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Author(s)	齋藤, 大嗣
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博 士 論 文

Minimum measurement time of masseteric electromyogram required for assessment of awake bruxism during the daytime
(咬筋筋電図を用いた日中覚醒時ブラキシズム評価に必要な最小測定時間に関する検討)

令和2年3月申請

北海道大学
大学院歯学研究科口腔医学専攻

齋 藤 大 嗣

Abstract

Objective Assessments of diurnal awake bruxism (d-AB) by using masseteric electromyogram (EMG) during various lengths of measurement time within a day were examined as the first step of research to clarify the minimum measurement time required for assessment of d-AB by subject-unit.

Methods Subjects were 33 outpatients. Assessment of d-AB by EMG during partial measurement time (PMT) with durations ranging from 30 minutes to 6 hours was compared with that during total measurement time (TMT) used as the reference standard.

Results No significant difference was found between TMT data and each PMT data. There were significant correlations in all combinations between TMT data and each PMT data. Accuracy was 0.909 or more during 2.5 h or longer.

Discussion The results suggested that the tendency of daytime muscle activity in one day can be assessed even by using masseteric EMG data obtained during a relatively short measurement time.

Keywords bruxism, diurnal bruxism, awake bruxism, electromyogram, wearable electromyographic device

Introduction

Bruxism is a repetitive jaw-muscle activity characterized by clenching or grinding of the teeth and/or by bracing or thrusting of the mandible [1]. Bruxism is thought to be a risk factor for various diseases in dental medicine [2-5]. It is considered as an important issue to clarify actual state of bruxism in detail. In a broad sense, bruxism is classified into diurnal awake bruxism (d-AB) [6-7] and sleep bruxism (SB). Criteria for diagnosis of sleep bruxism, including clinical diagnostic criteria based on interviews and clinical findings and criteria for electromyography, have been established [8-9]. Unconscious tooth contact and muscle tension associated with d-AB have attracted much attention in clinical dentistry [10], but research works for clarifying the actual situation of d-AB have been delayed.

In recent years, the development of wearable portable electromyographic devices has progressed, and it has become possible to measure masticatory muscle activity during the daytime [11-15]. Watanabe et al.[11] measured masseter muscle EMG activity during the whole day in normal subjects without clinical findings of sleep bruxism, and they analyzed masseter muscle EMG activity during the daytime other than meal times and sleeping time.

For assessment of the degree of d-AB in a patient, it would be ideal to measure masticatory muscle activity for as long a period as possible during the daytime in the study by Watanabe et al [11]. However, it is not clear whether it is necessary to measure EMG activity over the whole daytime in order to assess d-AB by patient-unit, i.e., to determine whether an individual is d-AB patient or not. In other words, no study has been conducted to determine the minimum EMG measurement time required to assess d-AB by patient-unit.

In the present study, as the first step of research to clarify the minimum measurement time required for assessment of d-AB by subject-unit, the authors examined assessments of d-AB by using masseteric EMG during various lengths of daytime measurement time within a day.

Materials and methods

Subjects

The subjects of this study were outpatients who were suspected of having sleep and/or awake bruxism and who underwent masseteric electromyographic measurement during the daytime and nighttime. Among those outpatients, 33 subjects (9 males and 24 females, average age of 44.2 ± 13.9 years) with achieved measurement time for EMG of 6 hours or more excluding meal times and 30 minutes before and after meal times were finally selected for analyses. Among the 33 subjects, 25 subjects had self-awareness of d-AB according to the results of a questionnaire and the other 8 subjects did not have self-awareness of d-AB.

The exclusion criteria were as follows : (1) patients with systemic, functional or mental disorders that cause serious problems in daily life, (2) patients who had 19 or less teeth remaining, (3) patients who had temporomandibular disorders with pain or mouth opening limitation, tooth mobility or tooth pain, and (4) patients who were not able to attach or remove the measuring device by themselves at home.

Ultraminiature wearable electromyogram system

Masseter muscle electromyograms were recorded by means of an ultraminiature wearable electromyogram device, FLA-500-SD (FLA, Furusawa Lab Appliance Co., Ltd. Japan). The FLA contains electrodes, an amplifier, analog-to-digital converter at a sampling frequency of 1 kHz, CPU, a coin-shaped lithium battery, and a micro SD card (Fig. 1).

Measurement procedure

An EMG was induced from electrodes embedded in FLA attached to the center of the unilateral masseteric portion on the side where the subject preferably masticated (right, 15; left, 18) based on self awareness. To find out the preferred chewing side, a questionnaire with a sentence "Which side do you mainly chew on the right or left side when you eat something?" was used. After thoroughly wiping the skin surface, FLA was set with dedicated double-sided adhesive tape, and additional adhesive tape was applied over the body of the device. Measurement was performed at home and other places where the subjects spent their daily life. Handling of the device and measurement procedure were explained to each subject in advance according to the instruction manual. The subjects set the device by themselves at home. At the start and end of measurement, maximum voluntary contraction, i.e., clenching, (MVC) was performed as a calibration exercise. The subjects were instructed to write description and time of daytime activities, e.g., eating, talking, using a personal computer, walking and other physical exercise, into a dedicated table during measurement.

Data analyses

Selecting EMG bursts

EMG data on the second or third day were analyzed. Only the data with a daytime measurement time of 6 hours or more excluding meal times and 30 minutes before and after meal times were used. By means of 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). EMG bursts of more than three times the baseline amplitude with a duration of

0.08 s or more and with an interval of 0.08 s or more to the adjacent burst were selected [11].

The number of EMG bursts/h calculated from the data of each subject during the daytime measurement excluding meal times was designated as the total measurement time (TMT) data. In addition, the number of EMG bursts/h during 12 steps of partial measurement time (PMT) from the start of daytime measurement was calculated. PMT durations ranged from 30 minutes to 6 hours in steps of 30 minutes, and PMTs were designated as PMT0.5 to PMT6.0.

Multiple comparisons were performed using Friedman's test with Steel's method as a post-hoc test between TMT data and data for each PMT. Correlations between TMT data and each PMT data were analyzed using Spearman's rank correlation coefficient analyses. An add-in software, Statcel 3 (OSMS publication, Japan), in Microsoft Office Excel (Microsoft Co.) was used for statistical analyses, and $P < 0.05$ was considered statistically significant.

Calculation of accuracy of the d-AB assessment by length of measurement time

Cut-off values to discriminate between d-AB patients and normal subjects have not yet been established. Therefore, in this study for convenience, the authors referred to the data of normal subjects who had no self-awareness of clenching in the daytime without subjective and objective clinical findings concerning SB and temporomandibular disorders [11]. Then, the average+2 standard deviations (2 SD) of the normal subjects, i.e., 432.0/h, was used as a cut-off value to distinguish between d-AB patients and normal subjects. Assessment based on TMT data with a cut-off at the burst number of 432.0/h was used as the reference standard for d-AB assessment. That is, if number of bursts for

TMT of a subject was greater than 432.0/h, the subject was assessed as d-AB (+), and if the number was smaller than the cut-off value, the subject was determined as d-AB (-). Then, d-AB assessments based on data for each PMT were performed with the same cut-off value, i.e., burst number of 432.0/h. The results of assessment based on PMT data were compared with the results of assessment based on the reference standard (TMT data) to determine sensitivity, specificity, and accuracy (Fig. 2).

Ethical approval

All procedures performed in the human participants were in accordance with the ethical standards of ethical committee of Hokkaido University Hospital and approval was obtained (No. 010-0303, No. 015-0122).

Informed consent

Informed consent was obtained from all individual participants included in the study.

Results

Difference between numbers of EMG bursts in TMT and PMT

Average ± SD of TMT for all of the 33 subjects was 11.6 ± 2.2 h, and TMT ranged from 7.5 h to 16.4 h (Fig. 3). The average number of EMG bursts per hour in TMT for all of the subjects was 385.7/h. No significant difference was found between the number of EMG bursts/h for TMT data and that for data obtained from PMT0.5 to PMT6.0 (Fig. 4).

Correlations between TMT data and data for each PMT

The correlations between TMT data and data for each PMT are shown in Fig. 5. There were significant correlations in all combinations, but the correlation for PMT0.5 was marginal. The correlations became stronger as PMT became longer from PMT0.5 to PMT2.0. For PMT beyond 2.0, however, correlations were relatively consistent and maintained at high levels (Fig. 6). The correlation coefficients for PMT3.0, PMT3.5 and PMT4.0 were 0.905, 0.894 and 0.903, respectively, indicating strong correlations. Extremely strong correlations were observed for PMT4.5 or more with correlation coefficient of 0.917 or higher.

Accuracy of d-AB assessments using data for each PMT

According to assessment based on the reference standard, i.e., data obtained from TMT, 10 of the 33 subjects were evaluated as d-AB (+) and the other 23 subjects were evaluated as d-AB (-).

Table 1 shows an example of sensitivity, specificity and accuracy using assessment based on TMT data as the reference standard. In the example, 9 of the 10 subjects who were assessed as d-AB (+) based on the reference standard were assessed as d-AB (+) based on the PMT2.5 data, and sensitivity was 0.900. Twenty-two of the 23 subjects who were assessed as d-AB (-) based on the reference standard were assessed as d-AB (-) based on the PMT2.5 data, and specificity was 0.957. Accuracy was calculated to be 0.939.

Analysis of the sensitivity, specificity and accuracy of PMT data showed that these values tended to increase as PMT became longer (Fig. 7). Sensitivity was 0.900 for all assessments based on the data for PMT2.0 or longer. Specificities were 0.913 or longer for PMT2.0 or more and 0.957 for PMT2.5. Accuracy was 0.909 or more for all assessments based on data for PMT2.0 or longer.

Discussion

To the best of authors knowledge, there has been no study which compared daytime masseter muscle activities for actual outpatients according to the length of measurement time in such a large number of subjects as that in the present study. In addition, there has been no study in which the accuracy of assessment of d-AB using data obtained in different durations of EMG measurement was investigated. In the present study, the authors were able to analyze a relatively large amount of data from actual outpatients by taking advantage of the performance and easiness of operation of an ultraminiature wearable electromyographic device. It was found that there was no significant difference between the numbers of EMG bursts/h in TMT data and PMT data for 0.5 h to 6.0 h. In addition, significant correlations between TMT data and PMT data were found. It was demonstrated that the sensitivity, specificity and accuracy tended to improve as the measurement time increased, and they were almost constant when the measurement time was 2.5 h or more.

Variation in daytime activity of the masseter muscle within a day

Although the mechanism of SB has not yet been clarified, a rise in sympathetic nerve system activity, microarousal, stress and hereditary factors have been suspected as factors associated with the onset of sleep bruxism [16-19]. Elucidation of causal factor of d-AB is delayed further than that of SB. However, a rise in sympathetic nervous activity, stress and inheritance have been suggested to be involved in d-AB as well as in SB [16, 20]. As for sympathetic hyperactivity and stress, it is thought that this can be divided in chronic and transient. Therefore, variation of masseteric EMG activity during the daytime within a day may be influenced by a transient rise in sympathetic nerve system activity and transient stress. The measurement time required for EMG analyses is thought to depend on the ratios of transient and variable risk factors to chronic and stable risk factors such as genetic predisposition and other chronic risk factors. That is, if the effects of stable and chronic risk factors are dominant, it will be easy to assess the degree of d-AB in patients in a short measurement time, and if the effects of transient and variable risk factors are dominant, a longer measurement time will be required. Since the results of this study showed extremely strong correlations between TMT data and PMT data even at relatively short measurement times, it is thought that there are some chronic and stable characteristics that exceed the range of daily variation in degree of d-AB for each subject.

Cut-off value for d-AB assessment

A cut-off value for d-AB assessment by daytime masseteric EMG measurement has not been strictly established. Hence, in this study, the mean + 2SD of daytime masseteric EMG data in healthy normal subjects was used as a cut-off value for convenience with reference to a previous study [11].

According to questionnaires given to the subjects, 25 subjects had self-awareness of daytime clenching and 8 subjects had no awareness. On the other hand, in the assessment by daytime masseteric EMG with a cut-off value based on the average + 2SD of healthy subjects, 10 subjects were assessed as d-AB (+) and 23 subjects were assessed as d-AB (-). Thus, there was a discrepancy between assessment based on self-reports and assessment by using masseteric EMG. It has been suggested that the diagnostic accuracy of evaluation based on clinical findings such as a medical interview about SB is not high in comparison with diagnosis based on electromyographic analysis by using polysomnography (PSG) with audio-visual (PSG-AV) recording as the gold standard [21-23]. Although the cutoff value used in the present study was tentatively set for convenience, the results may indicate that the diagnostic accuracy of findings based on patients' self-reports concerning awareness of daytime clenching for d-AB is not high, as is the case for SB.

Investigation of minimum measurement time

Various portable devices for measuring masticatory muscle activity have been developed, and measurements of daytime masticatory muscle activity have begun to be attempted. However, the measurement time required for assessment of d-AB has not been clearly defined. In general, measurements obtained with a long measurement time are close to the actual situation of the whole day. However, even with a simple device, measurement over a long period will increase the burden on the person using the device. Therefore, it is desirable to clarify the minimum measurement time that can provide assessment results necessary for the purpose of investigation with a level of accuracy similar to that of results provided by measurement for a long time. The strong correlation between TMT data and PMT data and the high level of accuracy verified by using TMT as a reference standard indicated that the tendency of the amount of daytime muscle activity in one day can be shown by masticatory EMG measurement for a certain period, i.e., 2.5 to 3.0

h or more, even though there is some variation within a day in number of EMG bursts.

From the viewpoint of variation within a day, required measurement time can be interpreted as 2.5 to 3.0 h or longer. From the viewpoint of day-to-day variations, however, the required number of days for measurement could not be determined in the present study design. This is one of the limitations of the present study and is an issue for further study. Another limitation of this study is that the cut-off value used for the assessment of d-AB was set tentatively for convenience as mentioned above. The current gold standard for assessment of SB is PSG-AV in a laboratory, and two or more SB episodes/h are used as a cutoff value for diagnosis of sleep bruxism. On the other hand, a gold standard like PSG-AV has not been established for d-AB. Therefore, the authors plan to accumulate data from multiple samples and to study cut-off values that can be boundaries between bruxers with d-AB and non-bruxers without d-AB.

In the present study, the authors used the number of EMG bursts/h, which was used in previous research of d-AB, as a measurement variable. Other variables such as total duration of muscle activity and an integral value will be examined in further studies.

Conclusion

Assessment of d-AB by using masseteric EMG during PMT was compared with that during TMT, which was used as the reference standard. No significant difference was found between the number of EMG bursts during TMT and that during each PMT. Strong and significant correlations and high levels of sensitivity, specificity and accuracy were found for data obtained during PMT2.5, PMT3.0 and longer. The results suggested that the tendency of the amount of daytime muscle activity in one day can be determined even by using masseteric EMG data obtained during a relatively short measurement time.

These findings provide useful information for future establishment of assessment method for d-AB from the viewpoint of minimum measurement time for masseteric EMG.

Conflicts of interest

The authors have no conflicts of interest to declare concerning the present study.

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Legend of figures

Table 1 An example of sensitivity, specificity, accuracy, PPV and NPV.

Fig. 1 Image of an ultraminiature wearable electromyogram system, FLA-500-SD, attached to the skin surface in the masseteric region.

Fig. 2 Flow chart of the calculation of sensitivity, specificity and accuracy for data obtained in a short measurement time.

h: hour.

TMT: total measurement time.

PMT: partial measurement time.

d-AB (+): subjects with diurnal awake bruxism.

d-AB (-): subjects without diurnal awake bruxism.

Fig. 3 Number of EMG bursts per hour during total measurement time excluding meal times.

Fig. 4 Number of EMG bursts per hour during TMT and each PMT (0.5 to 6.0 h) .

Vertical lines indicate standard deviation.

TMT: total measurement time.

PMT: partial measurement time.

Fig. 5 Correlations between number of bursts/h during TMT (horizontal axis) and that during each PMT (vertical axis). There were significant correlations for all combinations

($p<0.05$).

TMT: total measurement time.

PMT: partial measurement time.

Fig. 6 Correlation coefficient between TMT data and data for each PMT.

TMT: total measurement time.

PMT: partial measurement time.

Fig. 7 Sensitivity, specificity and accuracy in assessments based on data for each PMT.

PMT: partial measurement time.

Table1. An example of sensitivity, specificity,accuracy,PPV and NPV (assessment based on PMT2.5).

	Assessment based on TMT* (Reference standard)			
	ｄ - AB（＋）	ｄ - AB （－）	total	
Assessment based on PMT2.5*				
ｄ - AB（＋）	9	1	10	PPV=0.90
ｄ - AB（－）	1	22	23	NPV=0.96
total	10	23	33	
	Sensitivity=0.90	Specificity=0.96		Accuracy=0.94

＊Cut-off value between d-AB(+) and d-AB(-) was set at 432.0/h.

PPV: positive predicted value.

NPV: negative predicted value.

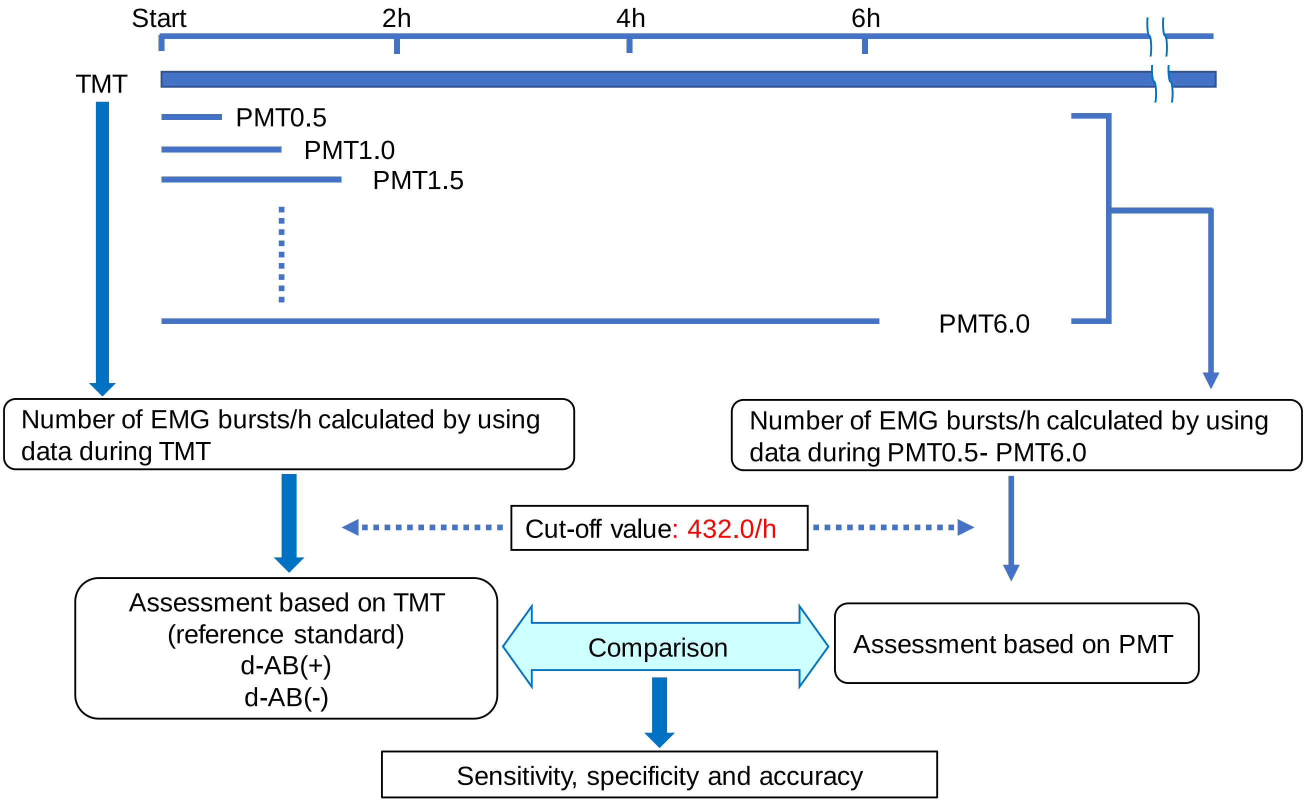
TMT: total measurement time.

PMT2.5: partial measurement time with duration of 2.5 hours.

ｄ - AB（＋）: subjects with diurnal awake bruxism.

ｄ - AB （－）: subjects without diurnal awake bruxism.

Fig. 1 State of attached FLA-500-SD
State of an ultraminiature wearable electromyogram system, FLA-500-SD, attached to the skin surface in the masseteric region.



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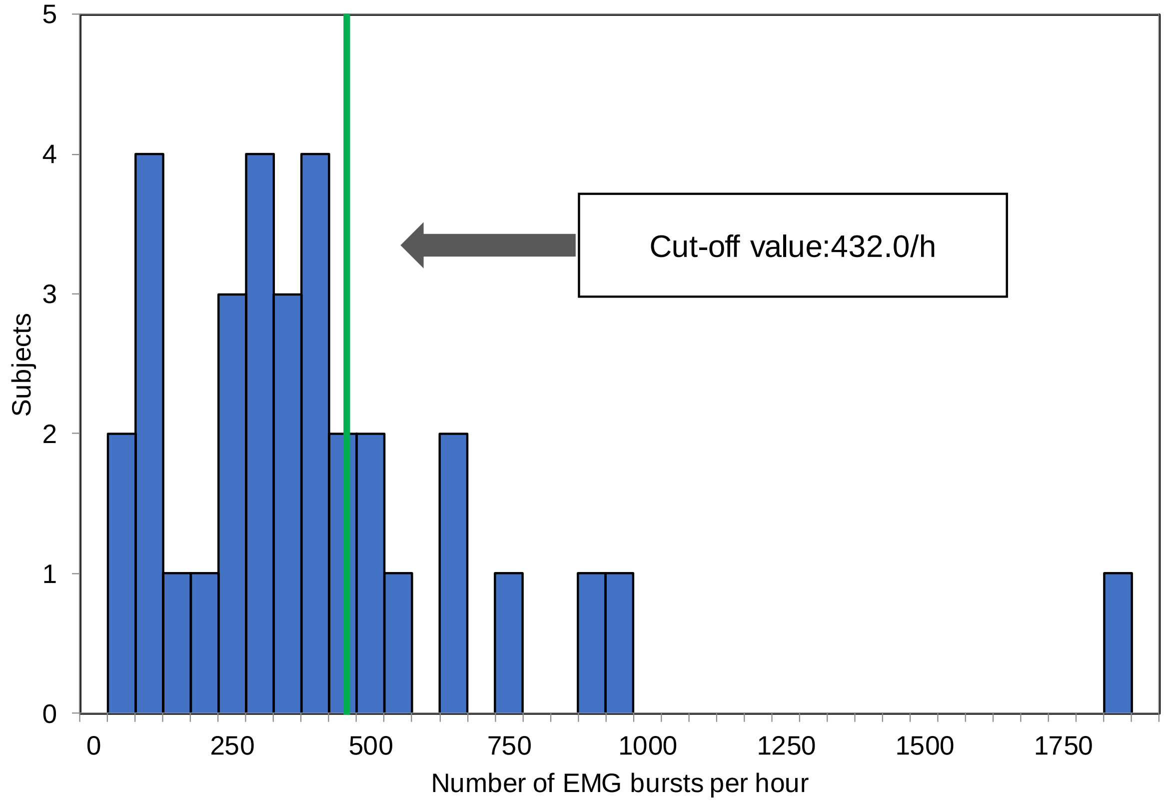

Fig. 3 Number of EMG bursts per hour during total measurement time excluding meal.

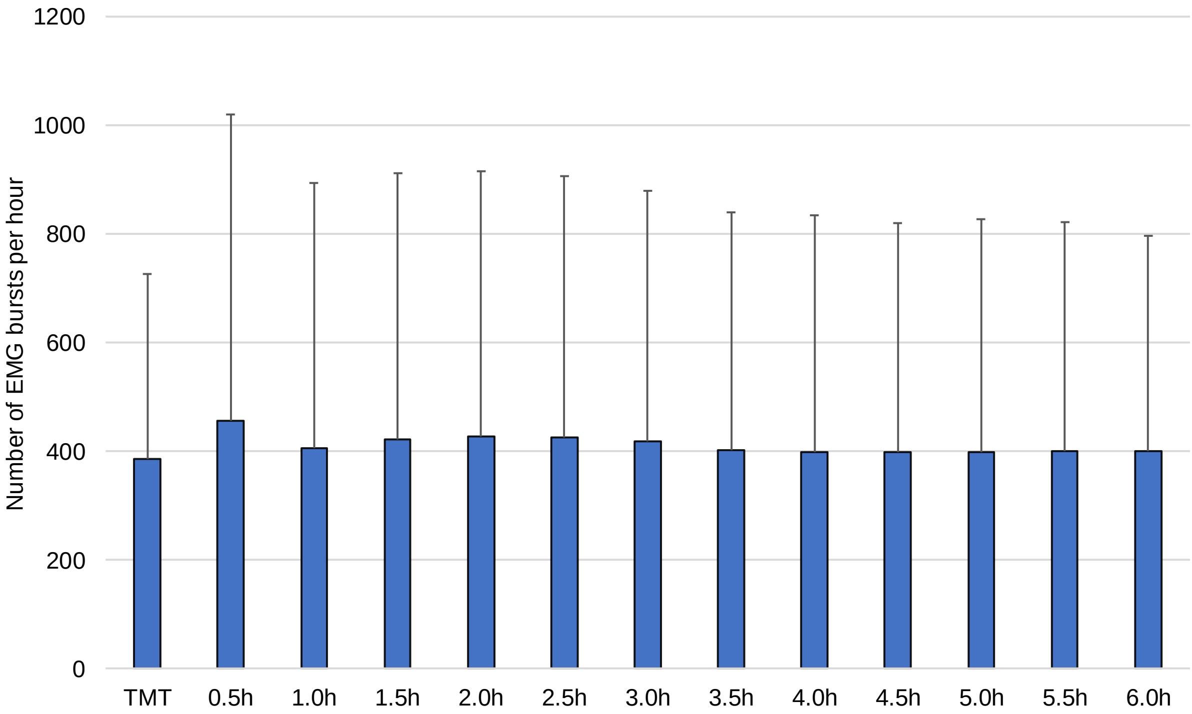

Fig. 4 Number of EMG bursts per hour during TMT and each PMT (0.5 to 6.0 h) .Vertical lines indicate standard deviation.
TMT: total measurement time.
PMT: partial measurement time.

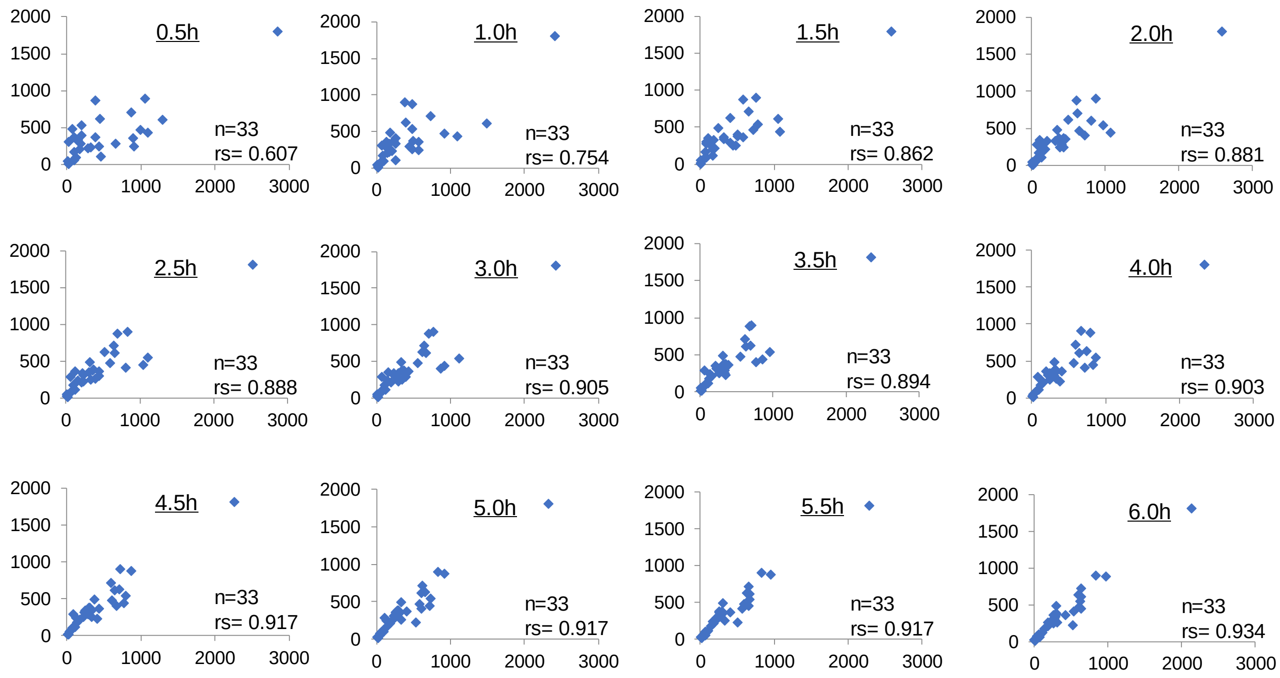

Fig. 5 Correlations between number of bursts/h during TMT (horizontal axis) and that during each PMT (vertical axis). There were significant correlations for all combinations ($p<0.05$).
TMT: total measurement time.
PMT: partial measurement time.

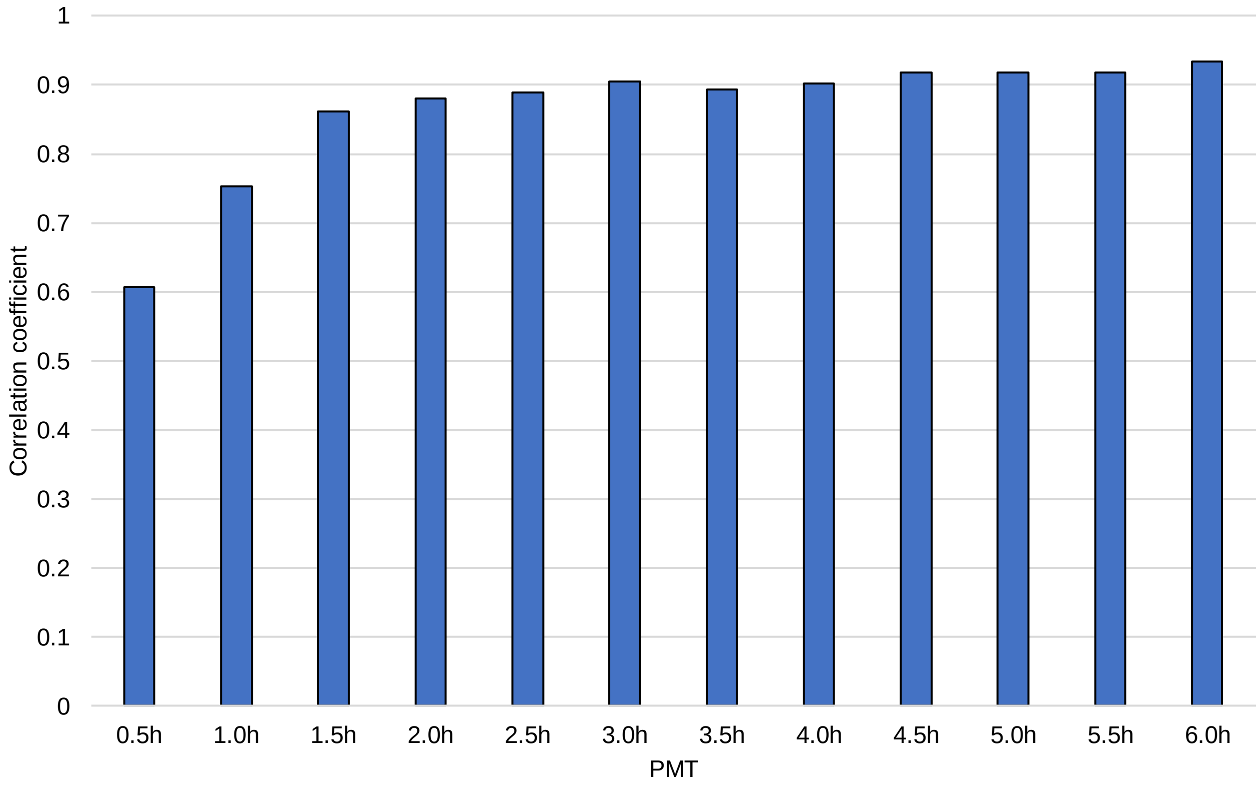

Fig. 6 Correlation coefficient between TMT data and data for each PMT.
TMT: total measurement time.
PMT: partial measurement time.

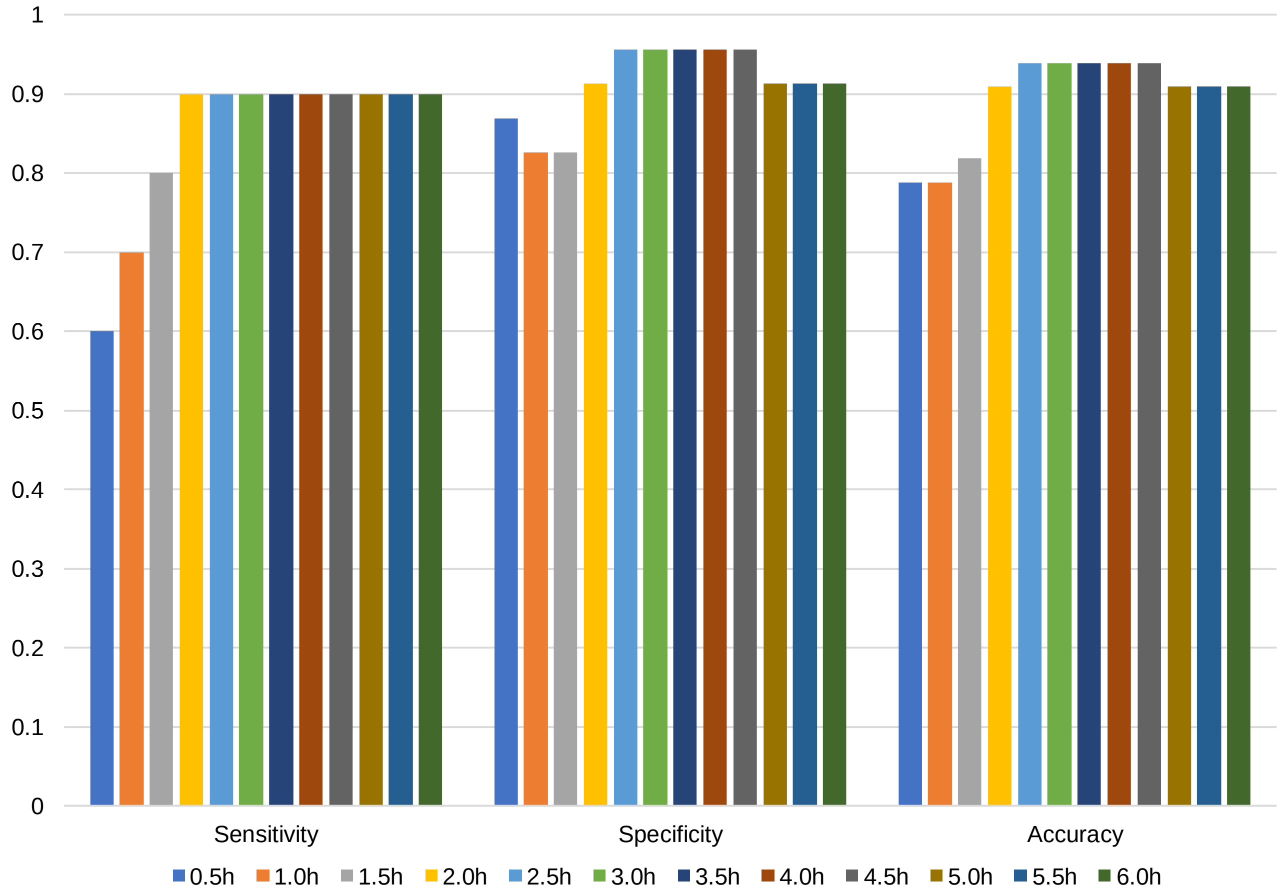

Fig. 7 Sensitivity, specificity and accuracy in assessments based on data for each PMT.
PMT: partial measurement time.