Influence of psychological symptoms on home-recorded sleep-time masticatory muscle activity in healthy subjects

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SUMMARY The present investigation attempts to describe the correlation between sleep-time masticatory muscle activity (MMA) and psychological symptoms by the use of a four-channel electromyography (EMG) home-recording device in a group of 15 healthy volunteers completing a battery of psychometric questionnaires for the assessment of anxiety, depression and anger. The integrated EMG signal was adopted to quantify the work (μV × s) produced by each of the four muscles (bilateral masseter and temporal) during the 5-h recording span and per each 1-h increment. The duration of MMA events and the muscle work during the first hour of sleep was related to trait anxiety scores for both masseter ($P = 0{\cdot}007$) and temporalis muscles ($P = 0{\cdot}022$). Trait anxiety was also significantly correlated to the total amount of MMA duration (in seconds) of the temporalis muscles ($r = 0{\cdot}558$; $P = 0{\cdot}031$). The present investigation provides support to the hypothesis that the duration of sleep-time masticatory muscle activity, especially during the early phases of a night's sleep, may be related to anxiety trait and not to anxiety state, depression or anger. These findings may support the view that features related to the individual management of anxiety, viz. trait, are likely to be more important than acute episodes of anxiety, viz. state, in the aetiology of sleep-time masticatory muscle activity. The role of other psychological symptoms is likely to be less important.

KEYWORDS: sleep bruxism, electromyography, sleep-time masticatory muscle activity, anxiety, depression, anger

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Introduction

Sleep bruxism is a motor activity related to an arousal response of the central nervous system (1) and recognises a multifactorial generator pattern in which several interacting factors contribute to its onset (2, 3). The study of sleep bruxism presents several points of concern with regard to its aetiology, diagnosis and treatment (4–6), and its study is complicated, among others, by issues concerning the differential diagnosis with awake bruxism and by the presence of different bruxism-related motor activities, viz. clenching and grinding (7).

In particular, as far as concerns aetiology, it seems that studies on the role of psychological factors, e.g. stress, anxiety and depression, among the others, reported controversial findings (8–12). A recent systematic review on the argument suggested that differences in the reported findings may be because of the non-homogeneous diagnostic approaches adopted in the different studies, with potential bias influencing the self-report diagnosis of bruxism as well as psychosocial disorders (4).

Consistency of findings from the literature can be increased with the adoption of standardised techniques to record masticatory muscle activity. Indeed, bruxism

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is not a disorder *per se* and may be viewed as a physiopathological continuum, because about 60% of asymptomatic subjects reportedly show signs of rhythmic masticatory muscle activity during sleep (13). Moreover, because of the difficulties to find adequately equipped sleep laboratories and to the potential bias related to a laboratory-based diagnostic approach, it seems plausible to hypothesise that the use of electromyography (EMG) home-recording devices may help increasing knowledge on the above-sketched argument.

The present investigation attempts to describe the correlation between sleep-time masticatory muscle activity (MMA) and psychological symptoms by the use of an EMG home-recording device in a group of healthy volunteers completing a battery of psychometric questionnaires.

Materials and methods

Study population

A total of 20 asymptomatic volunteers willing to participate in the investigation were recruited from among university students at the TMD Clinic, Department of Maxillofacial Surgery, University of Padova, Italy. Candidates for inclusion in the study were selected through a clinical evaluation according to the Research Diagnostic Criteria for Temporomandibular Disorders guidelines (14), which excluded TMD signs or symptoms, and a standardised psychiatric instrument for the exclusion of clinically evident mental diseases (15). Some subjects were aware of their clenching or sleep bruxism habits, but none had ever sought treatment or felt the need to seek treatment for this behaviour. One subject declined to continue the protocol because of time constraints, and another four failed to record nocturnal EMG data.

Data analysis referred to a final sample of 15 subjects (eight men and seven women) in good physical and psychical health, with an age ranging between 21 and 29 years. The subjects did not receive any payment to take part in the study.

The study design provided that every subject underwent one night of electromyographic recording, with the concurrent evaluation of four different muscles (bilateral masseter and anterior temporalis muscles). Sleep-related EMG recording was preceded by the completion of a battery of validated psychometric tests and by the recording of a brief EMG track to set the home-recording device for the detection of cut-off values (EMG Sleep Recording Session).

Questionnaires

General Health Questionnaire (GHQ) test (Golberg Scoring Method) in the validated Italian version (15–17) was used as a baseline pre-investigation instrument to exclude from the sample those subjects with a high risk (>80%) of being affected by clinically evident conditions like pathologic anxiety or major depression. General health questionnaire is designed specifically to detect psychiatric disorders in primary care settings. The original version has 60 questions, but in the present investigation, a shorter 12-item validated version was used. Items include questions for the assessment of clinically evident depression and anxiety, social functioning, psychophysiological symptoms, general health, and vague aches and pains. According to the Goldberg (15) scoring method adopted in this study, a dichotomic score is attributed if the subject answers that recently the symptom has grown in its importance compared to subject's normality (0 = less than usual or no more than usual, 1 = slightly more or much more than usual).

At the time of the EMG sleep recording session, other psychometric tests were also administered to the participants: the State-Trait Anxiety Inventory X-form (STAI-X) (18); the State-Trait Anger eXpression Inventory (STAXI) (19, 20); and the Beck Depression Inventory (BDI-II) (21, 22). All instruments were used with the adoption of a systematically translated Italian version currently used in the psychiatric setting and aimed at quantifying the presence of psychological symptoms that may be related to the occurrence of MMA events (23).

The STAI-X includes 40 items with four possible responses to each. It consists of two subscales, with 20 items assessing state anxiety, and the other 20 trait anxiety. State anxiety is defined as a transient, momentary emotional status that results from situational stress. Trait anxiety represents a predisposition to react with anxiety in stressful situations. Score for each subscale ranges from 20 to 80, with higher scores indicating higher anxiety. The two subscales differ as concerns the items' wording, in the response format (intensity versus frequency), and in the instructions on how to respond. The STAI-X clearly differentiates between the temporary condition of state anxiety and the more general and long-standing quality of trait anxiety (18).

The State-Trait Anger eXpression Inventory was used for dispositional state and trait anger, as well as for anger expression (19). It consists of three different scales, viz. State Anger (10 items), Trait Anger (10 items) and Anger Expression (24 items). The first scale refers to the intensity of the individual's angry feelings at the time of testing. The second one measures the extent to which an individual is predisposed to experience anger or frustration in a range of situations. Individuals are asked to indicate on a four-point scale how often they generally react or behave in the situation described by each item. The Anger Expression scale consists of three subscales, viz. Anger-In (it measures the extent to which people hold things in or suppress anger when they are angry or furious), Anger-Out (it describes the extent to which a person expresses his/her emotional experience of anger in an outwardly manner) and Anger-Control (it involves expenses of energy to monitor and control the physical or verbal expression of anger). A high score on each of these scales represents a high tendency or frequency to express that mode of anger. The STAXI has demonstrated good internal reliability and validity based on results from a variety of samples and cultures (20).

The BDI-II evaluates the presence of depression using the DSM-IV criteria (24) for the Major Depression Episode and is one of the most commonly used self-report measures of depression severity. The BDI-II consisted of twenty-one questions about how the subject has been feeling in the last 2 weeks. Each question has a set of at least four possible answer choices, ranging in intensity. When the test is scored, a value of 0–3 is assigned for each answer, and then, the total score is compared to a key to determine the depression's severity. The instrument was shown to have good reliability and concurrent validity with respect to clinical ratings and other scales (21, 22).

EMG sleep recording session

Masseter and temporalis muscle activity was measured bilaterally using a new portable device designed for use in the present investigation (BTS PocketEMG®*). Four of the 16 channels supported by the EMG recorder were used (right and left masseter and temporalis muscles); signals were amplified and digitalised at a sampling frequency of 1000 Hz (with a 16 bit A/D resolution).

The body of the device, weighing about 300 g, was fastened to the subject with a belt, and an external auxiliary battery was used to support the full-time length of the recording session. Data were stored into a memory card included in the device and then transferred to a PC via USB connection. All electrodes were applied and connected by the same operator (A.F.) at the subjects' own houses. The protocol provided that the skin was cleaned with alcohol and that the electrodes were placed bilaterally on the skin overlying the anterior temporalis and the body of masseter muscles, as identified with clinical palpation. Bipolar surface electrodes† were adhesively fixed to the skin by means of strips‡ and were connected with a clip to the wires inserting into the body of the device. The devices were provided with a user-friendly interface, which was set by the examiner before leaving the subjects' home. All subjects received precise instructions on how to handle the device (namely on how to start the recording session when going to bed and how to stop it when waking up). All participants performed a whole night EMG recording. Data analysis was based on a 5-h span, starting approximately 1 h after the subjects went to bed and turned on the device and ending approximately 1 h before the subjects woke up. Such choice was made to minimise potential bias because of voluntary movements occurring during the phases immediately preceding falling asleep and waking up.

At the beginning of each recording session, the subjects performed three swallowing movements to set the cut-off values (average muscle activity of the three attempts) for the non-functional muscle activities, viz. the EMG activity recorded during swallowing was considered as the higher extreme of function, and all EMG events above that activity were considered as markers of non-functional muscle activity. Literature data showed that EMG activity of the masseter muscles during swallowing might be discriminated from those recorded during other activities in 90% of cases (25), thus providing a theoretical and practical support to the use of such parameter to create a threshold for the detection of the non-functional EMG events.

A semi-automated dedicated software (SmartAnalyzer®*) was used to analyse EMG data; the traces were rectified and averaged, and the root-mean-squared

*BTS Bioengineering™, Milan, Italy.

†Duotrode®, Myotronics Inc., Seattle, WA, USA.

‡Mefix®, Monlicke Health Care, Goteborg, Sweden.

(RMS) amplitude was calculated. The software was set to automatically detect any EMG event with a higher amplitude with respect to the RMS recorded with swallowing movements. Because sleep variables were not scored and other higher-than-swallow amplitude confounding oro-facial activities like apnoea/hypopnea and sleep talking cannot be identified on the basis of EMG alone, the data cannot be interpreted strictly in terms of sleep bruxism behaviour. Therefore, in line with previous studies adopting EMG alone (12) and using unspecific terms, in the present investigation, the generic term sleep-time MMA was used. For each muscle, the total MMA duration (in seconds) during the 5-h span and per each 1-h increment was assessed. The integrated EMG signal was adopted to quantify the work produced by each muscle (μV × s) during the 5-h span and per each 1-h increment.

Statistical analysis

Descriptive data were calculated for each of the above variables, viz. psychometric scores and parameters related to muscle activity. A *t*-test was run to compare means between each pair of symmetric muscles, and right and left data were pooled together for statistical analysis. Correlations between the MMA duration (total and per each 1-h increment) for masseter and temporalis muscles and scores endorsed in the psychometric instruments were tested with Pearson p test. Linear backward regression models were created to identify predictors of muscle work for masseter and temporalis muscles, by the adoption of parameters related to EMG data (muscle work [μV × s] during the 5-h span and during each 1-h increment) as dependent variables, while total scores obtained in the psychometric tests (STAI-X, STAXI, BDI-II) were considered independent variables. Statistical significance was set at $P < 0{\cdot}05$.

All statistical analyses were performed using the SPSS® 17 software[§].

Results

Psychometric scores showed that the mean values for the assessment instruments were non-pathologic (Table 1). No awaking was reported by the study subjects during the 5-h recording span.

Table 1. Mean scores and standard deviations for the psychiatric questionnaires

Psychometric test	Mean ± s.d.	Range
STAI-T	42·7 ± 4·3	35–52
STAI-S	42·9 ± 3·7	35–49
STAXI	88·4 ± 8·8	73–112
BDI	6·2 ± 5·5	0–23

The average total number of MMA events during the 5-h recording period ranged between 180·4 for the right masseter and 285 for the right temporalis muscle, respectively, with a total duration ranging between 111·5 and 230·6 s for the same muscles. The differences between each pair of right and left muscles were not statistically significant (Table 2).

EMG data for paired muscles were pooled together to assess the resulting muscle work (μV × s) that was mainly related to the temporalis muscles in every 1-h increment. The amount of muscle work produced by the right and left temporalis muscles was variable within the 5-h span and ranged between 1·58 and 2·25 μV × s, while the work produced by the masseter muscles was within the 0·75–1·03 μV × s range. The total amount of muscle work of the four muscles during the whole recording period was in average 13·5 μV × s (Table 3).

Trait anxiety scores were significantly correlated to the total amount of MMA duration (in seconds) of the temporalis muscles ($r = 0{\cdot}558$; $P = 0{\cdot}031$). The duration of MMA events during the first hour of recording was related to trait anxiety scores for both temporalis ($r = 0{\cdot}584$; $P = 0{\cdot}022$) and masseter muscles ($r = 0{\cdot}660$; $P = 0{\cdot}007$). The significant correlation between MMA duration in temporalis muscles and trait anxiety was also detected in the second-hour increment ($r = 0{\cdot}676$; $P = 0{\cdot}006$) and got progressively lost in the following hours. No significant correlations emerged between the duration of MMA and scores endorsed in the other psychometric instruments (Table 4). Subjects with high trait anxiety scores, viz. higher than the median value, had a significantly higher temporalis muscles MMA duration in the first 3-h increments and masseter muscles MMA duration in the first recording hour with respect to low-anxiety trait subjects (Figs 1 and 2).

Regression analysis showed that the total amount of work produced by the four muscles during the 5-h span was unrelated to any of the psychometric scores.

[§]SPSS Inc., Chicago, IL, USA.

Table 2. Total duration and number of sleep-time masticatory muscle activity events during the 5-h recording period

Muscle	MMA (5-h)	Mean ± s.d.	Range	Muscle-value comparison of paired muscles (T-test)
Right temporalis	Duration (s)	230·6 ± 265·9	18·6–1042·5	Duration: $P = 0{\cdot}468$
	Events (*n*)	285 ± 207·8	59–678	Events: $P = 0{\cdot}607$
Left temporalis	Duration (s)	172·3 ± 147·9	16·7–611·7	
	Events (*n*)	245·8 ± 198	52–863	
Right masseter	Duration (s)	111·5 ± 103·8	9·5–301·3	Duration: $P = 0{\cdot}451$
	Events (*n*)	180·4 ± 136·8	14–411	Events: $P = 0{\cdot}381$
Left masseter	Duration (s)	145·7 ± 131	27·6–407·4	
	Events (*n*)	239·1 ± 205·6	16–846	

Table 3. Work produced by each pair of symmetric muscles per hour increments (mean ± s.d.)

Hour increments	Muscles	Work (μV × s)	Range
h1	T	1·58 ± 2·48	0·4–10·1
	M	0·9 ± 0·84	0·16–3·15
h2	T	1·66 ± 1·24	0·11–4·6
	M	0·84 ± 0·70	0·07–2·63
h3	T	1·72 ± 1·4	0·09–3·9
	M	0·75 ± 0·74	0·02–2·75
h4	T	1·82 ± 1·34	0·27–4·86
	M	0·93 ± 0·92	0·06–3·11
h5	T	2·25 ± 1·47	0·17–6·04
	M	1·03 ± 0·82	0·10–2·55
Total	All	13·53 ± 8·12	1·65–29·48

T, temporalis muscles; M, masseter muscles.

Significant relationship did emerge between STAI-T ($P = 0{\cdot}038$) scores and work produced during the first recording hour ($R^2 = 0{\cdot}408$). STAI-T scores ($P = 0{\cdot}013$), along with BDI scores ($P = 0{\cdot}014$), were also related to the second-hour work ($R^2 = 0{\cdot}471$). No other significant psychometric predictors were identified for any of the other 1-h increments (Table 5).

Discussion

The literature on bruxism aetiology and on the role of psychosocial factors within the multifactorial bruxism generator pattern has not been conclusive so far, among others because of the lack of homogeneity in the diagnostic criteria adopted in the different studies. A recent systematic review of the literature pointed out that one of the most controversial points was the role of anxiety, depression and stress in the aetiology of bruxism (4). Early EMG studies reported a bruxism-stress association (8), which was not replicated in more recent papers (9, 12), and clinically or self-reportedly diagnosed bruxism appeared to be associated with other psychosocial disorders, such as anxiety and depression (10, 11, 26, 27). More in general, it seems that results of studies adopting a clinical and/or self-report diagnosis of bruxism were not able to replicate findings from EMG and sleep laboratory investigations

Table 4. Correlation coefficients between psychometric scores and total and hourly sleep-time MMA duration (in s) for each muscle

	STAI-T	STAI-S	STAXI	BDI
T Tot	0·558	−0·257	−0·175	0·358
	(0·031)*	(0·355)	(0·534)	(0·190)
M Tot	0·452	−0·033	−0·082	0·426
	(0·090)	(0·906)	(0·771)	(0·113)
T h1	0·584	−0·435	−0·370	0·301
	(0·022)*	(0·105)	(0·175)	(0·276)
M h1	0·660	−0·329	−0·245	0·455
	(0·007)**	(0·231)	(0·379)	(0·088)
T h2	0·676	−0·269	−0·193	0·474
	(0·006)**	(0·332)	(0·491)	(0·074)
M h2	0·358	−0·060	−0·074	0·505
	(0·191)	(0·833)	(0·793)	(0·055)
T h3	0·390	−0·025	−0·101	0·017
	(0·151)	(0·931)	(0·720)	(0·952)
M h3	0·110	0·102	0·274	0·446
	(0·696)	(0·718)	(0·323)	(0·096)
T h4	0·313	0·122	0·256	0·490
	(0·256)	(0·664)	(0·358)	(0·064)
M h4	0·439	0·022	−0·044	0·325
	(0·101)	(0·938)	(0·876)	(0·238)
T h5	−0·167	−0·028	0·162	0·123
	(0·552)	(0·922)	(0·564)	(0·662)
M h5	0·102	0·231	0·010	0·089
	(0·718)	(0·408)	(0·970)	(0·754)

P-values are indicated in parentheses (**$P < 0{\cdot}01$;*$P < 0{\cdot}05$). T, temporalis muscles; M, masseter muscles.

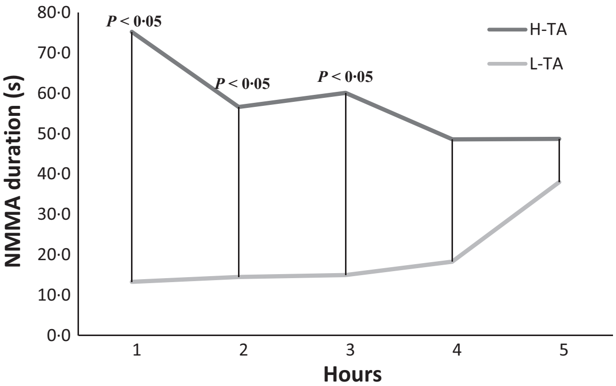

Fig. 1. Average NMMA duration per each hour increment (temporalis muscles). Subjects with high trait anxiety scores (H-TA) versus low trait anxiety scores (L-TA).

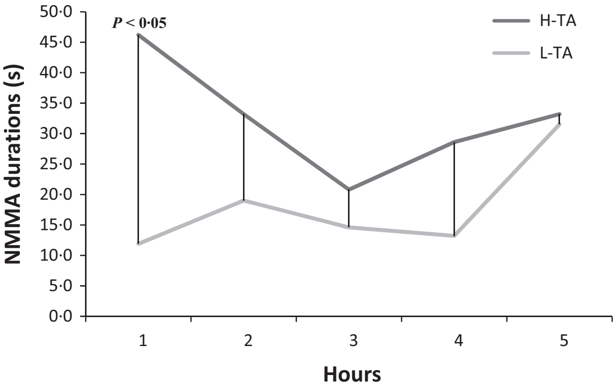

Fig. 2. Average NMMA duration per each hour increment (masseter muscles). Subjects with high trait anxiety scores (H-TA) versus low trait anxiety scores (L-TA).

(4). Such findings may be explained with the hypothesis that the different diagnostic approaches might be differently suitable to detect the various forms of bruxism activities and may be partly attributed to the problems in clinically studying bruxism on the basis of, e.g. pain-like symptoms (7). Thus, a need for more strict basic research, taking into account and controlling for some potential confounding factors for the study of the bruxism–psychosocial disorders association (i.e. age, presence of pain, measurement of bruxism activity), was recently pointed out (28, 29). Also, the view of bruxism as a physiological muscle activity in continuum with potentially pathologic muscle hyperactivity, and not as a disorder *per se*, gained support within the scientific community. Consequently, attempts to quantify the masticatory muscle activity over night-time, rather than generically dichomotised bruxism as present/absent, were strongly encouraged (13, 30).

The present investigation was based on EMG data alone, so it is not suitable for a direct comparison with studies adopting PSG criteria. It provided data on the correlation between home-recorded sleep-time masticatory muscle activity and the presence of psychological symptoms. In a group of healthy subjects, the role of anxiety trait symptoms, viz. STAI-T scores, seems to be correlated with MMA duration in the temporalis muscles during the 5-h recording span and with MMA duration in both temporalis and masseter muscles during the early phases after sleep onset.

Importantly, even though the total amount of work produced by the four investigated muscles during the 5-h recording span was not predicted by any of the psychometric instruments, STAI-T scores predicted the muscle work produced during the first- and second-hour increment. The only other significant predictor was BDI depression score for the second-hour increment work, a finding that is worthy to be reassessed with future studies as a potential type I error, viz. association found by chance. Anger symptoms seem to be unrelated with neither MMA nor muscle work. Multivariate analysis did not retrieve any other significant associations with respect to univariate correlation analysis.

Table 5. Regression analysis. Predictors for total muscle work during the 5-h recording span and for each 1-h increments

Hour increments	Predictor(s)	Sig. (univariate)	B-coefficient	Sig. (multivariate)	Model's R^2
h1	STAI-T	0·038	0·438	0·073	0·408
h2	STAI-T	0·013	0·417	0·091	0·471
	BDI	0·014	0·409	0·069	
h3	–	–	–	–	–
h4	–	–	–	–	–
h5	–	–	–	–	–
Total	–	–	–	–	–

Such findings suggest that temperamental anxiety, viz. trait, may be more important than acute anxiety, viz. state, for the pathogenesis of non-functional masticatory muscle activity during sleep, fitting well with results from studies on the bruxism–acute stress relationship. Several studies reported that such relationship is not linear, and the complexity of stress responses is likely to be related by an individual's coping ability and psychological traits (31). Pierce *et al.* (9) in a study on 100 sleep bruxers over a 15-night recording period found a lack of association between stress and bruxism in 92% of the study population; Lobbezoo *et al.* (32) suggested that the presence of 8% of subjects who did show a stress–bruxism association in the study by Pierce *et al.* (9) can be interpreted as the possibility that certain bruxers are 'sensitive' to stress, while the large majority are not sensitive. Such a hypothesis is also in line with the clinical work by Manfredini *et al.* (11, 33) who showed that stress sensitivity is one of the domains in the anxiety spectrum that mostly differentiate bruxers from non-bruxers. To our knowledge, this is the first investigation relating anxiety to EMG-assessed sleep-time non-functional masticatory muscle activity and may be viewed as a point of convergence towards findings from studies with clinical or self-report diagnosis of bruxism, which provided support to the bruxism–psychosocial disorders relationship.

In the present investigation, the amount of MMA duration during the first recording hour was related to trait anxiety in all the investigated muscles, while the correlation got progressively lost in the following hours, thus suggesting that during the hours immediately following the onset of sleep, the anxiety trait is much more important to induce non-functional masticatory muscle activity than in the following hours. Literature data showed that oro-facial EMG events mainly happen during the sleep stages 1 and 2 (34). Interesting findings came from a work (35) describing a peak of bruxism activity during the first few hours of sleep, but unfortunately, a direct comparison with findings from the present investigation is not possible because of the lack of full polysomnographic recordings in this study and to the absence of any psychometric assessments in the previous works. It may be hypothesised that trait anxiety might prevent some subjects from easily achieving REM and the deepest sleep stages, which are less subject to microarousals related to motor muscle events. Also, on the basis of animal models supporting the view of bruxism as an attempt to unload psychological stress caused by internal conflicts (36), it may be hypothesised that the emerging correlation between sleep-time MMA and anxiety trait in the first hours of sleep responds to a need to get the emotional tension out as early as possible while asleep.

The finding that the amount of MMA duration seems to explain the correlation with psychological symptoms is in line with the suggestions from van der Zaag *et al.* (37), who hypothesised that the assessment of the Bruxism Time Index (BTI, the total time spent in bruxing divided by the total sleep time and multiplied by 100%) is the pivotal factor to implement knowledge on bruxism aetiology and effects.

A key parameter discussed in the present investigation is the quantification of muscle work, here described as the integrated signal of EMG activity during the 5-h recording span. The total muscle work of the four muscles was not predicted by any psychometric variables, but again, anxiety trait is the most important predictor of combined muscle work during the first 2 h of sleep.

No strong correlations were found with the other psychological disorders under investigation. Such findings are interesting and quite surprising, because they are in contrast with some clinical studies suggesting a bruxism–depression association (10, 32) and also in contrast with studies suggesting that anger and hostility are related to the severity of bruxism (38).

Findings from the present study need to be supported by investigations taking into account the potential shortcomings, such as the sample size, the single-night EMG recording, and the unassessed specificity and sensitivity of the EMG definition of MMA with respect to the actual sleep bruxism activity. The literature on bruxism has suggested that an accommodation night is needed to validate sleep laboratory studies (13), but the high costs have prevented such studies from becoming a routine procedure. Longitudinal trials on the night-to-night variability of bruxism suggested that, even if the problem of variability of sleep bruxism parameters may be an important factor to consider at the individual level, the sleep bruxism diagnosis remains constant over time (39). Also, the so-called first night effect, viz. the potential abnormality of sleep parameters during the first recording night, was partly ruled out in a trial on six bruxers and six non-bruxers undergoing four non-consecutive ambulatory PSG recording nights (40). For this reason, some reports on single-night PSG recordings have yielded important outcomes that contributed to gather the current body of evidence on bruxism (41, 42). Also, in the attempt to gather as many data as possible on the aetiology and diagnosis of non-functional masticatory movements, portable EMG devices have been introduced in the bruxism research, and some multiple-night studies were performed (9, 12, 43). Notwithstanding that, for technological and feasibility reasons, all EMG-based studies were limited to single-channel recordings of the right masseter muscle, further limiting the external validity of findings with respect to PSG investigations. A major strength of the present study was the adoption of a four-channel portable device, which may find interesting fields of application in the near future for the study of the temporal relationship between the activation of the different jaw muscles during sleep-time, on the way to an EMG-based discrimination between the different jaw muscle activities. Despite the feasibility of the device was less than optimal because of the four electrodes placed on the face and to the wires connecting them to the recorder, an encouraging finding is the relatively low rate of failures in EMG recordings, viz. about 25% (4 of 19 subjects), which is similar to that reported for single-channel EMG devices (12, 43). In view of these considerations, future research on enlarged samples and with multiple-night protocols is recommended to validate findings from this preliminary work.

A difference with similar work in the literature is represented by the adoption of EMG values during swallowing as the cut-off threshold for non-functional masticatory movements. The most common diagnostic approach to sleep-time masticatory muscle activity is based on percentile assessment of the maximum voluntary clenching (MVC), usually set at 10% or 20% (13). The four-channel device allowed the adoption of a more specific approach based on the assessment of swallowing movements, which should be considered the cut-off threshold for physiological jaw muscle activity during sleep. At present, the only investigation assessing the muscle activation during different jaw activities found that the EMG activity of the masseter muscle during swallowing might be correctly identified and discriminated from other jaw tasks in about 90% of cases (25). Thus, the assumption that all EMG events above the swallowing threshold should be considered as markers of non-functional movements is likely to be less arbitrary than the adoption of single-muscle MVC-based diagnosis, and the definition of the specificity and sensitivity of the chosen EMG threshold with respect to the wide spectrum of jaw motor activities is a target for the near future.

The selection of healthy subjects within a strict age range increased the internal validity of the present findings, thus allowing to control for potential biasing factors, such as pain. Indeed, the complexity of the relationship that both bruxism and psychosocial disorders may have with pain (7, 44) represents an obstacle to the design of unbiased investigations. Hence, the assessment of the bruxism/sleep-time EMG activity–psychosocial factors association is likely to benefit from research designed in selected populations of pain-free subjects, in line with other experimental studies on the argument (45, 46). Notwithstanding that, the external validity of findings should be supported by investigations conducted on more representative samples.

Conclusions

The present investigation provide support to the hypothesis that the duration of sleep-time MMA, especially during the early phases of a night's sleep, may be related to anxiety trait, and not to anxiety state or other psychological symptoms. The total work produced by the four investigated muscles, viz. bilateral masseter and anterior temporalis, during the first 2 h of EMG sleep recording, was also predicted by anxiety trait scores, while anxiety state levels were not predictors of the work produced during sleep. The role of depression symptoms seems to be less important. Neither state nor trait anger was predictors of sleep-time MMA.

Taken together, these findings may support the view that personality features related to the individual management of anxiety, viz. trait, are likely to be more important than acute episodes of anxiety, viz. state, in the aetiology of sleep-time MMA. The role of other investigated psychological symptoms (e.g. depression and anger) is likely to be less important.

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