Modulation of Jaw Muscle Motor Response and Wake-Time Parafunctional Tooth Clenching with Music

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Aims: To evaluate the effects of Guided Music Listening (GML) on masticatory muscles and on the amplitude of wake-time tooth clenching in individuals with higher vs lower frequency of clenching episodes. **Methods:** The electromyographic (EMG) activity of the right masseter was recorded during three 20-minute music (relaxing, stress/tension, and favorite) tasks and a control no-music task in 10 (mean age ± standard deviation [SD] = 21.4 ± 3.0 years) and 11 (22.6 ± 2.9 years) healthy volunteers with higher (HP) vs lower (LP) frequency of tooth-clenching episodes, respectively. EMG episodes greater than 10% of the maximum voluntary contraction (EMG activity of the masseter during tooth clenching) and below 10% (EMG activity during rest) were analyzed. Nonparametric tests were used to assess between-group and within-group (between-task) differences in primary outcome measures. **Results:** In both groups, EMG activity during rest was the greatest during the stress/tension task, and it was the lowest during the favorite task in the LP group and the relaxing task in the HP group (all $P < .001$). In the HP group, the amplitude of clenching episodes was significantly lower during the favorite and stress/tension tasks than during the relaxing task (all $P < .05$), while in the LP group, it was significantly lower during the stress/tension task than during the control task ($P = .001$). The experiment did not affect the frequency or duration of clenching episodes. **Conclusion:** GML modulates masticatory muscle activity. The response to GML depends on the frequency of clenching and the type of music. *J Oral Facial Pain Headache 2018;32:167–177. doi: 10.11607/ofph.1960*

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Temporomandibular disorders (TMD) include a set of pathologic conditions involving the temporomandibular joints (TMJs) and the muscles of mastication. This disorder is known to be associated with facial pain, TMJ clicking, headaches, soreness and fatigue of the masticatory muscles, and masticatory dysfunction[1] and can significantly impair quality of life.[2–4]

The etiology of TMD has been reported to be multifactorial. Known contributing factors include, but are not limited to, trauma, genetics, and anatomical, pathophysiologic, psychosocial, and oral parafunctional behaviors.[5–8] These parafunctional activities, which go beyond physiologic functioning such as chewing, swallowing, and talking,[9] can include gum chewing, tooth clenching, and nail, lip, or cheek biting. These activities are usually harmless, but when their forces and frequency exceed an individual's physiologic structural tolerance, they could lead to jaw muscle overloading and fatigue,[10] a predictor of TMD.[11]

Wake-time tooth clenching has been reported to contribute to TMD pain and be highly frequent in subjects with TMD of muscular origin. A significantly higher frequency of wake-time tooth-clenching episodes has been demonstrated in individuals with TMD pain of the masticatory muscles by both self-reported[7,8] and objective recordings.[12,13] Moreover, experimental tooth clenching has been shown to induce tenderness and soreness in jaw elevator muscles and TMD-like symptoms in healthy subjects.[10,14] Finally, tooth clenching has been reported to lead to tooth wear in both young and adult individuals.[15,16] The contribution of psychological factors to this oral parafunction has been mostly verified,[17] given that the frequency of tooth clenching correlates positively with psychological distress and anxiety.[18–21]

Guided music listening (GML) is based on models of mood mediation and attention modulation and is a highly accepted intervention aimed at reducing pain by modulating stress and anxiety in individuals suffering from chronic pain conditions.[22,23] Listening to music can positively impact the levels of psychological distress and anxiety,[2,24] which are known to be increased in people reporting frequent wake-time tooth-clenching episodes.[13,18–21] In addition, it has been shown that listening to music modulates corticospinal excitability and affects motor nerve response.[25] The effect on the motor cortex is dependent on musical groove, which is a musical quality that can induce movement in a listener.[26] Therefore, music with different tempos and styles may be used to either increase muscle activity or promote muscle relaxation, thus making GML a potential tool for modulating jaw muscle activity in individuals with TMD.

Parafunctional tooth clenching is likely to occur more frequently in individuals with high levels of stress and anxiety and is related to concentration and increased attention and focus.[27] Therefore, it could be conceivable that listening to selected music pieces (that is, those that may be able to reduce stress and anxiety and/or those promoting distraction) could decrease the activity of the masticatory muscles, thereby affecting parafunctional tooth clenching.

This study aimed to evaluate the effects of GML on masticatory muscles and on the amplitude of wake-time tooth clenching in individuals with higher vs lower frequency of clenching episodes. It was hypothesized that GML modulates masticatory muscle activity and that the response to GML depends on the frequency of wake-time clenching; more specifically, since GML is known to reduce stress and anxiety,[22,23] it was hypothesized that the effect of GML on the amplitude of parafunctional tooth clenching would be greater in individuals with a higher frequency of wake-time clenching episodes (as these individuals generally have an anxious personality disposition compared to people with a lower frequency of these activities[17,20]).

Materials and Methods

Study Sample

A total of 92 students at the University of Toronto reporting no pain in the cheeks or temples in the last 30 days were invited to complete the Oral Behavior Checklist (OBC), which includes 21 items assessing self-reported awareness and frequency of waking-state oral parafunctions. The reliability and validity of the OBC in detecting waking-state oral parafunctions have been previously demonstrated.[9,28] The students were asked to report the daily frequency for each oral parafunction listed in the questionnaire by choosing among the following options: none of the time, a little of the time, some of the time, most of the time, and all of the time. Each answer was scored from 0 to 4. The scores corresponding to the OBC items 3, 4, 5, 10, 12, and 13 (ie, grinding teeth together during waking hours; clenching teeth together during waking hours; pressing, touching, or holding teeth together other than eating; biting, chewing, or playing with tongue, cheeks, or lips; holding between the teeth or biting objects such as hair, pipe, pencils, pens, fingers, etc, using chewing gum) were summed into a total OBC6 score and the frequencies were tabulated in order to select two study groups: a high parafunctional (HP; ≥ 80th percentile) group and a low parafunctional (LP; ≤ 20th percentile) group. The rationale for using only these items was that these oral behaviors are characterized by pressing against soft tissues, objects, or teeth, whereas the other constructs included in the OBC do not.[13]

A clinical examination was performed according to the Diagnostic Criteria for TMD (DC/TMD).[29] Exclusion criteria included wearing extended dental fixed prostheses (≥ three teeth); ongoing orthodontic (fixed or removable) or dental treatment; neurologic disorders; habitual intake of drugs affecting the central nervous system (CNS) or the activity of masticatory muscles; current orofacial pain and/or TMD pain; and refusal to participate in the study.

The final study sample included 10 healthy volunteers (8 females, 2 males; mean age ± standard deviation [SD] = 21.4 ± 3.0 years) with OBC6 scores ≥ 80th percentile of the score distribution (OBC6 ≥ 9; mean OBC6 ± SD = 12.4 ± 3.6) in the HP group and 11 healthy volunteers (9 females, 2 males; mean age ± SD = 22.6 ± 2.9 years) with OBC6 scores ≤ 20th percentile (OBC6 ≤ 3; mean OBC6 ± SD = 1.9 ± 0.9) in the LP group.

After recruitment, all subjects were asked to complete the State-Trait Anxiety Inventory[30] (STAI) and the Somatosensory Amplification Scale[31] (SSAS). Trait anxiety is the tendency to report negative emotions such as worries and anxiety.[30] Somatosensory amplification is the tendency to perceive a given somatic sensation (including acoustic stimuli) as intense, noxious, and disturbing.[31] Trait and state anxiety were measured because of their documented effects on jaw muscle activity,[13] while somatosensory amplification was measured because it may account for an altered response to auditory stimuli.

This study was reviewed by the Research Committee at the Faculty of Dentistry, University of Toronto for scientific merit and approved by the Local Research Ethics Board (protocol #33029). Each subject was informed that the aim of the study was to measure the effects of music on the activity of chewing muscles and that they were recruited because they were healthy subjects reporting either a higher or a lower frequency of wake-time tooth-clenching episodes. Informed consent was obtained from all subjects. Participants were compensated with a gift card valued at 50 Canadian dollars after the experiments.

Pressure Pain Thresholds

Pressure pain thresholds[32] (PPTs) were collected to evaluate subjects' sensitivity to pressure stimuli and jaw muscle tenderness, which could affect electromyographic (EMG) recordings, and to check whether the study groups were similar at baseline. A digital algometer (Medoc) equipped with a 1-cm^2 rubber tip was used to measure PPTs before the experimental tasks, as done previously.[13]

The algometer was positioned perpendicular to the skin, and the pressure was increased at a rate of 20 kPa/second by using visual feedback provided by the software. The PPT was defined as the pressure measurement at which the stimulus produced pain.[32] Each subject was able to determine the PPT by pressing a button on a joystick, which stored the current pressure value in the software. All subjects received instructions before the test and were told to keep the jaw muscles relaxed and to not look at the screen. PPTs were assessed by a single examiner (M.S.) who was blinded to the allocation of subjects to groups. All measurements were collected at both trigeminal and extratrigeminal locations (superficial masseter, anterior temporalis, and thenar muscle) on both the right and left sides. For the superficial masseter, the measurements were collected midway between the origin and insertion and 1 cm posterior to its anterior limit; for the anterior temporalis, the measurement site was situated on the line connecting the top edge of the eyebrow to the most cranial point of the pinna of the ear, behind the anterior margin of the muscle as determined by palpation. Finally, measurements were collected on the thenar eminence on the palmar side. The measurements were repeated four times for each muscle with 1-minute intervals between the measurements. The order of trials was randomized. All subjects faced a black panel during the assessments.

Surface Electromyography

A wireless device (BTS TMJoint) was used to record the EMG activity of the right masseter muscle. The probe was placed along a line going from the mandibular angle to the canthus approximately 20 mm above the mandibular angle,[33] and recording was started about 5 minutes later. The weight of the probe was approximately 20 g. The signal was sampled at 1,024 Hz. A hardware filter was used (bandpass 10–500 Hz). Before placing the electrodes (24-mm diameter, Covidien Kendall, Medtronic), the skin was cleaned with a gel (Nuprep, Weaver and Company) to diminish impedance.

Before starting the experimental tasks, subjects were asked to clench as hard as possible and to maintain the same level of force for 3 seconds to record the maximum voluntary contraction (MVC) in intercuspal position. This test was repeated three consecutive times with 5-second intervals. A trial was performed to assess the correct placement of the electrodes before starting the definitive recordings. Finally, each subject was asked to swallow twice and to touch the EMG probe to check whether it was functioning properly. This test lasted approximately 2 minutes.

The EMG signal of the right masseter was recorded over four 20-minute tasks (see experimental protocol) for a total duration of 80 minutes. The raw EMG signals were processed. Root mean square (RMS) values were computed, and the mean RMS value of the three MVC tests was used to calculate EMG activity periods greater than 10% (AP10) of the MVC.[13] All AP10 episodes were identified via a software program (OTBiolab, OT Biolettronica).

Experimental Protocol

The experimental procedures were completed in a silent and temperature-controlled room. Subjects sat with their head unsupported with a natural upright posture. Before the experimental phase, they were asked to switch off their mobile phones. Participants were instructed not to speak to the operator, touch the electrodes, shake their head/shoulders/hands, cross their legs, or chew gum/candies during the whole experimental recording session. They were also informed to avoid coffee and energy drinks for at least 3 hours before taking part in the experiment.

The experimental phase was composed of four tasks (20-minute duration each), during which the EMG activity of the right masseter was recorded while the subject was reading a gossip magazine (control task); listening to a favorite music playlist (ie, the music they usually listen to and like [favorite music task]); listening to harmonic and consonant music with a slow tempo (relaxing music task); and highly dissonant, atonal, and rhythmically unstable music (stress/tension music task) in a random order (Fig 1). Randomization was performed by using a custom-made Java Script. Subjects were also told not to worry about the jaw and only to focus on music or reading.

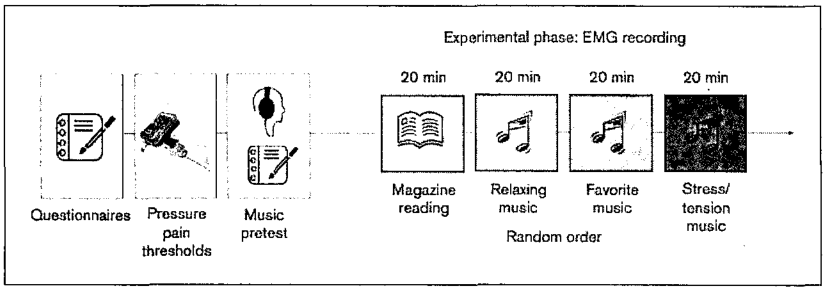

Fig 1 Experimental protocol.

The music playlists to be played during the actual experiment were selected after a music pretest session. After each experimental task, each subject was invited to report the perceived stress/relaxation by using two visual analog scales (VAS) of 0 to 100 mm where the endpoints corresponded to "no stress" and "maximum stress" and to "no relaxation" and "maximum relaxation." They were also asked to rate the music on three VAS (100 mm) in regard to *(1)* physical activation (right endpoint: highly physically activating, left endpoint: not activating at all); *(2)* pleasure intensity (right endpoint: very pleasurable, left endpoint: not pleasurable at all); and *(3)* associations (right endpoint: many memories, pictures, etc triggered by music, left endpoint: no associations at all). These measurements were collected to verify that GML was indeed able to affect relaxation, stress, and mood changes in the research participants. All subjects were asked to use their earphones to have the best listening experience and to avoid discomfort from having new earbuds.

An examiner (M.S.) delivered standardized instructions before each experimental task and monitored the subjects throughout the experiment. This examiner was blinded to the subjects' allocation to groups.

Music Pretest

Before the experimental tasks, three pretest sessions were performed to build the music playlists to be played during the actual experiment. The music volume was set by subjects at the start of the session via a remote control (for both the music pretest and the actual experiment, subjects used their earphones).

For the favorite music pretest session, subjects were asked to bring 20 minutes of their favorite music on their mobile phone. The operator (M.S.) set the music player on shuffle mode. After listening to a 5-minute excerpt from their list, subjects were asked to rate music on three 100-mm VAS in regard to *(1)* physical activation (right endpoint: highly physically activating, left endpoint: not activating at all); *(2)* pleasure intensity (right endpoint: very pleasurable, left endpoint: not pleasurable at all); and *(3)* associations (right endpoint: many memories, pictures, etc, left endpoint: no associations at all). This pretest served to confirm that the music playlist that each subject brought in was indeed the subject's favorite.

During the relaxing music pretest session, the subjects listened to a list preselected by the same experimenter of 12 excerpts (1 minute each) of instrumental music from four different genres (classical, rock, pop, and new age, with three excerpts for each genre) and were asked to rate all of them on a 100-mm VAS (right endpoint: no relaxation, left endpoint: maximum relaxation). An overall score for each music genre was computed by summing the scores of the three music excerpts. The two pieces with the highest ratings within the top-ranked genre served as a model for selection by the experimenter (A.H.) of the relaxing pieces to be played during the actual experiment (relaxing music task). The music playlist to be played during the relaxing music task included pieces with the same genre, similar slow tempo range, and harmonic tonality to those rated by the subjects as the two most relaxing during the pretest.

During the stress/tension music pretest, the subjects listened to 12 excerpts (1 minute each) preselected by the same experimenter characterized by being highly dissonant, atonal, and rhythmically unstable and were asked to rate the excerpts on a 0- to 100-mm VAS on which the endpoints corresponded to no stress and maximum stress, respectively. As in the relaxing music pretest, the music pieces belonged to four different genres (classical, rock, pop, new age) with three excerpts for each genre, and the two pieces with the highest ratings within the top-ranked genre (ie, maximum stress) served as a model for the selection of the stress-inducing pieces to be played during the actual experiment (stress/tension music task).

Hence, during the actual experiment, the subjects listened to their music only in the favorite music task. During the other experimental tasks (relaxing and stress/tension music tasks), the subjects listened to new music; however, this music had been selected according to their genre/style ratings.

Data Analyses

The primary outcome measures of this study were: the EMG amplitude, duration, and frequency of AP10 episodes and the EMG amplitude of the activity of the masseter during rest. Secondary outcome measures

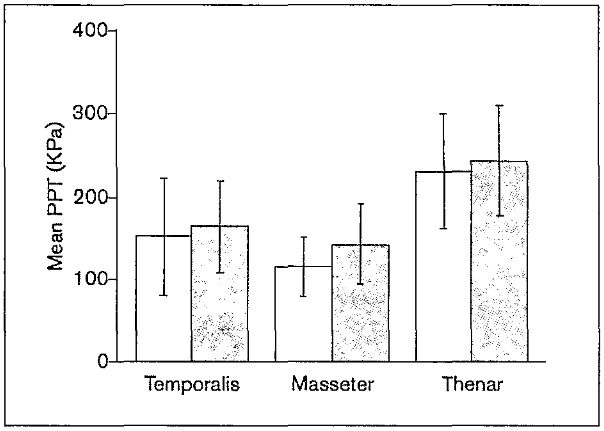

Fig 2 Mean pressure pain threshold (PPT) values (KPa) measured in both groups before the experimental tasks (data pooled from right and left locations). Light gray = low parafunctional group; dark gray = high parafunctional group. The error bars indicate standard deviations.

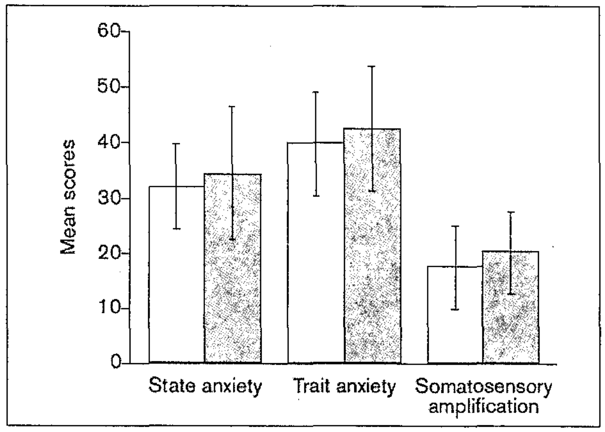

Fig 3 Mean scores for state anxiety, trait anxiety, and somatosensory amplification measured in both groups before the experimental tasks. Light gray = low parafunctional group; dark gray = high parafunctional group. The error bars indicate standard deviations.

were: Psychophysical measurements (STAI, SSAS, and PPTs) and VAS ratings (0 to 100 mm) for relaxation and stress, physical activation, associations, and pleasure intensity during the experimental music tasks. Secondary outcome measures were analyzed to check whether study groups were similar at baseline for psychophysical characteristics, which are known to affect EMG data,[13] and to verify that GML was indeed able to affect relaxation, stress, and mood changes in the subjects.

The mean MVC was computed by averaging the RMS peaks of the three trials performed by the subjects before the experimental tasks. This value was scaled to 100% and was used to normalize the EMG signal throughout the experiment. All EMG data entries greater than 10% MVC were identified and classified as parafunctional activities in the dataset (AP10), while the EMG signals below 10% MVC were used to analyze the activity of the masseter during rest. One investigator (M.S.) continuously monitored the subjects and noted activities that could be sources of EMG artifacts (eg, coughing, scratching, touching electrodes, yawning, talking, etc). These episodes were deleted from the EMG data during postprocessing. AP10 episodes were counted, and the durations of the single episodes were measured. The duration of all AP10 episodes was summed in each task to compute the cumulative duration of AP10 episodes.

Before the effect of GML on the primary outcome measures was analyzed, between-group differences in STAI scores, SSAS, and PPTs were tested with independent sample *t* tests. The mean PPT of the three trials obtained at each PPT location was calculated after the first measurement was discarded. A paired *t* test was used to assess differences between the right and left sides in both the study groups. Since no between-side differences were detected, data were pooled. Also, since PPTs, trait anxiety, and somatosensory amplification did not differ between the study groups, it was decided not to include these variables as potential confounders in the statistical models used to measure the effect of GML on the primary outcome measures.

Kolmogorov-Smirnov and Shapiro-Wilk tests were used to verify the normality of EMG data and VAS ratings collected during the experimental tasks. Nonparametric tests (Kruskal-Wallis and Mann-Whitney) were used to assess between-group and within-group (between-task) differences in primary outcome measures. Multivariate analysis of variance (MANOVA) was used to test the effect of GML on VAS ratings for relaxation and stress, physical activation, associations, and pleasure intensity determined by the experimental music tasks by using transformed data.[34] The Bonferroni method was used to adjust for multiple comparisons.

Statistical significance was set at $P < .05$. SPSS software version 24 (IBM) was used for the statistical analysis. The allocation of subjects to groups was masked in the final dataset; thus, the operator performing the analyses (I.C.) was blinded.

Results

PPTs and Questionnaires

Descriptive statistics and comparisons between groups for PPTs are reported in Fig 2. No significant PPT differences were found for any muscle location (all $P > .05$), and no significant differences between groups were found in STAI or SSAS scores (all $P > .05$, Fig 3).

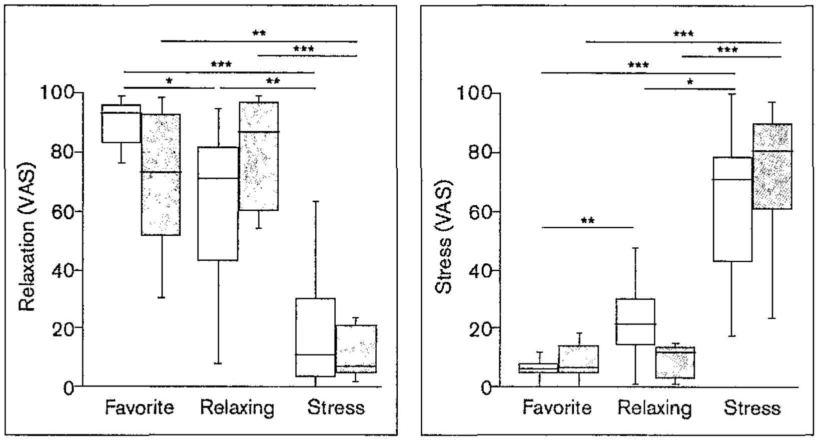

Fig 4 Visual analog scale (VAS) ratings (0 to 100 mm) for relaxation and stress during the experimental music tasks. Light gray = low parafunctional group; dark gray = high parafunctional group. *P < .05. **P < .005. ***P < .001.

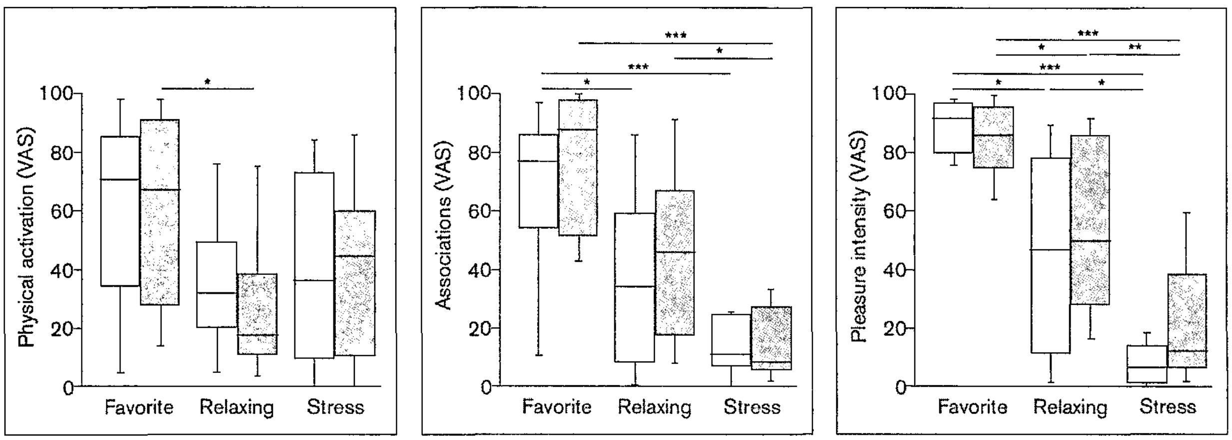

Fig 5 Visual analog scale (VAS) ratings (0 to 100 mm) for physical activation, associations, and pleasure intensity during the experimental music tasks. Light gray = low parafunctional group; dark gray = high parafunctional group. *P < .05. **P < .005. ***P < .001.

Music Selection and VAS Ratings

During the relaxing music task, seven people in the HP group listened to new-age music and three to classical. In the LP group, five people listened to new-age music, four to classical music, and two to pop music. During the stress/tension music task, seven people in the HP group listened to rock music and three to classical music. Eight people in the LP group listened to rock music, two to classical music, and one to new-age music.

The VAS ratings for each of the music tasks differed significantly across the experimental conditions (F [5, 51] = 11.22, P < .001, Wilk's Λ = 0.227, partial η^2 = .520). A significant interaction between group and experimental task was found (F [10, 102] = 2.15, P = .027, Wilk's Λ = 0.682, partial η^2 = .174). Between-group and within-group (between-task) post hoc comparisons are reported in Figs 4 and 5.

For both HP and LP individuals, the levels of stress were greater during the stress/tension music task than during the other music tasks (all P < .05).

In the HP group, the amount of relaxation was greater during the favorite and relaxing tasks than the stress/tension music task (all P < .05). No differences were found between the relaxing and favorite music tasks.

In the LP group, the amount of relaxation was greater during the favorite and relaxing tasks than the stress/tension task (all P < .05). Also, it was greater during the favorite than the relaxing task (P < .05).

In both the HP and LP groups, pleasure intensity was greater during the favorite than the other music tasks (all P < .05). No differences were found between groups.

Physical activation was greater during the favorite music task than the relaxing music task only in the HP group (P < .05). No differences were found between groups. The amount of associations triggered by music were greater during the favorite than the stress/tension music tasks for both groups (all P < .05) and during the relaxing task than the stress task for the HP group (P < .05).

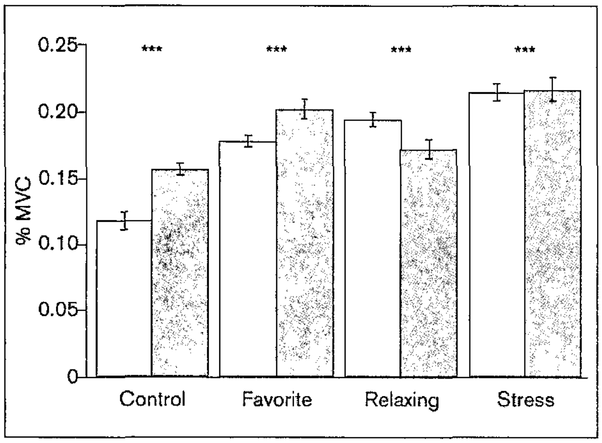

Fig 6 Median electromyographic (EMG) amplitude of masseter activity during rest during the experimental tasks. Error bars indicate 95% confidence intervals. MVC = maximum voluntary contraction; light gray = low parafunctional group; dark gray = high parafunctional group. All within-group (between-task) pairwise comparisons were statistically significant (all ***$P < .001$).

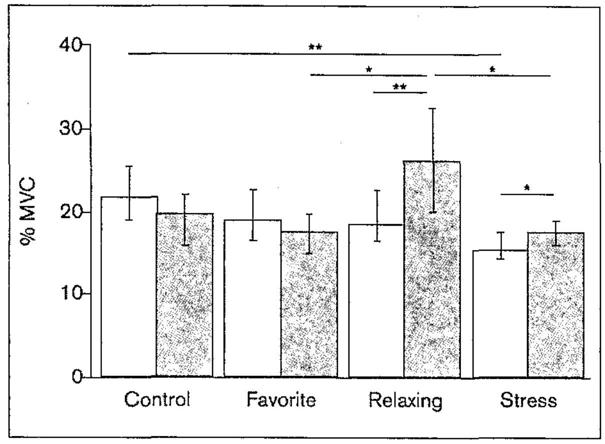

Fig 7 Median electromyographic (EMG) amplitude of AP10 episodes (parafunctional tooth clenching episodes) during the experimental tasks. Error bars indicate 95% confidence intervals. MVC = maximum voluntary contraction; light gray = low parafunctional group; dark gray = high parafunctional group. *$P < .05$. **$P < .005$.

Effect of GML on Muscle Activity

In the HP group, the EMG amplitude of the masseter muscle activity during rest significantly changed across the experimental tasks (χ^2 [3] = 339.01, $P < .001$) and increased from the control task to the stress/tension task (in the ascending order: control, relaxing, favorite, stress/tension; all $P < .001$). This was also the case for the LP group (χ^2 [3] = 363.20, $P < .001$, ascending order: control, favorite, relaxing, stress/tension; all $P < .001$). Between-group and within-group differences are reported in Fig 6. Although these differences were statistically significant, the clinical relevance seems to be limited, as these values were below 1% MVC.

In both the HP and LP groups, the EMG amplitude of AP10 episodes was significantly affected by the experimental task (HP: χ^2 [3] = 12.78, $P = .005$; LP: χ^2 [3] = 14.89, $P = .002$). Between-group and within-group differences are reported in Fig 7. In the HP group, the amplitude of the AP10 episodes was significantly lower in the favorite task as compared to the relaxing task ($P = .007$) and in the stress/tension task as compared to the relaxing task ($P = .013$). The difference was about 7% MVC, which was approximately 25% of the EMG amplitude of the parafunctional clenching episodes measured in the control session. No statistically significant differences between the control (no-music) session and the other music conditions were found in the HP group. In the LP group, stress/tension music induced a statistically significant decrease of the EMG amplitude of AP10 episodes as compared to the control session ($P = .002$). The difference between the conditions amounted to 6% MVC, which was approximately 25% of the EMG amplitude of the parafunctional clenching episodes measured in the control session.

Overall, due to the lack of clinical relevance of the findings regarding EMG activity of the masseter during rest, listening to music had a greater impact on parafunctional tooth clenching than on jaw muscle activity during rest. The count of AP10 episodes, their duration, and their cumulative duration did not differ significantly between groups or between tasks (all $P > .05$, Fig 8).

Discussion

To the best of the authors' knowledge, this is the first attempt to evaluate the effects of listening to music on jaw muscle activity and parafunctional wake-time tooth clenching. For this study, individuals with higher vs lower frequency of oral parafunctions were recruited to test the effect of listening to music on wake-time tooth clenching, a condition that is known to be associated with TMD.[1,7,8,11–13] Subjects reporting orofacial pain and/or TMD were excluded in order to eliminate a confounding variable (ie, pain) that may have affected the EMG measurements and data analyses.[13] Also, it was decided to use 10% MVC as the threshold level to detect parafunctional tooth clenching (as done previously[13,35]), since a contraction of about 5% MVC is sufficient to bring the teeth in contact.[36]

The PPT measurements demonstrated that the study groups were similar at baseline and differed only for the self-reported frequency of oral parafunctional behaviors. The PPT values were within

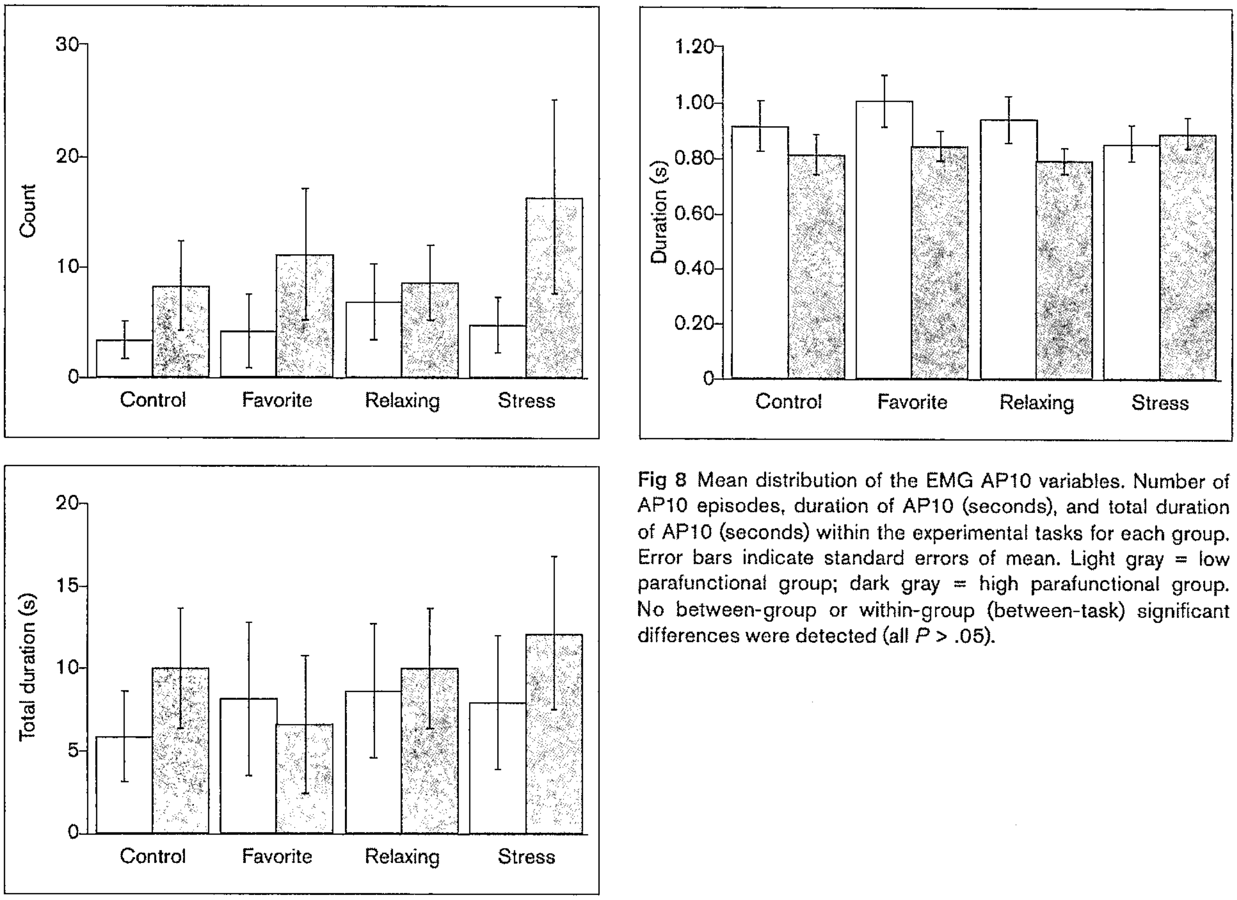

Fig 8 Mean distribution of the EMG AP10 variables. Number of AP10 episodes, duration of AP10 (seconds), and total duration of AP10 (seconds) within the experimental tasks for each group. Error bars indicate standard errors of mean. Light gray = low parafunctional group; dark gray = high parafunctional group. No between-group or within-group (between-task) significant differences were detected (all $P > .05$).

the ranges found in other studies.[13,21,37,38] Contrary to what was expected and to previous findings, the scores for state and trait anxiety did not differ between groups. In a previous investigation,[20] Michelotti et al recruited university students with high vs low frequency of oral parafunctional behaviors and reported that individuals with highly frequent parafunctional events presented greater trait anxiety than subjects with less frequent episodes; however, in contrast to that study, the subjects analyzed in the present study did not present with TMD pain. In a previous investigation,[21] it was found that individuals with high combined scores of trait anxiety and somatosensory amplification had a greater frequency of self-reported oral parafunctions than those with lower combined scores. It is likely that increased trait anxiety is a characteristic of individuals with frequent wake-time clenching episodes and concurrent TMD pain, and that anxious individuals with a heightened bodily hypervigilance have more frequent oral parafunctions.

GML within music therapy interventions has been shown to improve mood in patients with painful disorders and chronic diseases[39] and is effective in reducing preoperative anxiety[40] and psychological distress.[22] The VAS music ratings confirmed that both HP and LP subjects felt more stressed during the stress/tension music task than during other music tasks and that their relaxation was greater during the favorite and relaxing tasks than during the stress/tension task. The LP group found the favorite music more relaxing than the music played during the relaxing task, but in both groups, the pleasure intensity was greater during the favorite music task. Favorite music was also able to trigger more associations and memories than the other music tasks.

The effects of musical rhythms on muscle contraction have been investigated in different experimental settings, and it has been shown that musical rhythm has a strong influence on the human motor system and that music with different tempos can affect muscle response differently. Indeed, listening to music activates motor and premotor cortices[41] and affects corticospinal excitability, thus modulating the contraction pattern of skeletal muscles.[42] Wilson and Davey[42] suggested that rock music modulates corticospinal excitability and disrupts the physiologic correlation in activation between the tibialis anterior and lateral gastrocnemius during foot tapping. This was also confirmed later by Stupacher et al,[26] who demonstrated that motor-evoked potentials recorded from the hand and arm induced by transcranial magnetic stimulation were facilitated with high-groove vs low-groove music and noise. These findings suggest that music and movement are closely intertwined and that rhythmic and pleasant music with a groove may actually facilitate the response of muscles. On the other hand, atonal music may disrupt the functional connectivity between the motor cortex and the muscular system. In agreement with these studies, the present results reveal that GML can modulate motor output in the stomatognathic system and that the musical valence (ie, its pleasantness or unpleasantness[43]) differentially affected the activity of the masseter muscle.

Although the effect of music on the EMG activity of the masseter during rest was found to be statistically significant, it seems to be of very limited clinical relevance (the values were well below 1% MVC). The subjects were not asked to perform specific oral activities during the experimental tasks, and yawning/coughing and other activities that may have altered the signal from the recordings were eliminated from the analysis. Therefore, it is plausible that the EMG data entries were mainly due to muscle tone.

Music increased the EMG amplitude of the masseter during rest in both groups. In the LP group, it was greatest during the stress/tension task (ascending order: control, favorite, relaxing, stress/tension). The effects on the habitual muscle activity in HP individuals were slightly different from those in LP individuals; in HP individuals, it was the greatest during the stress/tension task and lower during the relaxing task than the other music conditions (ascending order: control, relaxing, favorite, stress/tension). The increased EMG amplitude of the masseter activity during rest may be partly ascribed to the increased cortical excitability determined by music.[41,42] On the other hand, the highest EMG amplitude during the stress/tension task may be related to the dissonance of the music pieces played during this task. However, further analyses are needed to evaluate this observation.

The type of music had a great impact on the amplitude of parafunctional tooth clenching in individuals reporting a higher frequency of wake-time clenching episodes. Indeed, in the HP group, the amplitude of the AP10 episodes was lower during the favorite than during the relaxing music task, as well as during the stress/tension task than during the relaxing task. The difference was about 7% MVC, which was approximately 25% of the EMG amplitude of the parafunctional clenching episodes measured in the control no-music session. No statistically significant differences between the control session and the other music conditions were found. This is probably due to the limited time of the experimental tasks (20 minutes) and to the larger variability in the frequency of parafunctional tooth clenching.

In the LP group, stress/tension music induced a statistically significant decrease of the EMG amplitude of AP10 episodes compared to the control session. In this case, the effect is of great clinical relevance, since the difference between the conditions amounts to 6% MVC, which is approximately 25% of the EMG amplitude of the parafunctional clenching episodes measured in the control session.

The current study has revealed that listening to music had almost opposite effects on the masseter EMG activity during rest as compared to during parafunctional tooth clenching. Parafunctional wake-time tooth clenching is a conscious activity associated with psychosocial factors and emotional tension, which could force the subject to a prolonged contraction of masticatory muscles.[17] This is quite different from the EMG activity recorded during rest, which was mainly determined by muscle tone (ie, an involuntary muscle contraction). It is therefore plausible that the effect of listening to music on parafunctional tooth clenching may be due to the effects of music on emotions and cognition. Indeed, pleasant, harmonious, and consonant music (such as that played during the relaxing task) could have promoted concentration and increased attention and focus,[44,45] similar to wake-time clenching, which typically occurs while concentrating.[27] This may explain the high EMG amplitude of AP10 episodes during the relaxing music task. On the contrary, atonal and dissonant rock music, which was mostly played during the stress/tension task, and favorite music, which triggered more memories and was associated with the greatest pleasure intensity, may have favored distraction[44,46] and caused a decrease in the amplitude of AP10 episodes in both groups. While the atonal music played during the stress/tension task had similar effects on the amplitude of parafunctional tooth clenching in both groups, it is likely that relaxing music may be more detrimental to HP individuals, who had greater activity during this task than LP individuals. This finding contrasts with the authors' original expectation; ie, that relaxing music could decrease the activity of masticatory muscles and impact parafunctional tooth clenching. On the other hand, it suggests that music promoting distraction (either atonal stress/tension music or favorite music) is what could be beneficial to the detrimental activity of the jaw muscles.

The possible difference in muscle response to music stimuli between HP and LP individuals may be ascribed to different physiologic mechanisms. It should be noted that during a non-music condition (ie, the control session), the EMG activity of the masseter during rest was greater in HP individuals than in LP individuals, thus suggesting that the muscle was more tense in HP individuals. One possibility is that the muscle response to music is dependent on the basal myoelectric activity, and therefore HP individuals may react differently to music compared to LP individuals. Another possibility is that the perception of musical rhythm is different between HP and LP individuals, and that the music tasks may have affected differently the levels of attentional focus and/or distraction in the two study groups. Further studies are needed to test these hypotheses.

This study had some limitations. First, the assessment of relaxation and perceived stress of subjects during the music tasks was based on self-reports. A more accurate estimate of these mental states could have been performed by measuring cortisol levels before and after each experimental task. Second, it is likely that the duration of the experimental tasks did not allow for sufficient power to detect within-group (between-task) differences in the frequency of AP10 episodes. However, the total duration of the experiment, including the music pretest session and the evaluation of PPTs, amounted to approximately 2.5 hours. Increasing the duration of the experimental tasks could have made subjects extremely tired and may have affected the EMG measurements. Third, the results of the current study cannot be extended to the general population. Indeed, the research subjects were recruited based on the distribution of OBC scores in a sample of young students, who may react differently from others to the music stimuli. Fourth, it might be argued that EMG recordings may be contaminated by artifacts; however, all the experimental conditions were monitored by an operator (M.S.), and all the possible sources of contamination were removed from the EMG signals during postprocessing. Finally, subjects were not blinded to their condition; ie, they completed the OBC and were therefore aware of how often they clenched their teeth during waking time.

Conclusions

This study has revealed that: *(1)* GML modulates motor output in the stomatognathic system; *(2)* listening to music has greater impact on parafunctional tooth clenching than on jaw muscle activity during rest; *(3)* effects on the activity of masticatory muscles are dependent on the type of music; *(4)* motor response to music is dependent on the self-reported frequency of oral parafunctional behaviors; and *(5)* favorite and stress/tension music may have a more beneficial effect on the amplitude of wake-time tooth clenching than relaxing music in HP individuals, while stress/tension–inducing music may be beneficial to LP individuals.

Although this study has shown that music may increase masseter muscle activity during rest to a slight and not clinically relevant extent (less than 1% MVC), the current data suggest that GML may be a potential tool to decrease the intensity of parafunctional tooth-clenching episodes in individuals with awake bruxism, a condition that is frequently associated with TMD. Further studies will be needed to confirm whether this modulation occurs through distraction or other centrally or peripherally mediated mechanisms and to investigate the effects of GML on pain levels and jaw muscle activity in patients with TMD.

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