Oral Behaviors Checklist: Reliability of Performance in Targeted Waking-State Behaviors

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Aims: *To assess the consistency of intentional behavioral performance as an index of whether individuals understood the meanings of the behavioral terms of the Oral Behaviors Checklist, which is a self-report scale for identifying and quantifying the frequency of jaw overuse behaviors.* ***Methods:*** *Surface electromyography was used to measure bilaterally the activity of the masseter, temporalis, and suprahyoid muscles (for assessment of oral behaviors) and the biceps muscles (reference task of biceps curl) in 27 temporomandibular disorder (TMD) cases and 27 controls. Subjects were asked to perform (1) biceps curls to lift 5 weights, with explanation, and (2) 10 oral behaviors (eg, "clench," "yawn") without explanation.* ***Results:*** *Biceps-curl performance resulted in assignments of excellent or very good for linearity-reliability based on inspection and correlation. Test-retest reliability of the 10 performed oral behaviors generally ranged from 0.6 to 0.98 for all 3 muscle groups, and many tasks had reliability coefficients comparable to those for the biceps curl. Across tasks, elevator muscle reliability of cases was 0.87, compared to 0.75 for controls; group values for opening muscles were similar.* ***Conclusion:*** *Individual subjects performed each task at a high level of consistency. Performance was not appreciably altered by being a TMD case versus a control and was not significantly different from the performance level of a reference task, indicating that each individual understood well the meaning of each oral behavior-related word.* J OROFAC PAIN 2006;20:306–316

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Oral parafunction has been described repeatedly in the clinical research literature as a significant factor believed to contribute to temporomandibular disorders (TMD).[1,2] While many studies have explored sleep-related bruxism, few have explored the more complex and subtle types of oral parafunctional behaviors that occur during the waking hours. Early studies[3,4] of waking oral parafunctional behavior focused primarily on the relationship between intentional clenching and bruxism and symptom onset, providing the initial evidence for believing that such behaviors contribute to TMD pain; however, because those types of studies relied upon extreme levels of behavior, they have been limited in furthering our understanding of these behaviors. In contrast, Glaros and colleagues[5] used a more clinically ecological design by asking subjects to minimally increase the muscle activity. Electromyographic (EMG) feedback was used as a method for controlling that increase; the parafunctional activity resulted in the production of TMD-like pain. In a subsequent study, Glaros and

Burton[6] observed in a non-TMD group a high association between self-reported pain and masseter EMG activity during several parafunctional behaviors. Based on the studies by Glaros and colleagues, extraneous muscle activity appears to have a causal role for TMD. However, what individuals actually do muscularly to produce the behavioral outcome is not clear. Consequently, little is known about the types of oral parafunctional behaviors people engage in with respect to *(1)* whether there is common understanding of the terms that refer to the identified behaviors and *(2)* whether the actual behaviors might differ in those individuals with versus individuals without TMD pain.

Moss and colleagues[7] attempted to address this lack of understanding by providing some descriptive data about oral parafunctional behaviors. EMG values were measured from 6 muscle groups of the face (ie, bilateral masseter, temporalis, and orbicularis oris) in normal subjects. This study showed, not surprisingly, that each of the targeted behaviors was associated with its own magnitude of EMG activity. Limitations of that study included a rather limited set of behaviors tested and, importantly, failure to compare these behaviors between individuals with versus those without TMD. Behaviors of potentially greater relevance to TMD, by virtue of their being commonly reported by or attributed to patients, were not explored, limiting the study's generalizability to TMD patients.

Using waveform templates and expert systems, Gallo and colleagues[8,9] provided strong evidence for specificity of EMG patterns related to common oral behaviors; they demonstrated excellent validity (ie, high sensitivity and specificity) of EMG patterning for oral behaviors that occur during sleep and for functional behaviors that occur during the waking state. The underlying psychophysiologic mechanisms of parafunction during waking hours and during sleep are clearly delineated in the literature regarding control of oromotor excitability and are now regarded as separate processes.[10,11] Thus, inferences made in the literature about waking-state behaviors from data obtained during sleep should be read with reserve. With strong evidence for EMG specificity regarding sleep-related oral parafunctional behaviors and preliminary evidence for EMG specificity regarding waking oral functional behaviors, the need for explicit investigation of waking-state parafunctional behaviors in individuals with and without TMD becomes clear.

The intention of this study was to provide descriptive analyses and test-retest reliability of masticatory EMG activity when subjects performed various parafunctional and functional behaviors. More specifically, the purpose was to assess the consistency of intentional behavioral performance as an index of whether each individual had an understanding of the behavioral terms. The fundamental importance of this goal as an essential step in the study of waking parafunctional behaviors may require some explanation. While reference to the existence of such behaviors is very common in the clinical literature, and while such behaviors undoubtedly occur during experimental stress studies,[2,12,13] the terms commonly used, such as "clenching" or "bracing," have only an assumed relationship to actual behaviors and are of unknown reliability in terms of cortical processing. Because these behaviors are largely if not completely unobservable, it is unclear whether behavioral understanding of the various terms is sufficient to satisfy scientific inquiry. A goal of this study was to determine, using EMG recordings, whether the behavioral terms are reliable.

Materials and Methods

Subjects

TMD subjects were selected on the basis of having been given a TMD diagnosis in accordance with the Research Diagnostic Criteria for TMD (RDC/TMD).[14] On the basis of available data regarding reported base rate of these behaviors in TMD populations,[15] an RDC/TMD diagnosis was believed to increase the likelihood that at least some of the targeted behaviors might occur regularly in some subjects. However, if TMD subjects frequently performed the targeted behaviors, then any observed relationship in consistency might be amplified due to possible practice effects. To address this problem, control subjects, selected on the basis of lifetime absence of reported pain and jaw problems and therefore not meeting criteria for having a TMD diagnosis, were also recruited, on the assumption that they would report few, if any, such behaviors. The TMD cases were recruited from a private orofacial pain practice, while the control subjects were recruited from the community. There were 27 cases (6 men, mean age 34.3, SD 13.6 years; 21 women, mean age 43.2, SD 13.0 years) and 27 controls (6 men, mean age 44.6, SD 10.1 years; 21 women, mean age 36.1, SD 12.9 years). For the case group as recruited, RDC/TMD Axis I diagnoses were distributed as follows (recognizing that subjects can have multiple diagnoses): Group I diagnosis, 26 subjects;

Group IIa, 12; Group IIb, 1; Group IIc, 2; Group IIIa, 9; Group IIIb, 2; and Group IIIc, 1. RDC/TMD examination data were missing for 1 subject. The study was approved by the institutional review board. Informed consent was obtained from each subject.

Variables

The Oral Behaviors Checklist[16] (OBC) was constructed by the RDC/TMD Validation Study Group (see Acknowledgments) as part of a larger study of diagnostic reliability and validity for TMD. The OBC was used in the present study in order to assess internal validity, that is, whether the subject recruitment strategy resulted in an adequate subject mix for the purposes of the study. A special laboratory version of the OBC was created for this study. The assessed behaviors included clench, touch, press, hold, and tense the muscles of the face; press the tongue forcibly against the teeth; hold the jaw forward or to the side; hold the jaw in a rigid position; talk out loud; and yawn. For each item, the subject was asked to report frequency of occurrence over the past month, using response options of "none of the time," "a little of the time," "some of the time," "most of the time," and "all of the time" (on a visual analog scale [VAS] from 0 to 4).

EMG magnitudes were measured from 1 nonjaw muscle (dominant biceps) and bilaterally from 3 jaw muscle groups (masseter, temporalis, and suprahyoids). The nonjaw muscle served as a reference for interpreting the observed relationships within the oral behaviors. These jaw muscles were used in order to broadly sample the presumed vectors of force applied to the jaw during each behavior. The subject's skin was prepared with Nu-prep (D.O. Weaver) followed by an alcohol wipe. Standard 1 cm^2 electrodes were placed overlying each muscle[17] with an inter-electrode distance of 1 cm. An additional pair of electrodes was attached to the skin overlying the dominant biceps muscle. A ground electrode was attached to the ear lobe. EMG acquisition was sampled at 2 KHz.

Procedure

Subjects completed the OBC, and electrodes were affixed to skin overlying targeted muscle groups. Subjects were instructed in lifting weights of 1, 3, 5, 10, and 15 lbs by using their dominant biceps with the upper arm in a vertical, unsupported position. This task was selected because it is concrete and completely observable. It could be directed by the experimenter, and provided a hierarchical task series that escalated simply in terms of difficulty in execution. Lifting a weight with the biceps is a commonly used task in physiology experiments,[18] and abundant data indicate clear linearity[19–21] within the range of forces employed in this study between EMG output and task demands (ie, lifting a weight); consequently, it serves as an excellent reference task. The upward and downward movements of the forearm were paced by the experimenter at 3 seconds each; subjects practiced until they consistently performed the task. Baseline recordings preceded each task. Subjects performed 2 trials of curling each weight in sequence; trials were repeated if necessary in order to adhere to the paced pattern.

EMG activities for oral behaviors were then recorded on an oscilloscope starting with a 3-second baseline period, followed by a 3-second task and a 6-second recovery period; 2 trials of each behavior were recorded. The subject was asked to do each behavior in turn, eg, "please clench your teeth"; if the subject asked for clarification, the experimenter always responded, "do whatever you think the word means." At the end of the recovery period following each task, if the subject had not reduced the EMG activity to less than 25% of the maximum level of EMG activity exhibited during the requested behavior by visual inspection of the oscilloscope by the experimenter, additional time was added to the recovery period until the subject had sufficiently relaxed before proceeding to the next task.

Data Analysis

EMG data were reduced offline to root mean square (RMS) values. The raw EMG biceps data were graphed by amount of weight for each subject, and the first 2 authors independently scored each subject's data for linearity; disagreements (n = 3) were resolved by joint evaluation of that data. The data for right versus left masseter and temporalis were inspected with exploratory analyses (means, SDs), and the 2 sides exhibited very similar values; subsequently, those values were averaged within each muscle group in order to improve EMG reliability. A task-only design was used for comparing EMG activity across the different oral behaviors.[22] Pearson correlation was used to assess the reliability between trials for each of biceps and oral behavior data. However, because intraclass correlation coefficients (ICCs) are extremely sensitive to range effects,[23] and because it was necessary to directly compare test-retest relationships

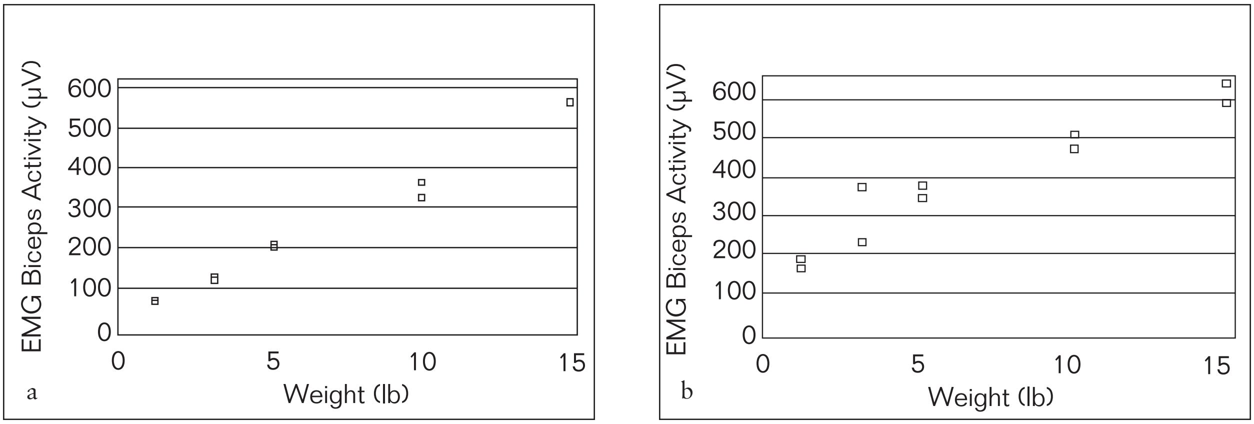

Fig 1 Single-subject examples of EMG activity versus requested task performance when lifting weights with the biceps. Two patterns were detected: *(a)* a linear and highly reliable relationship, and *(b)* linear data with 1 to 2 outliers.

across all tasks with some expected variability in the observed ranges, the Pearson correlation was regarded as a more appropriate index of consistency. To compensate for not using the ICC, the data were evaluated with graphical methods with reference to the line of unity slope. Outlying values were excluded from task test-retest reliability calculations; EMG values in a trial that were 3 standard deviations or more above the mean for that trial were regarded as outliers and were not included in the Pearson correlation for that muscle group. The reported frequencies of the oral behaviors, via the OBC, were averaged within groups (TMD, controls) by using a mean value. Stata 8.0 software (StataCorp) was used. *P* values less than .05 were considered significant.

Results

Biceps Performance

The overall biceps task linearity of EMG activity across the 5 weights was divided into the following 2 patterns: linear and reliable (subject produced the expected linear physiological relationship between required force and the weights for both trials), and linear and not reliable (expected linear relationship was present, but at least 1 trial of 1 weight exhibited substantial departure from what would be expected, ie, an outlier defined as greater than 40% error from the value from the contralateral side. Data illustrative of these 2 patterns from individual subjects are shown in Fig 1. TMD cases and controls each exhibited similar types of patterning in lifting weights with their arm (χ^2 = 0.72, *P* = .70); the linear and reliable group comprised 24 cases and 22 controls, while the linear with outliers group comprised 3 cases and 5 controls.

Intertrial reliability was computed for each weight within each of the 2 overall biceps task linearity groups in order to judge the reliability of weight lifting (Fig 2). The intertrial reliability ranged from 0.80 to 0.99, and outliers in the "linear but not reliable" group did not compromise the reliability coefficients. These data, stemming from the reference task, provide an upper limit of task reliability for task understanding and performance of the more diffuse oral tasks, where reliability is unknown.

Oral Task Performance

Intertrial reliability was assessed using the natural groups of cases versus controls, as well as by using the groups created by the reference-task formed groups (linear and linear with outliers). Raw data illustrating masseter data for trial 1 versus trial 2 for 3 representative tasks, "clenching the teeth," "tensing the jaw," and "yawning," are shown in Fig 3; the raw data for the other tasks and other 2 muscle groups (temporalis, suprahyoids) were very similar and are not presented. These raw data clearly demonstrate that *(1)* cases and controls produced the requested behaviors similarly in terms of magnitudes and outliers; *(2)* there was a linear relationship between trial 1 and trial 2 for cases and controls for the requested behaviors; and *(3)* the linear relationship coincided with the line of unity. Accordingly, Pearson correlations were performed for trial 1 versus trial 2 for each muscle

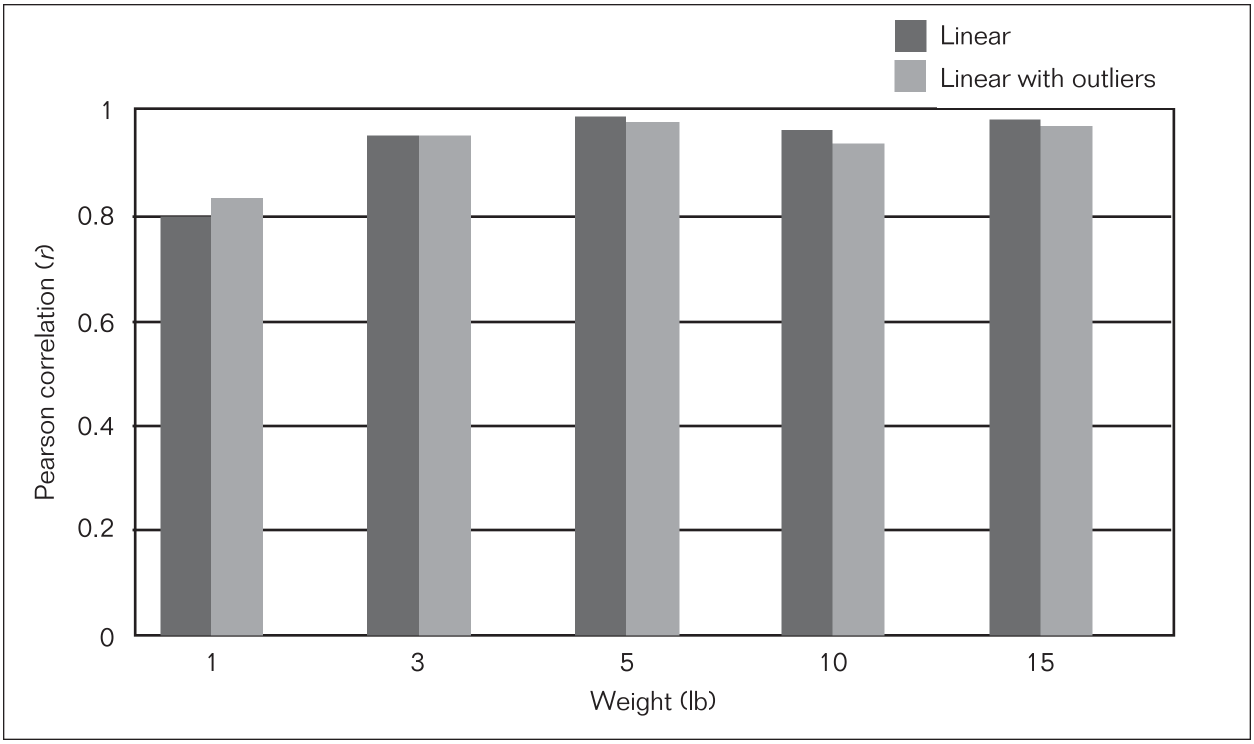

Fig 2 Graph showing high reliability between the 2 trials for whether the EMG activity was linear and reliable or reliable with outliers.

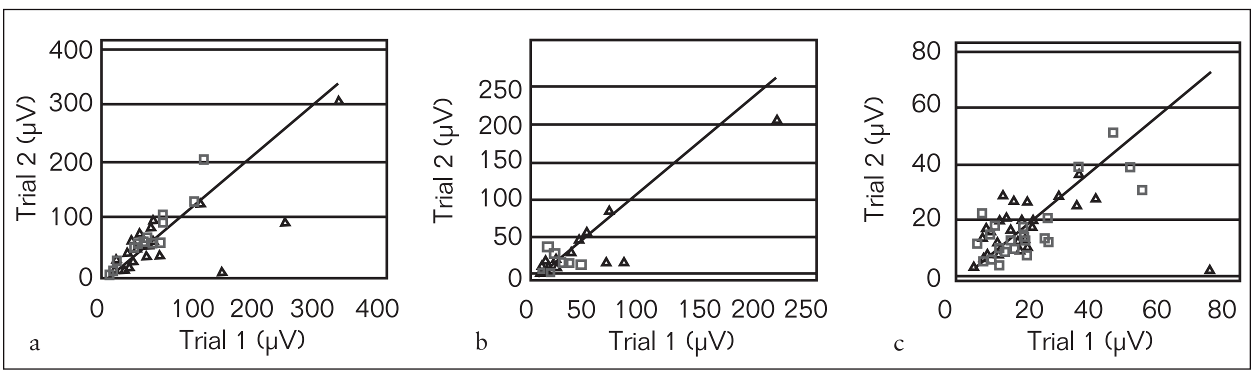

Fig 3 Examples of relatively high test-retest reliability of masseter EMG activity (μV) for tasks such as *(a)* clenching, *(b)* tensing the muscles of the face, and *(c)* yawning. Triangles = TMD cases; squares = controls.

and each task within each group (case and control groups); the resultant correlation coefficients are depicted in Fig 4. Excluding the control group in the clenching and yawning tasks, both groups demonstrated moderate to high intertrial reliability among the tasks tested.

In order to assess whether the presence of prior behavioral treatment in some of the cases (n = 13) had biased the reliability estimates, reliability testing of trial 1 versus trial 2 was performed comparing TMD subjects who had received behavioral treatment prior to study enrollment versus TMD subjects who had not. Of the 30 reliability correlations across the 10 tasks measured in 3 muscles, generally the correlations clustered around those as shown in Fig 4; 8 correlations improved in favor of the treatment group, with 18 in favor of the nontreatment group, indicating that behavioral treatment had not biased the observed estimates of task reliability. Given the comparable statistics in the controls, this finding was not surprising.

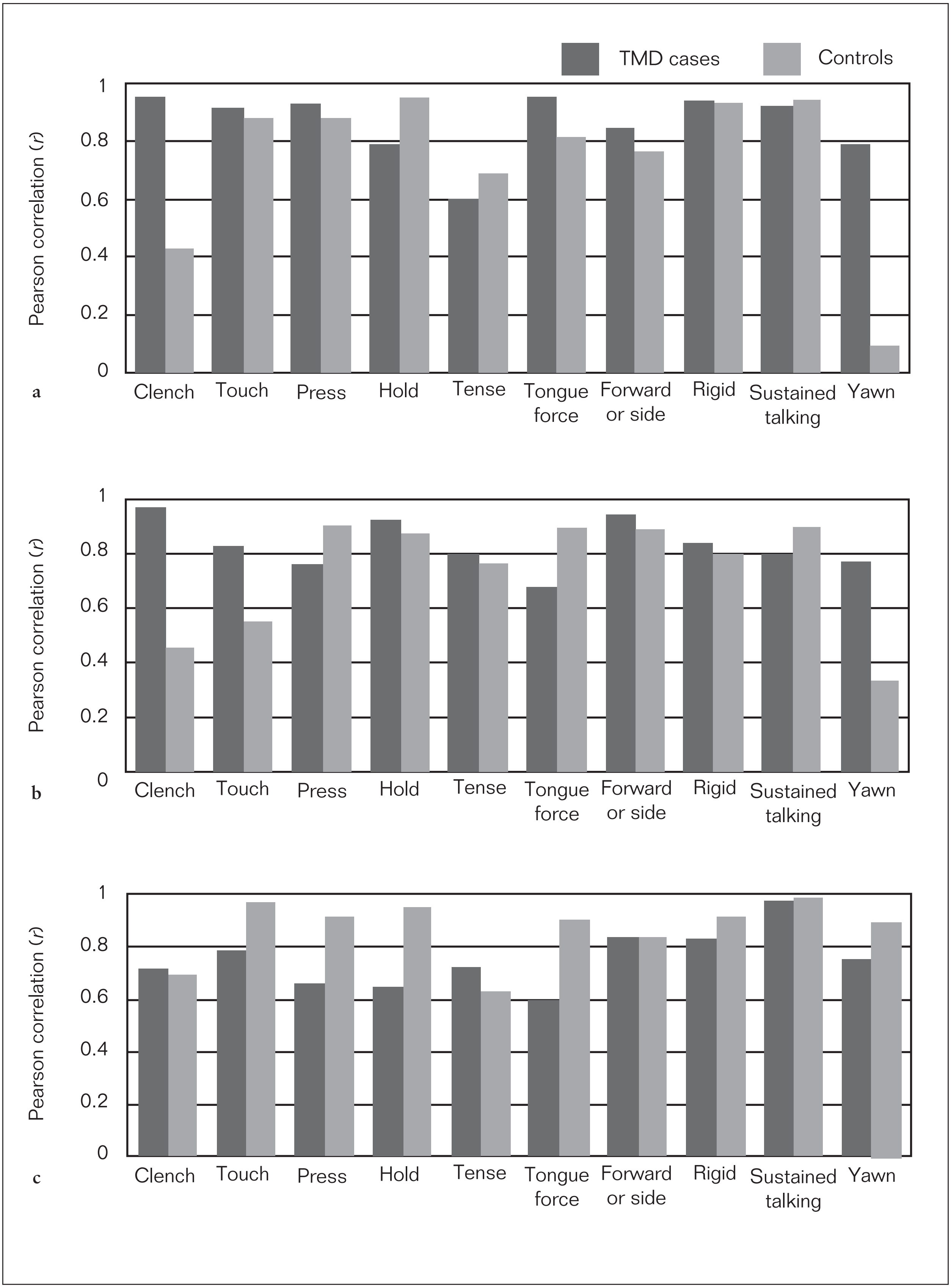

Fig 4 Graphs showing relatively high test-retest reliability during the assessed behaviors for *(a)* the masseter, *(b)* the temporalis, and *(c)* the suprahyoids.

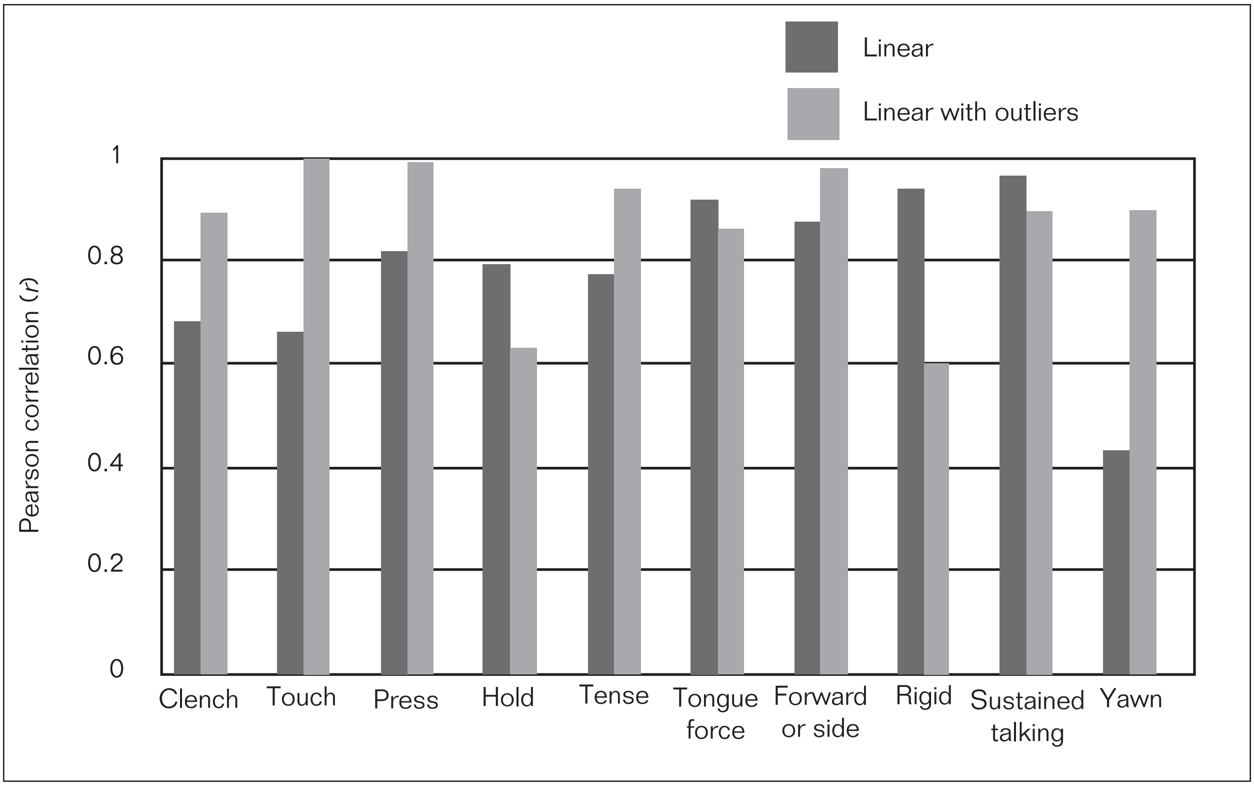

Fig 5 Test-retest reliability of the masseter EMG activity among the 2 different biceps groups during the assessed behaviors. Note the comparably high reliability in each group.

The intertrial reliability of the oral tasks was also evaluated by comparison across the biceps groups, providing an orthogonal assessment for a grouping based not on natural frequency of the oral behaviors among the 2 experimental groups (ie, possible effects of learning and practice) but on capacity for correct performance of an unrelated motor task. The correlations for the masseter muscle are depicted in Fig 5; the results for the temporalis and suprahyoid were similar. Overall, the correlation coefficients were in the same range as those shown for TMD cases versus controls.

OBC data

The reported rates of occurrence for each behavior assessed by the OBC are shown in Fig 6 for cases versus controls. Statistical testing (*t* tests) was undertaken to compare the resultant stated frequencies of each item, and except for the question regarding frequency of talking (How often ... "sustained talking?"), TMD subjects reported performing all other identified behaviors significantly more often than did the control group.

Discussion

The purpose of the present study was to assess, by measurements of EMG activity, the reliability of behavioral performance of oral tasks in relation to the terms that refer to those behaviors. These data provide evidence that the individuals tested, regardless of whether they perform these behaviors seldom or often, had a very concrete understanding of each behavioral concept and were able to execute the same behavior repeatedly in relation to that concept. This "very concrete understanding" is reflected in the levels of behavioral reliability, which were generally comparable to the expected upper limit in reliability set by the reference task. Increased muscle load should be accompanied by consistently increased EMG output,[19–21,24,25] as shown in Fig 1a. Biceps curling is regarded as a common and easily understood task and therefore should exhibit the expected linear relationship between muscle resistance and EMG activity, yet it is clear that subject error is common. Woods and Bigland-Ritchie[21] described multiple theories for this nonlinearity in the EMG activity/force rela-

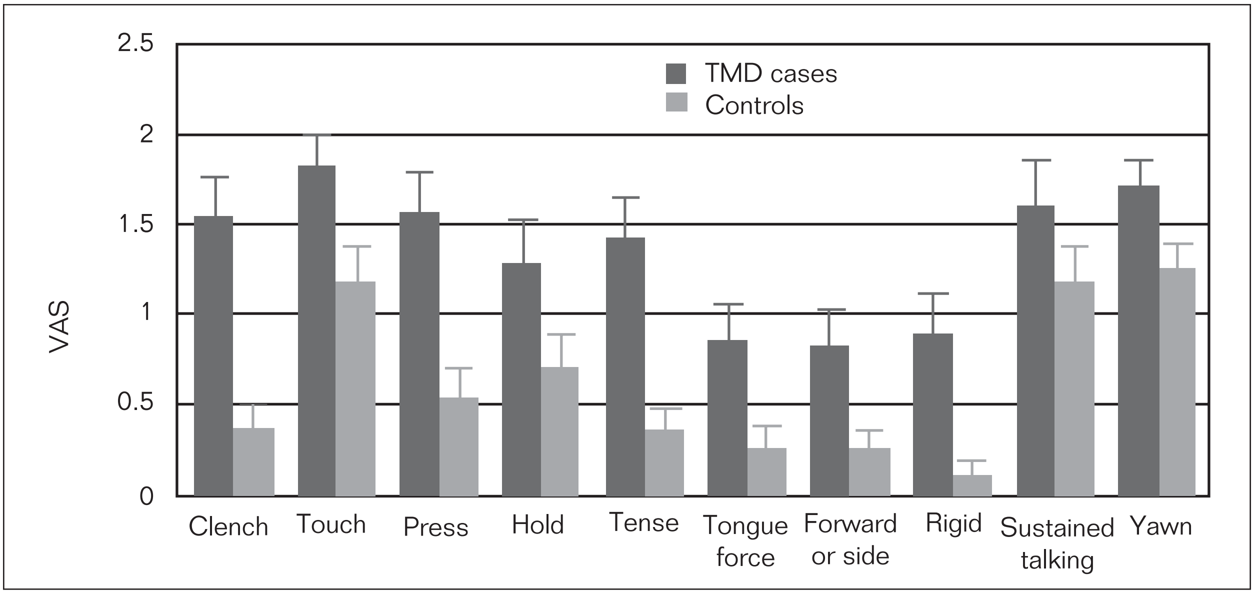

Fig 6 Graphs showing higher self-reported engagement during the day of the tested oral behaviors of TMD subjects when compared with controls during the past month. Possible scores ranged from 0 to 4; bars represent mean and standard error.

tionship, which included the roles of uneven muscle fiber distribution, motor unit potential amplitudes, and "supratetanic motor unit driving." The latter results from variables such as mood, attitude, and expectation, which can be expected to be active in both daily life and during studies assessing muscle function such as this one. Such factors clearly affected some subjects during the biceps task. Our data demonstrate that some subjects, even when performing a well-understood behavior such as biceps curling, can show a surprisingly high variability between trials and between different weights. Although laboratory studies of muscle mechanisms can demonstrate lawful relationships in the mechanics of muscle contraction, those lawful relationships do not constrain what people actually do.[21] Subject performance in the biceps task exemplifies 1 aspect of parafunctional behaviors—behavioral performance of a task in a manner that recruits more motor units than necessary (and is likely accompanied by unnecessary recruitment of other muscles, by inference). We believe that this snapshot of biceps performance exactly parallels the general claim regarding the character of oral parafunctional behaviors. Specifically, Clark et al[10] demonstrated that headache subjects, compared to controls, exhibited greater levels of temporalis EMG activity during chewing and during other functional tasks.

Studies of the effects of experimental stress upon masticatory (or other) muscle behavior often demonstrate an increased level of muscle contraction during the manipulation,[12,13] and a critical review of that literature suggests that the findings are reliable when ecological variables are considered in the experiments.[26] These studies, however, have not identified the actual behaviors that might underlie the observed experimental increases in EMG activity. There is concern that the observed increases in the EMG activity during these experiments were not very large and hence of doubtful importance etiologically for chronic muscle pain,[27] but as this team of investigators has argued previously, the magnitude of the increase may not be the only relevant variable with respect to the possible pathogenesis of these behaviors.[28] Nonclenching behaviors clearly belong to the repertoire of behaviors that subjects might exhibit in experimental psychophysiologic studies but are likely to have lower EMG activity associated with them. The present data indicate why such behaviors might be pathogenic—people with TMD reported engaging in these behaviors at a significantly higher rate than control subjects. Yet, other data have demonstrated that the relationship between measured masticatory EMG activity during sleep and waking symptoms is not so clear,[29] which demonstrates the complexity of these behavioral patterns. These ideas should be further investigated using appropriate study designs.

Subjects showed high reliability during oral behavioral tasks; some outliers can be seen in Fig 3, and Fig 4 shows that, except for the controls in clenching, tensing, and yawning, and the cases in tensing, both groups had a good understanding of the behavioral concomitants of the labels presented to them as tasks. As compared with the upper limits set out by the reference task of biceps curling, the reliability of most of the oral behavioral performances in both groups was good. However, reliability in task performance does not necessarily imply that all subjects had a common understanding of the task—only that each subject in the present study understood the task.

Flor and colleagues demonstrated that both TMD and chronic back pain subjects differ greatly from normal subjects in discriminating muscle tension levels.[30] Subjects were asked to produce different tension levels as a variant of a psychophysical matching task. TMD patients underestimated the required tension levels of the masseter in the lower half of the range and overestimated in the upper half of the range. In contrast, the present subjects were asked to produce a behavior associated with a concept (eg, "clench"), and it appears that the motor recruitment associated with the respective concepts was quite reliable. It is unclear whether the present subjects would have failed in terms of discrimination had they been requested to produce levels of the behavior, like the subjects in the study conducted by Flor and colleagues, but this is a worthy hypothesis to consider. That is, while semantics-related motor recruitment appears reliable, it may be that that reliability is associated with activation of the motor cortex and poorly related to sensory discrimination, as suggested by Flor et al. This would certainly be consistent with clinical observation, wherein teaching biofeedback-based motor control can proceed relatively quickly, but ability to sense proprioception without feedback occurs separately and is often delayed.

While the analytical methodology of Gallo and colleagues[9] would lead to interesting extensions of the present study, their research is perhaps of greater importance due to its heuristic value: by demonstrating specificity of EMG patterning across the behaviors, they have provided strong evidence for differences in how central motor control of the behaviors is organized. We can only speculate that the central control for each of the behaviors observed here, which have clear semantic linkages, might be different; if that is true, then each behavioral pattern may have different meanings in terms of somatic engagement. This speculation is but an extension of the classic response-specificity theory in general psychophysiology,[31] which addresses differential patterning across systems (eg, muscular, autonomic to the heart, autonomic to the skin). With an organ as complex as the oral region in terms of functional development, beginning from birth, it is not unreasonable to suspect that differential patterning of behaviors, all based on muscle activation, might exist and that they may have different linkages emotionally and cognitively; if so, this could explain why trying to change such behaviors might be so difficult. Alternately, for some individuals, these behaviors may be just crude manifestations of a simple activation pathway, such as has been conceptualized as general arousal; in these individuals, behavioral pattern modification can occur relatively easily.

The present study has several limitations. Because these data are correlational, the high consistency in behavioral performance means that each subject did some behavior in the same manner during each of 2 trials in response to a verbal stimulus; however, the actual behavior that an individual performed reliably in response to the directive "please clench," for example, may not necessarily have been what all observers would agree upon as "clenching" in terms of the general behavioral definition of the term. This is an issue of validity, not reliability, and it is the subject for a subsequent paper. An obvious approach to this problem would be to directly observe the behavior, but identifying a method that would do this, without reactive effects due to the measurement itself, is harder than it might appear, and perhaps impossible for adequately distinguishing behaviors such as "holding" versus "touching" the teeth.

A second limitation is that about half of the TMD cases in the study had also received at the time of study participation some behavioral TMD treatment aimed at changing the behavioral patterns; in principle, this could have resulted in greater awareness and hence artificially increased reliability of the oral behaviors in that subgroup. However, the empirical absence of any appreciable difference in behavioral performance between cases and controls would appear to eliminate concern about this limitation. Furthermore, when the task performance involving the biceps is considered, it is clear that the cases and controls did not differ in their ability to operationalize a simple task. Consequently, the authors believe that the 2 study groups were sufficiently similar with respect to critical variables, and that the results associated with a subgroup reporting a prior history of behavioral treatment increase the robustness of the study.

A third limitation is that while the measure used, the self-report data from the OBC, for assessing internal validity suggests that cases compared to controls engage in much higher rates of the studied behaviors, as has been also reported elsewhere,[5,6] the OBC is still in development. It has not yet been established whether it can be used reliably for the self-reported rate of behaviors over a prior month; this is the subject of current studies.

In summary, this study has demonstrated that there are many different oral parafunctional behaviors, each with its own label, and that these labels appear to have ready recognition and understanding in behavioral terms. This study also provides data useful in addressing the contention of whether oral parafunctional behaviors might be related to psychological stress with respect to the possible behaviors that might underlie the EMG measurements in the experimental psychophysiological studies.

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