Prediction of Sleep Bruxism Events by Increased Heart Rate

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Purpose: To investigate the hypothesis that sleep bruxism (SB) events could be predicted by an increase in heart rate. ***Materials and Methods:*** Fourteen sleep bruxers were recruited. Each participant recorded his or her own electromyography (EMG) and electrocardiography (ECG) at home for 2 consecutive nights using a portable telemetry system. Ten heartbeats before (B10 to B1) and three heartbeats after (A1 to A3) the onset of SB events were analyzed, and the threshold for the prediction of an SB event was determined. The validity of the threshold was tested by EMG and ECG recorded in the same manner for an additional night. The prediction accuracy of SB events was evaluated for sensitivity and specificity. ***Results:*** A gradual increase in heart rate was observed before an SB event, and B1, A1, A2, and A3 were significantly higher than B10 ($P < .01$). The threshold value was set at 110% when the mean of all heart rates of the second night of recording was set at 100%. A total of 324 SB events were observed and 299 were preceded by increased heart rate that exceeded the threshold (sensitivity, 92.3%). The total number of increased heart rate events was 1,239, and the total number of threshold applications was estimated to be 120,000. The specificity was 99.2%. ***Conclusion:*** Over 90% of SB events could be predicted by an increasing heart rate of 110%. Since the sensitivity and specificity were extremely high, the hypothesis that SB events could be predicted by increased heart rate was positively verified. *Int J Prosthodont 2013;26:239–243. doi: 10.11607/ijp.3305*

Sleep bruxism (SB) is considered one of the major risk factors of temporomandibular disorders.[1–3] Moreover, SB causes various problems in teeth and prostheses[4,5] and generates sounds that may disturb sleep partners.[6] However, no definitive therapy has yet been found.[7,8] Electrical stimulation of the trigeminal nerve is known to cause reflex suppression of a voluntary contraction in jaw-closing muscles.[9] A few studies have attempted to apply this inhibitory reflex to modulate muscle activities during sleep. Nishigawa et al[10] reported a single case in which SB could be temporarily suppressed by contingent electrical lip stimulation. Jadidi et al[11,12] applied conditioning electrical stimuli to the temporal muscle to inhibit electromyographic activity during sleep. Although these approaches appear to be promising for the control of SB, complete suppression of the muscle activities of SB was impossible because the initial muscle activity of SB was used as a trigger for the stimulation. Therefore, a new technique that can suppress muscle activities prior to the onset of SB events is required to more effectively eliminate potentially harmful muscle activities during sleep.

A recent investigation has revealed a sequence of physiologic events that precedes SB. Lavigne et al[13] reported that an increase in heart rate (tachycardia) occurs 1 second before the onset of rhythmic masticatory muscle activity (RMMA) in the masseter muscles and tooth grinding. Based on this knowledge, SB events could be predicted by monitoring the heart rate, and thus a new treatment modality to effectively suppress the muscle activities of SB before its onset could be developed.

The purpose of this study was to test the hypothesis that SB events can be predicted based on the phenomenon whereby the heart rate increases immediately before the onset of SB.

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Materials and Methods

Subjects

Fourteen students and faculty members in the Department of Fixed Prosthodontics, Osaka University, who were sleep bruxers were recruited (7 women and

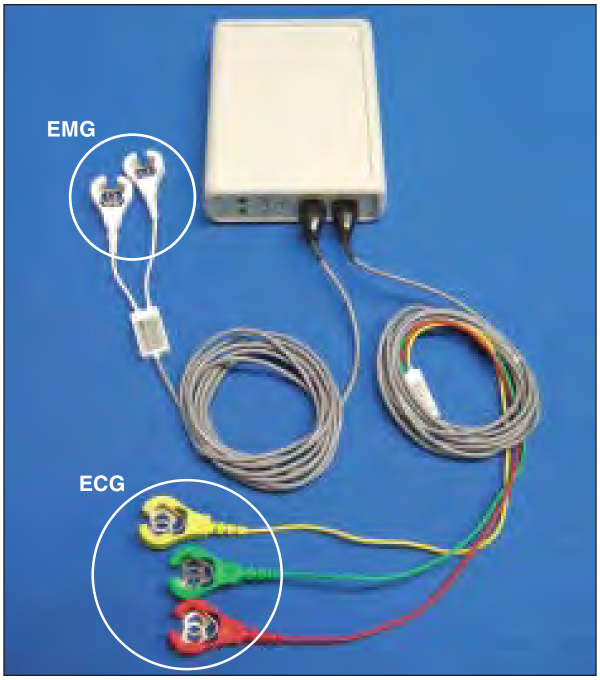
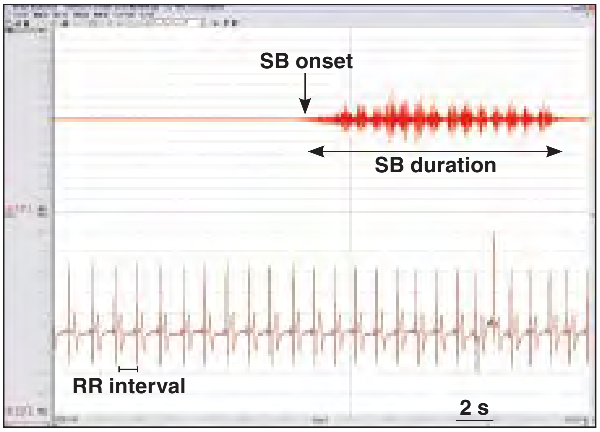


Fig 1 *(left)* Portable EMG and ECG telemetry system, including wireless EMG/ECG recording system with surface EMG and ECG electrodes. Data were transmitted to the receiver and stored in a notebook computer.

Fig 2 *(below)* Example of EMG and ECG recordings. Upper signal: EMG of the unilateral masseter muscle; lower signal: ECG. EMG signals were rectified and integrated.



7 men; mean age, 25.5 ± 3.5 years). The subjects were aware of their SB habits, but none felt the need for treatment and their tooth wear was not severe. Exclusion criteria included a history of sleep disorders or cardiovascular disturbance, absence of two or more molars (other than the third molars), and pain in the orofacial region. All subjects agreed to participate in this study, and informed consent was obtained from all participants. The present study was approved by the Ethics Committee of Osaka University Graduate School of Dentistry on December 1, 2006.

EMG and ECG Recording

Each participant recorded his or her own electromyography (EMG) of the unilateral masseter muscle as well as his or her own electrocardiograph (ECG) for 2 nights at home using a portable EMG and ECG telemetry system (EMG-ECG Telemeter 00, Harada Electronic Industry) (Fig 1). To avoid examiner bias, participants were provided instructions on the use of the telemetry system by one of the authors (MS) prior to the recordings. Alcohol and caffeine consumption were forbidden on the days of the recordings. Disposable electrodes (Vitrode F, Nihon Kohden) were used for the EMG and ECG recordings. Data were sampled at 1,000 Hz, transmitted to the receiver, and stored in a notebook computer (Let's Note CF-T2, Panasonic). To avoid any possible first night effects, only the data of the second night were analyzed, although the recordings were carried out for 2 nights.

EMG Analysis

EMG signals were rectified and integrated. EMG activity that exceeded the mean of the resting state with three standard deviations and lasted more than 0.25 seconds was defined as an EMG burst. Multiple EMG bursts lasting more than 3 seconds were considered to be an SB event (Fig 2). EMG activities with disturbed ECG signals were assumed to be body movements and were excluded from the analysis. The number of SB events per night and per hour, the number of EMG bursts per SB event, and the duration of SB events were calculated.

Heart Rate Analysis

The heart rate was calculated from the RR interval of the ECG using the following equation: heart rate (beats/min) = 60/RR interval (s), where RR interval is time in seconds between the two consecutive heartbeats in the ECG signal (Fig 2).

Ten heartbeats before (B10 to B1) and three heartbeats after (A1 to A3) the onset of an SB event were analyzed (Fig 3).

Statistical Analysis

Heart rates of B9 to A3 were statistically compared to the heart rate of B10 by the Dunnett test using the SPSS 17.0 software. The significance level was set at $\alpha = .05$, and the threshold for the prediction of the SB event was determined based on the statistical results.

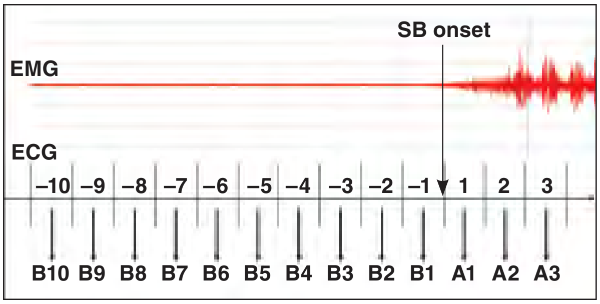


Fig 3 Heart rate before and after SB onset. Ten heartbeats before (B10 to B1) and three heart beats after (A1 to A3) the onset of SB events were analyzed.

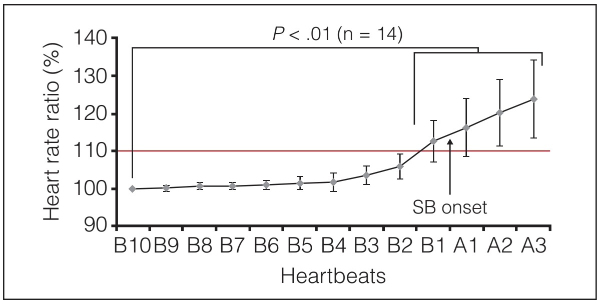


Fig 4 Heart rate changes before and after SB onset. A gradual increase in heart rates was observed starting at 10 heartbeats before the SB event. After B1 the increase was significant compared with B10 (Dunnett test, $P < .01$).

Table 1 Mean Number of SB Events (n = 14)

	Mean (SD)
Number of SB events per night	30.7 (12.5)
Number of SB events per hour	6.26 (1.80)
Number of EMG bursts per SB event	7.40 (2.02)
Duration per SB event (s)	16.1 (4.9)
Analyzed duration (h)	4.81 (0.96)

SB = sleep bruxism; SD = standard deviation; EMG = electromyography.

Table 2 Increased Heart Rates and SB Events (n = 10)

	SB event		
	(+)	(–)	Total
Increased heart rate			
(+)	299	940	1,239
(–)	25	118,736	118,761
Total	324	119,676	120,000*

SB = sleep bruxism.
*Estimation from 50 heartbeats per minute × 60 minutes × 4 hours × 10 subjects.

To test the validity of the threshold value, the 14 subjects were recruited again. However, four students had left the university after graduation. Therefore, EMGs and ECGs were recorded in the same manner for another night (third night) from the remaining 10 subjects (4 women and 6 men; mean age, 26.7 ± 3.5 years). The prediction accuracy of SB events obtained by applying the threshold value was evaluated based on sensitivity, specificity, and predictive values.

Results

The mean number of SB events per night was 30.7 ± 12.5 for the 14 subjects. The mean number of SB events per hour, the mean number of EMG bursts per SB event, and the duration per SB event were 6.26 ± 1.80, 7.40 ± 2.02, and 16.1 ± 4.9 seconds, respectively. The mean duration analyzed was 4.81 ± 0.96 hours (Table 1).

A gradual increase in heart rate was observed starting from 10 heartbeats before the SB event, and the heart rate of B1 (one beat before SB onset), A1, A2, and A3 (three beats after SB onset) became significantly higher than that of B10 (10 beats before SB onset) (Fig 4, Dunnett test, $P < .01$). Based on this result, the threshold value for predicting an SB event was set at an increasing heart rate of 110% when the mean of all heart rates of the second night of recording was set at 100%. Heart rates at B10 were mostly similar to the mean value and considered as normal level for the individual.

A total of 324 SB events were observed in 10 subjects during the third recording; 299 of these events were preceded by increased heart rate that exceeded the threshold value of 110% (sensitivity, 92.3%). The total number of increased heart rate events was 1,239, and the total number of threshold applications (= total number of heartbeats tested) was theoretically estimated to be 120,000 (50 heartbeats per minute × 60 minutes × 4 hours × 10 subjects). Using the theoretical number of heartbeats, the specificity, the positive predictive value (PPV), and the negative predictive value (NPV) were calculated to be 99.2% (118,736/119,676), 24.1% (299/1,239), and 99.98% (118,736/118,761), respectively (Table 2).

Discussion

SB is a sleep-related motor disorder characterized by tooth grinding and clenching.[14] This sleep disorder has been reported by 8% of the population.[15] Clinically, oral appliances (OAs) are frequently used for controlling SB.[8] However, the current consensus is that SB is a centrally controlled sleep disturbance,[15] and the effect of OAs on muscle activities is occasional relief for only a short period of time.[16,17] Electrical stimulation to modulate muscle activity in SB appears to be a potential treatment.[10–12] To control the muscle activity as early as possible, the authors focused on the physiologic sequence before the SB event. According to a report by Lavigne et al,[13] an increase in sympathetic cardiac activity was observed 4 to 8 minutes before an SB event. An increase in electroencephalographic activity occurred 4 seconds before an SB event, and a tachycardia emerged one heartbeat before the SB event. Then, the muscle tone in the jaw opening muscles increased and finally RMMA and an SB event occurred. In this sequence, an increase in pulse rate just before the onset of the SB event was thought to be especially useful for the prediction of the SB event because the increase occurred just before the SB event and the heart rate was relatively easy to monitor in real time. An increase in sympathetic cardiac activity is temporally separated 4 to 8 minutes from the onset of SB events and is not an accurate time predictor of SB events. An increase in electroencephalographic activity is also difficult to measure. Therefore, a detailed relationship between increased heart rate and SB events was investigated in the present study.

A1, A2, and A3 data were analyzed for the possibility that the heart rate increase would emerge later than expected. The increase of heart rate after the onset of a bruxism event may be a common phenomenon associated with muscle activation. Another assumption is that this increase of heart rate would be part of a continuous rise within the sequence of physiologic events that precedes sleep bruxism. Though both explanations may be possible, the physiologic meaning of the increase of heart rate after the onset of a bruxism event could not be determined by this study.

The absence of polysomnographic (PSG) recording is one of the limitations of this study. A portable EMG and ECG telemetry system was used at the subjects' homes under the assumption that a portable device for home use would be essential in a clinical setting.[18–20] Although a complete measurement of SB could be conducted using a PSG system in a sleep laboratory, a portable system has some advantages in certain experimental situations. The authors believe that the mental stress experienced by the subjects was greatly reduced because the subjects were not restrained by electric cords and had complete freedom of movement.[18] In addition, there is a smaller financial burden on the researchers.

Since data were collected from a single night, the results may contain simplistic decisions. Repeated measurements are preferable because one of the noted natures of SB is its fluctuation.[2,21]

No control group was included in the present study. A control group is needed when future studies investigate whether the increase of heart rate just before the onset of a bruxism event would be specific to sleep bruxers. However, the authors believe that because the distinction between sleep bruxers and non–sleep bruxers only depends upon the number and intensity of SB events and SB events can be observed even in non–sleep bruxers, the increase of heart rate is not specific to sleep bruxers only.

As a preliminary preparation for future studies that will target patients with orofacial pain, +3SD of resting EMG level was used as the threshold for detecting an EMG burst of SB. EMG burst amplitudes that are 10% or 20% of the maximum voluntary contractions (MVC) have often been used as the threshold amplitude criterion of SB events.[22–24] Manfredini et al[25] detected EMG events with an amplitude higher than the amplitude of swallowing movements. In this study, EMG activities exceeding the mean amplitude of resting EMG with three standard deviations were used as the threshold. The threshold obtained by this method was similar to 20% of the MVC and was larger than that of swallowing movements. The authors believe that this method for determining the threshold amplitude of SB events would be more suitable when patients, especially patients with orofacial pain, cannot exert voluntary clenching to maximum strength due to muscle pain or fear of pain or other pathologic conditions. ECG signal disturbances that showed an irregular undulating baseline were easily recognizable and used to exclude EMG signals generated by body movements.

Lavigne et al[22] introduced the following cut-off criteria for identifying SB patients: *(1)* more than four bruxism events per hour, *(2)* more than six bruxism bursts per event and/or 25 bruxism bursts per hour of sleep, and *(3)* at least two events that produce grinding sounds. Although the 14 subjects in the present study were selected on a self-report basis, 13 subjects had more than four SB events per hour, 11 had more than six EMG bursts per SB event, and all subjects met at least one of the above criteria for SB.

The hypothesis that SB events could be predicted by an increase in heart rate using a portable telemetry system was positively verified with high sensitivity and high specificity. Post-test probability was considerably low in PPV (24.1%), showing frequent false positive occurrence. This would be due primarily to the low prevalence of SB events compared to the theoretic number of heartbeats (324 SB events/120,000 heartbeats = 0.27%). The low PPV indicates that an increase in heart rate also occurs due to other physical activities, such as body movement or snoring. However, the NPV was extremely high (99.98%), and the high sensitivity and high specificity would compensate for the low PPV. Therefore, using increased heart rate for the prediction of SB events appears to be promising. The low PPV can be improved by eliminating false positive events, such as by detecting body movements using an accelerometer.

An experimental prototype of an automated SB suppression system using electric stimulation triggered by increased heart rate is currently under development. A pilot study has confirmed that electric stimulation at the sensation threshold level triggered by the increased heart rate can suppress SB events. In the future, the authors intend to incorporate a method to discriminate misleading signals into the proposed method and to develop a working prototype of an automated SB suppression system.

Conclusions

Over 90% of sleep bruxism events (299/324) could be predicted when the detection threshold was set to a 10% increase in heart rate. The sensitivity (92.3%), specificity (99.2%), and negative predictive percentages (99.98%) were extremely high, whereas the positive predictive value (24.1%) was considerably low. Other factors that increase heart rates, such as body movement or snoring, could cause false predictions. The discrimination of such misleading signals will be the next problem to consider in the move toward clinical application of the proposed method.

Acknowledgments

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