The Occurrence of Spontaneous Functional and Nonfunctional Orofacial Activities in Subjects Without Pain Under Laboratory Conditions: A Descriptive Study

Takafumi Kato, DDS, PhD
Associate Professor
Institute for Oral Science
Division of Oral and Maxillofacial Biology

Shiho Akiyama, DDS
Graduate Student

Yumiko Kato, DDS
Instructor
Interdisciplinary Dentistry

Shuichiro Yamashita, DDS, PhD
Professor
Institute for Oral Science
Division of Oral and Maxillofacial Biology

Yuji Masuda, DDS, PhD
Professor
Institute for Oral Science
Division of Oral and Maxillofacial Biology

Toshifumi Morimoto, DDS, PhD
Division Chair
Institute for Oral Science
Division of Oral and Maxillofacial Biology

Graduate School of Oral Medicine
Matsumoto Dental University
Nagano, Japan

Correspondence to:
Dr Takafumi Kato
Matsumoto Dental University
Institute for Oral Science
1780 Gobara Hirooka, Shiojiri
Nagano, 399-0781, Japan
Fax: +81 263 53 3456
E-mail: takafumikato@po.mdu.ac.jp

Aims: *To assess the occurrence and the modality of spontaneous orofacial behaviors of awake healthy subjects without pain who were unaware of bruxism during wakefulness.* ***Methods:*** *Sixteen asymptomatic subjects read silently for 30 minutes while polygraphic recordings, including electromyographic (EMG) activity from masticatory and leg muscles, chest respiratory movements, and the movements and sounds of larynx, were made with simultaneous audio-video monitoring. Orofacial behaviors were scored based on the polygraphic and audio-video records. The activity and duration of masseter EMG bursts were calculated for the types of orofacial behaviors.* ***Results:*** *The number of orofacial behaviors varied between subjects; swallowing was most frequently observed. Approximately half of the orofacial behaviors occurred closely with body movements. Of all masseter EMG bursts detected, 55% were associated with functional orofacial behaviors, while 45% were regarded as nonfunctional. More than 80% of these masseter bursts lasted for less than 2 seconds, with an activity less than 20% of maximal voluntary clenching. These values did not differ between the types of associated orofacial behaviors.* ***Conclusion:*** *Although the occurrence of spontaneous orofacial motor activity is variable, asymptomatic subjects can exhibit substantial masseter bursts during wakefulness that are not associated with functional orofacial behaviors. The use of physiological and audio-video records permits spontaneous orofacial behaviors to be specifically identified, thereby allowing nonfunctional masseter EMG activity to be differentiated from functional masseter EMG activity.* J OROFAC PAIN 2006;20:317–324

Key words: bruxism, electromyography, polygraphic recording, spontaneous orofacial behaviors, wakefulness

Oromotor activities can be classified into functional and parafunctional activities, regardless of whether the subject is asleep or awake.[1–4] Functional orofacial behaviors include those related to eating, drinking, speaking, and respiration (eg, breathing, yawning). Parafunctional orofacial activities are unrelated to functional activities. These include nonfunctional masticatory muscle activities associated with grinding, clenching, or nail/object biting.[1–4] Parafunctional orofacial activities can be further differentiated into those occurring during sleep and those occurring during wakefulness.[1–4]

The results of numerous experimental and clinical studies have suggested that an increased number and intensity of nonfunctional masticatory muscle activities during wakefulness may be an initiating and/or an exacerbating factor for orofacial pain problems such as temporomandibular disorders (TMD).[5–11] However, the causal relationship between nonfunctional oromotor activities and orofa-

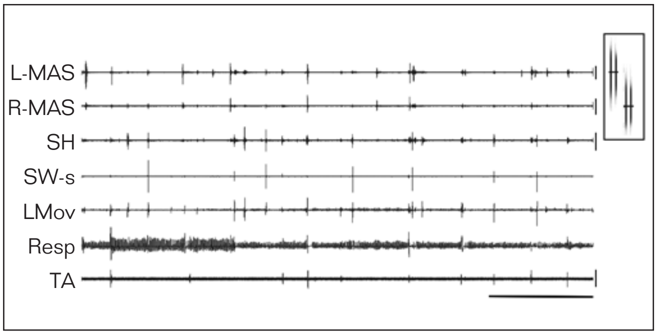

Fig 1 Polygraphic record of the 30-minute reading period for 1 subject. Several motor activities in jaw and leg muscles occurred during a 30-minute period of silent reading. In the upper righthand corner, 2 masseter EMG bursts of maximal voluntary clenching (5-second task) are shown. L-MAS = left masseter; R-MAS = right masseter; SH = suprahyoid muscles; SW-s = swallowing sound; LMov = laryngeal movement; Resp = chest respiratory movement; TA = anterior tibialis muscle. Vertical bar: 1 mV; horizontal bar: 6 minutes.

cial pain, as well as the physiological nature of such motor activities, remains to be determined.

Since various functional and nonfunctional orofacial activities occur concomitantly, the discrimination of nonfunctional masticatory muscle activity from functional activity has been identified as an important methodological process in studying the pathophysiological aspects of oral parafunctions during wakefulness (eg, daytime clenching).[1,12–16] The aim of this study was to describe the occurrence and modality of spontaneous orofacial behaviors and their relation to masseter muscle electromyographic (EMG) activity in normal healthy subjects without an awareness of bruxism during wakefulness.

Materials and Methods

Subjects

Sixteen healthy subjects (10 men and 6 women; mean age, 26.6 ± 2.3 years; range, 24 to 33 years) participated in the study. All gave informed written consent. The protocol was reviewed and approved by the university's research ethics board (no. 0019). One to 2 weeks before the experiment, participants were invited for an intra- and extraoral examination. Participants filled out the Research Diagnostic Criteria for TMD (RDC/TMD) (Japanese version) and questionnaires on several habitual behaviors (eg, hair touching, leg tapping, lip biting, supporting the jaw with the arm, clenching, finger tapping).[17,18] Subjects had to have at least 28 teeth without malocclusion. They could not have any history, signs, or symptoms of orofacial pain according to the RDC/TMD. Potential subjects with a history of psychiatric, neurologic, or respiratory problems; chronic pain; or xerostomia were also excluded. Subjects could not be using any drugs acting on the central nervous system. Finally, the subjects could have no awareness of oral parafunctional habits during wakefulness.

Recording Setup

EMG activity was recorded bilaterally for the masseter muscles, the anterior tibialis muscles, and the suprahyoid muscle complex using bipolar surface electrodes. EMG signals were filtered (band pass: 30 to 1,000 Hz) and amplified 1,000 times.[19] Movements of the larynx were detected by a piezoelectronic sensor (Optiflex; Sleepmate) placed on the skin of the larynx (time constant: 0.03 second; high-cut filter: 30 Hz);[20] swallowing-related sounds were monitored with a microphone (TA-701T, Nihon Kohden) attached on the side of the larynx;[21] and chest respiratory movements were recorded by a respiratory inductive plethysmograph (TR-651T, Nihon Kohden) (time constant: 0.3 second; high-cut filter: 30 Hz). Signals of EMG activity, laryngeal movements, swallowing sounds, and respiratory movements were digitized (5000, 500, 500, and 500 Hz, respectively) and fed into a personal computer using a commercial software (Spike2, Cambridge Electronic Design). In addition, simultaneous audio-video recording was carried out to monitor orofacial behaviors and body movements.

Recording Protocol

The recordings were made between 2:00 and 5:00 pm. Upon their arrival, the subjects were instructed about the equipment and experimental procedures. The sensors were positioned, and signals from these pieces of equipment were confirmed when subjects simulated various orofacial movements, including dry and saliva swallowing, chewing gum, coughing, tooth tapping, and maximal voluntary tooth clenching. Next, subjects were instructed to perform head/limb/body movements (eg, changing posture or leg position) while EMG activity was recorded from the anterior tibialis muscles. After the subjects had relaxed for 5 minutes, a recording was made while subjects read a book quietly for 30 minutes in a sitting position.

Identification of Orofacial Behaviors

As shown in Fig 1, several jaw and leg motor activities in muscles occurred during the 30-minute silent reading. These motor activities were scored offline using polygraphic signals and audio-video recordings.

Functional Orofacial Behaviors. Swallowing events were identified by the presence of swallowing sounds, laryngeal movements, and pauses in respiration in association with suprahyoid EMG activity (Fig 2).[20,21] The other functional orofacial behaviors were associated with facial expressions (eg, grimacing, smiling) or were related to respiration (eg, yawning, sighing, deep breathing, and coughing; Fig 2d).[22] Speaking and speaking-like behaviors in the absence of sound were not observed.

Nonfunctional Lip Movements. Lip movements were scored when not associated with any of the aforementioned behaviors (Fig 2).[23] Lip movements occasionally preceding or following the various orofacial behaviors were considered a part of these functional behaviors and were excluded from scoring. Nonfunctional orofacial behaviors of the jaw and tongue associated with jaw/facial activities, including jaw jutting, jaw excursion, and tongue clicking, were not observed.

Body Movements. In addition to the orofacial behaviors, trunk and limb movements were also scored.[23,24] Body movements were identified using video recordings and anterior tibialis muscle activity. They were classified as follows: gross body movements involving trunk movements, such as a change in posture, and leg and/or arm movements (Fig 2).

Quantitative Analysis of Masseter Muscle Activity

Masseter EMG activity was quantified using custom-made programs on Spike2 software. To determine the onset and offset of masseter EMG bursts, the following analyses were carried out. First, EMG activity of the left masseter muscle was rectified and smoothed by a low-pass finite impulse response filter at a cutoff frequency of 50 Hz. The mean of the digitized EMG during 10 randomly-selected quiet periods was calculated as a baseline for masseter muscle tone. The onset and offset of each burst were identified when muscle activity exceeded or fell below, respectively, the mean + 2 SD. This threshold was used to detect all masseter bursts. (An alternative would have been to consider only masseter bursts that exceeded an arbitrary threshold, such as a percentage of maximum voluntary contraction [MVC].) Thus, muscle activity increased from the mean resting value more than 1.96 times the SD of the resting level was regarded as a masseter burst. The activity of each muscle burst was calculated as a root mean square (RMS) value. It was normalized by the mean RMS value of 3 maximal voluntary clenching tasks.

Statistical Analysis

The concordance rate of event scoring between 2 scorers was calculated for randomly selected 10-minute sections. Kappa statistics were used to assess inter-rater variability. The number of orofacial behaviors scored was compared within subjects by means of the Friedmann test with post-hoc Wilcoxon tests. The data on the duration and activity of masseter EMG bursts were pooled for each subject. The median value of each subject was used for the pairwise comparison between burst types with Wilcoxon tests. A few subjects were excluded from the pairwise comparison because of missing data (ie, the absence of some orofacial behaviors). Paired comparisons between bursts associated with functional orofacial behaviors other than swallowing and those associated with other behaviors were made in 12 subjects. Similarly, burst data for nonfunctional lip movements were compared with data for other behaviors in 14 subjects. Differences were considered significant if the P value was less than .05.

Results

Motor Events

The concordance rate of scoring between the 2 scorers was 92.3%. Kappa was good (0.76). The occurrence of orofacial behaviors was highly variable between the subjects (Table 1). Swallowing events were the most frequently occurring orofacial motor activity observed ($P < .01$). Other functional orofacial events were less frequently scored; 82.2% of these events were associated with respiration, including sighing, deep breathing, yawning, and coughing. Facial expressions such as smiling were rarely observed. Nonfunctional lip movements were occasionally observed.

Body movements also occurred approximately once a minute. One third of movements were related to gross body movements, and the other two thirds were hand and/or leg movements.

Some orofacial behaviors were observed in association with body movements: a median of 55.1% ± 22.1% (range, 20% to 100%) of swallowing

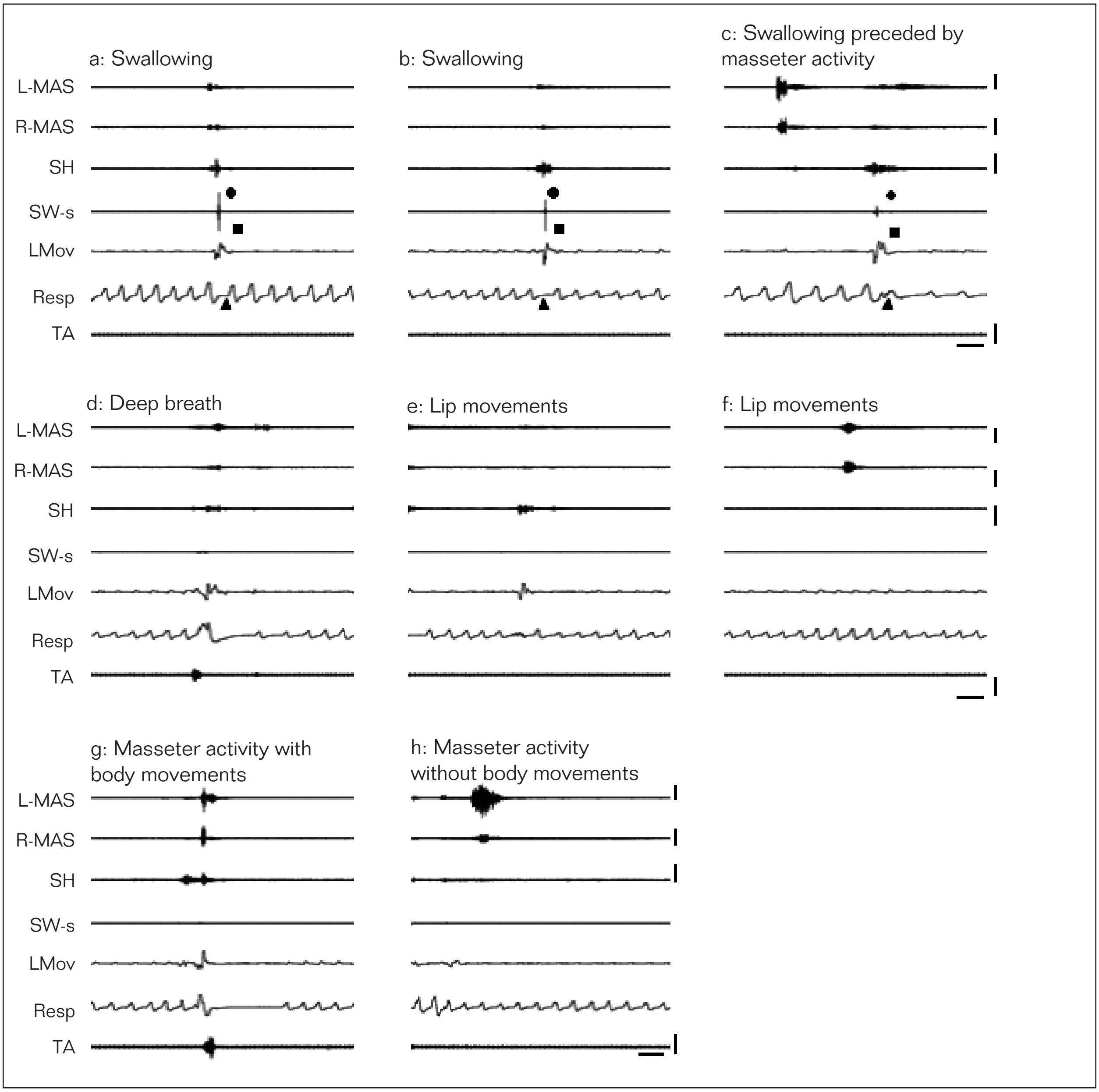

Fig 2 Examples of motor activity for scoring. *(a and b)* Spontaneous swallowing events in 1 subject. Swallowing was characterized by laryngeal movements (■) and swallowing sounds (●) associated with suprahyoid muscle contraction and respiratory pause (▲); masseter muscle activity was usually very low. *(c)* Swallowing in association with gross body movement (leaning on the desk with the elbows). Masseter muscle events, without any orofacial behavioral signs, occurred 10 seconds before swallowing. *(d)* Deep breath associated with a leg movement. Augmentation of respiration is characterized by the high amplitude of chest respiratory movements. Slight EMG increases in masseter muscle activity and contractions of the anterior tibialis muscle were observed. *(e and f)* Lip movements were identified on video recordings. Suprahyoid muscle activity was observed with laryngeal movement, but there were no signs of swallowing sounds or respiratory pauses. Lip movements were sometimes associated with masseter muscle activity *(f)*. *(g and h)* Masseter muscle contraction occurred either *(g)* in association with body movement (eg, leg movement, rubbing the nose with a hand) or *(h)* without accompanying body movement. In (g), a leg movement was observed while the subject rubbed the nose with a hand. Vertical bar = 1 mV; horizontal bar = 5 seconds.

Table 1 Spontaneous Orofacial and Body Events Scored

Behaviors	Behaviors per subject Mean	SD	Range	% of events associated with masseter bursts
Oromotor events				
Swallowing	20.5	15.0	5 to 60	73.8
Other functional behaviors	12.5	9.8	1 to 35	18.8
Respiration-related	7.1	4.4	1 to 19	–
Facial expression	2.3	7.7	0 to 20	–
Nonfunctional lip movements	12.3	11.8	1 to 47	57.1
Body movements	29.8	14.6	6 to 63	–
Body	10.3	6.7	0 to 23	–
Hand/limb	19.1	12.0	5 to 46	–

Table 2 Spontaneous Masseter Bursts

	Percentage of total bursts associated with event	Burst duration				Burst activity (% MVC)			
		Median (s)	Range (s)	< 1 s (%)	< 2 s (%)	Median	Range	Percentage < 10%	Percentage < 20%
Functional									
Swallowing events (n = 16)	48.0	1.06	0.55–4.6	55.7	89.9	10.2	1.9–45.4	63.9	84.5
Other functional events (n = 12)	7.1	0.91	0.16–2.92	54.1	83.8	11.8	3.8–29.8	51.4	79.7
Nonfunctional									
Nonfunctional lip movements (n = 14)	23.1	0.87	0.26–3.66	56.8	81.6	9.9	4.9–16.1	56.6	88.8
No behavior (n = 16)	21.8	1.06	0.27–4.14	56.5	81.6	10.6	1.6–20.3	48.5	90.8

events and 47.8% ± 30% (range, 0% to 100%) of other functional respiratory events occurred in association with body movements. Nonfunctional lip movements were less frequently associated with body movements (median, 28.0% ± 28.9%; range, 0 to 100).

Masseter EMG Bursts

Orofacial behaviors did not always occur with masseter EMG bursts. EMG bursts were most commonly associated with swallowing events (73.8%) and nonfunctional lip movements (57.1%) compared to other functional orofacial behaviors (18.8%).

A total of 1,049 masseter EMG bursts were detected (median, 65.6 ± 62.8; range, 8 to 235). Of these, 48.0% were associated with swallowing events, while 7.1% were scored during other functional events. Masseter bursts were also detected with some nonfunctional lip movements (23.1%). The remaining 21.8% were associated with none of these orofacial behaviors (Table 2).

For these 4 types of masseter EMG bursts, the distributions of burst activity and duration were skewed (Figs 3 and 4). More than 50% of bursts lasted less than 1 second, and more than 80% less than 2 seconds (Table 2). Burst duration did not differ between these 4 groups (Table 2). Similarly, the activity of most masseter EMG bursts was below 20% of masseter activity for MVC. No group difference was found for burst activity (Table 2).

Discussion

The combined use of polygraphy and audio-video recording revealed that the occurrence of orofacial behaviors varied across subjects in a laboratory setting. More than 40% of masseter EMG bursts were not associated with functional orofacial behaviors. For both functional and nonfunctional masseter bursts, more than 80% of bursts were of short duration (< 2 seconds) and of low activity (< 20% MVC).

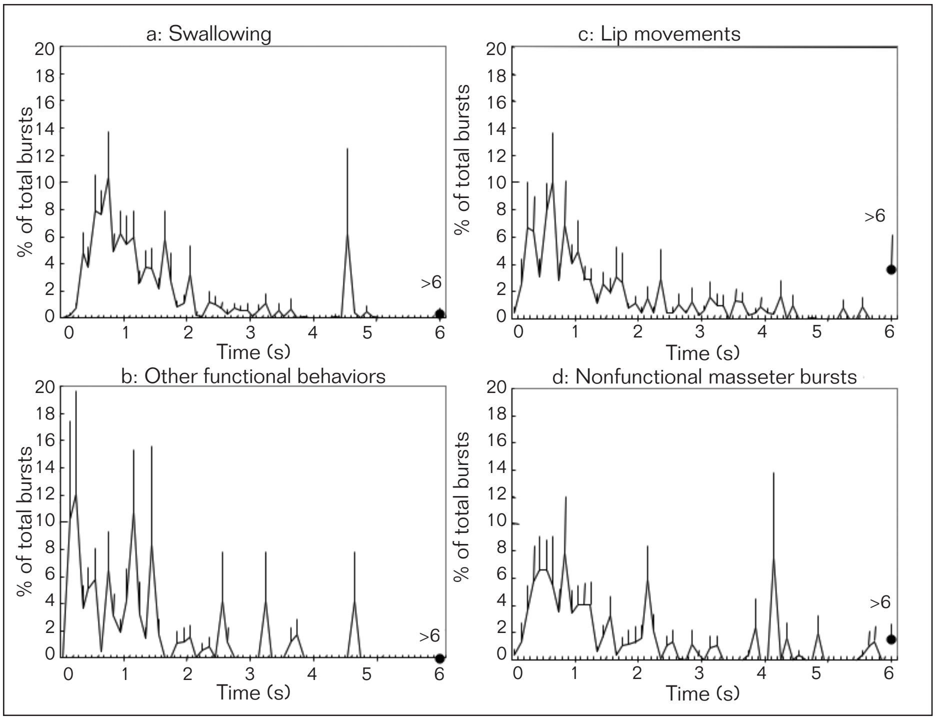

Fig 3 Distribution of burst duration. The percentage of total bursts was calculated for each category for each subject and pooled for 16 subjects. The durations of masseter bursts associated with *(a)* swallowing events, *(b)* other functional orofacial behaviors, and *(c)* nonfunctional lip movements, and *(d)* those not associated with any identifiable orofacial behaviors were shown. The data are presented as means + SEM.

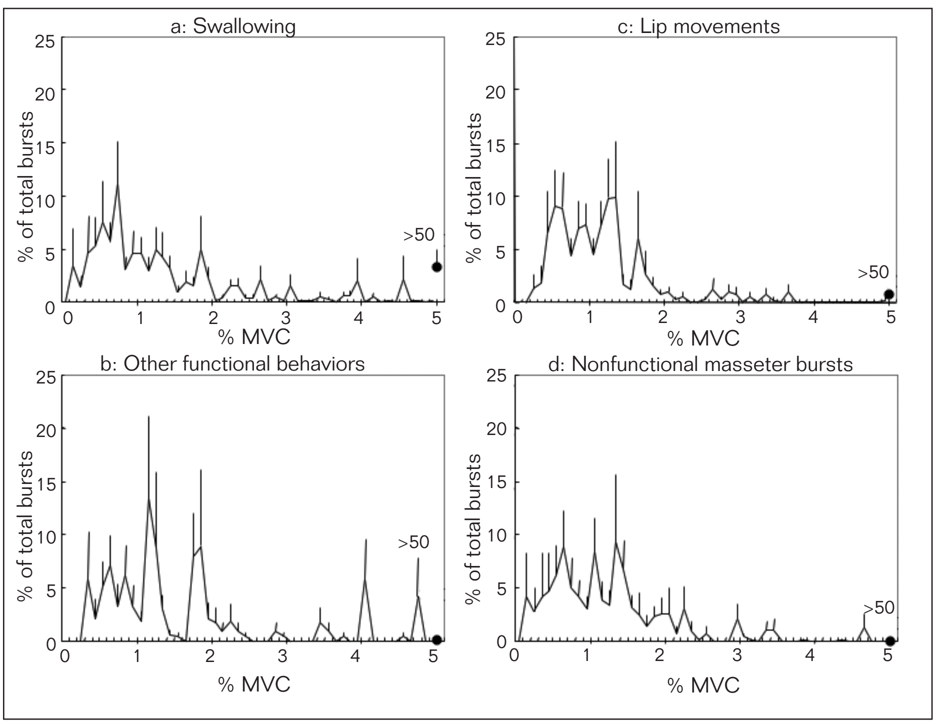

Fig 4 Distribution of burst activity. The percentage of total bursts was calculated for each category for each subject and pooled for 16 subjects. Masseter EMG bursts associated with *(a)* swallowing events, *(b)* other functional orofacial behaviors, and *(c)* nonfunctional lip movements, and *(d)* those not associated with any identifiable orofacial behaviors were shown. The data are presented as means + SEM.

Nonfunctional masticatory muscle EMG activities during wakefulness have been thought to be harmful to orofacial structures. Thus it is important to identify various spontaneous orofacial behaviors in order to clarify the specific influence of nonfunctional masticatory muscle activities on orofacial pain problems. With this aim in mind, several investigators have attempted to discriminate masticatory EMG activity associated with "simulated" functional and nonfunctional jaw motor tasks.[12–14] Other researchers have used arbitrary EMG thresholds to differentiate spontaneous masticatory muscle EMG activities in either natural or laboratory environments.[15,16,25] In the present study polygraphic recordings were used in combination with audio-video recordings. Measurements included

EMG activity of the jaw and leg muscles, movements of larynx and chest wall, and swallowing-related laryngeal sounds. Audio-video recordings have previously been used for identifying orofacial and limb behaviors during sleep and wakefulness because they can provide an overall picture of behaviors.[20,22–24] Thus, the use of physiological and audio-video recordings permits spontaneous orofacial behaviors to be specifically identified.

Several functional orofacial behaviors were scored under the laboratory conditions. Swallowing was the most common functional orofacial behavior. A large variability in the frequency of swallowing events has been reported previously.[21] Other functional orofacial behaviors (eg, yawning, deep breaths, coughing) were observed less often, as has also been reported previously.[26,27] Lip movements have been reported to occur during laboratory testing[23] and were noted in the present study in association with the orofacial behaviors mentioned; they might be considered a part of ongoing orofacial behavior, eg, collecting saliva in front of the mouth when swallowing. Isolated lip movements were scored separately when not associated with identified orofacial behaviors.

Approximately 50% of the functional orofacial behaviors occurred in close conjunction with body movements, but fewer nonfunctional lip movements had this association. Although behaviors involving the limbs and jaw or face are concomitantly reported by some patients with habit disorders,[18,24] it is not known whether these movements require the involvement of multisegmental structures or those in the different parts of the body occur simultaneously by chance.

Most swallowing events were associated with masseter muscle contractions, but some were not. This may suggest that spontaneous swallowing during nonnutritive behavior has different motor coordination compared to nutritive swallowing during ingestion.[28,29] Since most of the other functional orofacial behaviors were associated with respiration, the small number of masseter EMG bursts in these behaviors suggests that the masseter muscle is not closely involved in these behaviors. If it plays any role, it may contribute to stabilizing the jaw position to assist in maintaining a patent airway.[30] Nonfunctional lip movements associated with masseter bursts can be accompanied by subtle jaw movements that could not be clearly identified with the recording methods used in this study.

More than 40% of the muscle EMG bursts were not associated with functional orofacial behaviors, suggesting that nonfunctional masseter muscle activity can occur even in a nonpain population. Approximately 80% of the masseter bursts lasted for less than 2 seconds and at a level below 20% of MVC. These data were consistent with the results of recent studies in which masticatory muscle activities were recorded in the natural environment.[15,25,31] More importantly, the duration and distribution of these masseter bursts did not differ between the types of associated behaviors, which suggests that a finer analysis would be needed to discriminate behaviors by EMG data alone. Therefore, at least in nonpain subjects lacking an awareness of bruxism during wakefulness, the combined use of audio-visual recording and EMG assessment is needed for differentiating nonfunctional masseter muscle activity from functional activity.

Since subjects were recorded only once in this study, the repeatability of the motor activity over time could not be assessed. Several factors have been suggested to have an influence on repeatability, such as psychological conditions (eg, stress), the presence of orofacial sensory complaints (eg, pain), and awareness of tooth clenching.[11,12,14,15,32] In addition, it is not known whether nonfunctional masticatory muscle activity can be described as a normal variant of oromotor activity that, if exaggerated, can present as a clinical problem. Thus, the association between increased muscle activity, the occurrence of orofacial behaviors, and characteristics of masseter EMG bursts needs to be investigated in patients with oral parafunctions (eg, daytime clenching).

Conclusions

The occurrence of orofacial behaviors, including nonfunctional masseter muscle contraction, varies between nonpain subjects. Functional and nonfunctional masseter EMG bursts did not differ in duration and distribution, although a substantial number of masseter EMG bursts was regarded as nonfunctional. The use of physiological and audio-video records permits spontaneous orofacial behaviors to be specifically identified, thereby allowing nonfunctional masseter EMG activity to be differentiated from functional masseter EMG activity.

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