfamiliar measurement environment may have changed the occurrence of SB.

Although wearable EMG devices enable the recording of masticatory EMG in an unrestrained home environment, measurements conducted using only a wearable EMG device cannot provide information on sound and visual data as well as on sleep stage. A previous study indicated that a single-channel EMG assessment cannot definitely discriminate the wake stage from the sleep stage, and that it was difficult to distinguish SB from muscle activities during WASO.[28]. In single-channel EMG detection, the scoring data for EMG bursts might include non-specific movements, e.g., head motion, scratching, swallowing, snoring, and yawning, and it is difficult to distinguish SB from oromotor activities other than SB.[28]. These are inherent limitations of single-channel EMG assessments. In the present study, in order to avoid the influence of these limitations when comparing between the numbers of EMG bursts at home and under unfamiliar conditions in a laboratory equipped with PSG-AV, an identical single-channel EMG assessment using FLA was used under both conditions. In other words, PSG-AV equipment was only used as the sleep laboratory environment; we did not apply PSG-AV equipment for scoring SB bursts and did not discriminate non-specific movements using PSG-AV. While SPT and TST cannot be calculated without detailed sleep data obtained via PSG, TIB can be calculated in single-channel EMG measurements based on calibration jaw movements recorded at the time of going to bed and getting up. Thus, we defined TIB under both measurement conditions as the sleep time for calculating the number of SB bursts and episodes per hour.

In the present study, we compared extremes of measurement environments for SB assessments using EMG (that is, in an unrestrained environment at home [with a single-channel ultra-miniature wearable EMG device] and in a laboratory environment equipped with PSG-AV). Various differences in testing conditions, such as measurement location, room structure, the number of attached biological signal sensors, the presence or absence of cords connecting sensors to the device, and the presence or absence of video observations, were comprehensively included in the differences between the two measurement environments in this study. Within the present study design, it was not possible to determine which of the above factors influenced the obtained results with respect to the differences between the two measurement environments. To clarify the effects of more detailed differences in measurement environments, we plan to conduct additional studies on other measurement conditions, including measurements conducted using only a one-channel wearable EMG device in a laboratory without PSG-AV as well as measurements conducted at home using a single-channel wearable EMG device with a simple PSG device capable of scoring sleep stage.

With respect to diagnosing whether a patient is a sleep bruxer or not, a recent study demonstrated that a modified cut-off value for diagnosing SB using single-channel EMG can compensate for the above-mentioned disadvantage and that a diagnostic accuracy of single-channel EMG for SB that is equivalent to that of PSG-AV can be obtained given a cut-off value appropriate for single-channel EMG.[31] When assessing SB using EMG, the number of EMG waveforms in the measurement results must be handled in consideration of the manner of selecting SB events (that is, whether the number of events is scored in burst units or in episode units, and how the thresholds concerning amplitude and duration of the waveforms were set). Furthermore, in this study, it was clearly demonstrated that the occurrence of SB events in an unfamiliar environment (a sleep laboratory equipped with PSG-AV) differed from that in the actual state (unrestrained environment at home), indicating that the obtained measurement values should be interpreted in consideration of the measurement environment when assessing SB using EMG.
5. Conclusion

In the present study, we demonstrated that the number of SB events under the conditions in a sleep laboratory equipped with PSG-AV was statistically significantly smaller than that obtained under accustomed conditions without restraint at home using a wearable EMG device. These results suggest that the unfamiliar environment of a sleep laboratory equipped with PSG-AV affects the emergence of SB.

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Conflicts of interest

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