

SPECIAL TOPICS

EMG Biofeedback as an Experimental Tool for Studying Pain

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Surface electromyography (EMG) biofeedback is commonly used as a treatment modality, but it can also be used as an experimental tool for creating behavioral and psychological states. In this article, the author discusses how surface EMG biofeedback was used to develop an experimental model of temporomandibular disorder (TMD) pain and how the work carried out in his laboratory provided insight into potential etiological mechanisms and treatment modalities for TMD.

Biofeedback as an Experimental Tool for Studying Pain

Temporomandibular disorders (TMD) are a heterogeneous collection of disorders characterized by orofacial pain and/or masticatory dysfunction (Glaros & Glass, 1993). Typically, individuals diagnosed with TMD report pain in the temporomandibular joint, in the masticatory muscles, or in the region just in front of the ear (the preauricular area). A smaller proportion of patients may report clicking or popping noises when they move their jaws, and occasionally, some will have difficulty opening or closing their jaws normally. Many TMD patients report secondary symptoms such as headache, other facial pain, earache, dizziness, ringing in the ears, or pain in the neck, shoulder, or back. Given the constellation of symptoms, many TMD patients seek care from both dentists and physicians. In a tertiary care facial pain clinic affiliated with a dental school, patients typically visited at least 3 other providers before coming to the dental school for care (Glaros, Glass, & Hayden, 1995); a large proportion of these patients had consulted physicians. Many of these patients had received multiple diagnostic procedures for their complaints, including computed tomography and magnetic resonance imaging scans.

My personal work with these patients began in the clinic. The clinic had educational responsibilities but not a great deal of space to accommodate the large number of students who observed in the clinic during a semester. As a result, we mounted cameras in each of the examination rooms and had students watching patient interactions in a separate location. When I talked to the students afterward, they frequently

commented that the patients seemed to do a lot of clenching. (It's fairly easy to observe clenching in others. When an individual clenches, the belly of the temporalis and masseter muscles will bulge in the temples and jaw, respectively. To locate the position of these muscles, place your hands on the side of your face and bite down hard. You should feel both muscles on each side of the face. If you then remove your hands and bite again, you'll be able to see both muscles quite clearly.) Their observations confirmed my own, and I decided to investigate the issue further.

The literature then available contained several studies on the effects of maximum bite force on pain (Christensen, 1981a). These studies asked individuals to bite down for as hard and as long as possible. The pain produced by such maximal bite forces can be significant (Christensen, 1978; Waltimo & Kononen, 1993) but is generally short lived (Christensen, 1971, 1978, 1979, 1981b; Clark, Adler, & Lee, 1991). Maximal bite force can be maintained for only slightly more than 2 minutes time (Lyon, Rouse, & Baxendale, 1993), whereas experimental clenching at somewhat less than maximal levels or continuous chewing produces fatigue in about 5 to 8 minutes (Buzinelli & Berzin, 2001; Christensen, 1981a). If you carefully ask TMD patients about their clenching, they will tell you they clench for extended periods of time. In one study, for example, TMD patients with joint and muscle pain reported tooth contact, a behavioral measure of clenching, for 73% of a day (Glaros, Williams, Lausten, & Friesen, 2005). It was thus unlikely that clenching in TMD patients involved maximal force for long periods of time.

My students and I therefore decided to examine an alternative hypothesis: that sustained low-level clenching could produce TMD pain. In the first study of this series (Glaros, Tabacchi, & Glass, 1998), we recruited participants for a 6-week study. We used an A-B-A design. In the first and third (decrease) phases, participants were instructed to decrease the activity of their masticatory muscles to less than 2.0 μ V using conventional biofeedback techniques. In the second (increase) phase, participants were instructed to maintain the activity of these muscles to greater than 10.0

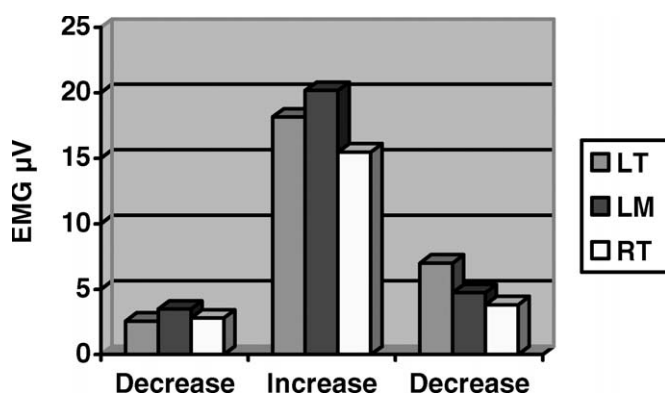


Figure 1. Electromyography activity (μV RMS) for three training phases. LT = left temporalis, LM = left masseter, RT = right temporalis. Figure adapted from Glaros, et al. (1998).

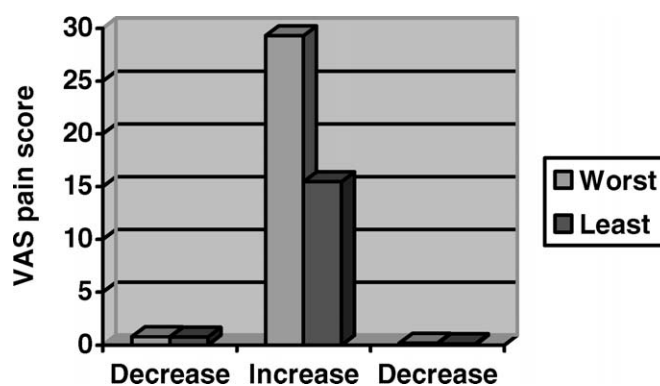


Figure 2. Self-reported pain rating at the end of the training sessions. Worst = worst pain reported during training session, Least = least pain reported during training session. Figure adapted from Glaros, et al. (1998).

μV . To obtain electromyography (EMG) values less than $2.0 \mu\text{V}$, participants were instructed to relax their chewing muscles and allow their teeth to separate; for $10.0 \mu\text{V}$, participants were told to clench lightly.

We monitored the activity of the left and right temporalis and masseter muscles. The training sessions were 17 minutes long, and we conducted training 5 days per week. During training, participants could view a computer screen showing the activity in all four sites. When they were successful in reducing or increasing each monitored site below or above the threshold as instructed, they received additional feedback in the form of a tone that chimed periodically. A blinded investigator carried out a screening examination based on the research diagnostic criteria for TMD (Dworkin & LeResche, 1992) at the end of every week.

Our participants were three women and two men ranging in age from 23 to 29 years. They reported no prior facial pain problem, chronic headaches, other painful condition, or the use of a mouth guard (also known as a splint or interocclusal appliance) prior to participation in the study. Mouth guards are among the most commonly used dental treatments for TMD (Glass, Glaros, & McGlynn, 1993). According to the screening examination, no participant received a diagnosis of TMD before the study began.

Two participants were diagnosed with TMD pain during increase training. Reports of facial pain increased significantly during increase training, and the pain typically resolved within 24 hours, but not for the two participants diagnosed with TMD. Figure 1 shows the EMG values we recorded during the three phases, and Figure 2 shows self-reported pain. One of the EMG channels failed midway through the study. Only the three channels with complete data are included in Figure 1.

We repeated this study several times, once using a crossover design (Glaros, Baharloo, & Glass, 1998) and

multiple times as a randomized, between-groups design (e.g., Glaros & Burton, 2004). In each study, the participants were individuals with no history of TMD, no current evidence of TMD according to a screening examination, and no other chronic pain problem. The training sessions were 20 minutes long, and participants in these subsequent studies performed their experimental task for a total of 2 weeks in the crossover study or 1 week in the randomized, between-groups study. Screening examinations were carried out by a blinded examiner.

Each of these studies reported significant increases in facial pain during increase training. No participant in the decrease phase or group was diagnosed with a TMD pain problem. Overall, 28% of the individuals in increase phases or groups received a diagnosis of painful TMD (technically, myofascial pain and/or arthralgia, according to the research diagnostic criteria). The correlations between EMG activity and pain ranged from $+0.44$ to $+0.80$.

For many members of the Association for Applied Psychophysiology and Biofeedback, a finding that tooth contact/clenching is associated with pain will not be surprising. In contrast, the classical dental view of TMD is that it is caused by ill-fitting teeth (also known as malocclusion). Although the evidence for this perspective is weak (Clark, Tsukiyama, Baba, & Watanabe, 1999), the viewpoint has a vocal, strongly committed group of proponents.

We have carried out other studies examining the rates of tooth contact/clenching in various groups of TMD patients and have shown that those with pain report the highest levels of clenching (Glaros et al., 2005). Treatment studies using habit reversal show significant reductions in TMD pain (Gramling et al., 1996), and we have also shown that the reduction in tooth contact is associated with the reduction in pain, even when dental splints are the primary treatment modality (Glaros, Owais, & Lausten, 2007). In

short, this series of studies raises serious doubts about the role of occlusion in TMD pain and strongly points to tooth contact/clenching as an important mechanism in the onset and maintenance of TMD pain.

The series of clenching studies also illustrates the importance of EMG biofeedback in developing this experimental model of pain. In these studies, we used EMG data as a proxy for clenching behavior. We used EMG data as evidence that individuals were relaxing the masticatory muscles and as evidence that individuals were making tooth contact. In other words, we had clear criteria for determining whether a research participant was actually performing the behavior we requested. Occasionally, a participant failed to maintain the 10.0- μ V levels we requested during the increase trials. When that happened, we could confidently exclude the participant's data on the grounds that she or he failed to follow experimental instructions. The use of EMG biofeedback increased the overall quality of the studies by eliminating outliers whose data could have had a negative effect on the results. Biofeedback data can be a wonderful tool for monitoring adherence to experimental instructions.

Andrew Crider, Richard Gevirtz, and I have published reviews and chapters examining the utility of EMG biofeedback as a treatment modality (Crider, Glaros, & Gevirtz, 2005). Because the number of randomized trials is small, we cannot give EMG biofeedback the strongest possible recommendation as a treatment for TMD. Certainly, the data from my laboratory provide an empirical foundation for believing that EMG biofeedback would be an effective treatment modality for TMD.

It may also be possible to use EMG biofeedback in a highly abbreviated form as a treatment mechanism. TMD patients, especially those with muscle pain, may not be particularly aware of their own clenching (Glaros, 1996). They may be, in other words, blind to this behavior and to the proportion of time they spend clenching. A therapeutic effect on these patients might be possible if we can enhance their awareness of this behavior and supplement this awareness with simple techniques for reducing tooth contact.

One mechanism for doing this is to show patients what happens when they relax their masticatory muscles and how the activity of these muscles changes when they bring their teeth together. The act of making tooth contact typically increases temporalis EMG activity 2.5 to 3.0 times over a relaxed baseline and increases masseter activity by about 1.5-fold (Roark, Glaros, & O'Mahony, 2003). When viewed on a suitably configured feedback screen, the change in EMG activity can be very informative and a significant motivator to patients. In a small, randomized, pilot trial,

we used a similar approach, coupled with simple relaxation techniques and frequent monitoring of tooth contact. Other participants received dental splints. Both groups reported significant reductions in pain, and both were equivalent in pain reduction (Glaros, Lausten, Kim, & Horrigan, 2003). The biofeedback intervention in this study was very short but was coupled with techniques that assisted patients in learning how to alter their behaviors.

Our common view of EMG biofeedback is that it's often a treatment modality. The studies carried out in my laboratory show that EMG biofeedback can also be a very effective experimental tool for generating desired behavioral and psychological states.

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