Journal of Electromyography and Kinesiology 25 (2015) 653–657

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Activation time analysis and electromyographic fatigue in patients with temporomandibular disorders during clenching

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ARTICLE INFO

Article history:
Received 15 July 2014
Received in revised form 14 April 2015
Accepted 15 April 2015

Keywords:
Temporomandibular joint dysfunction syndrome
Electromyography
Masticatory muscles
Fatigue

ABSTRACT

Introduction: The use of surface electromyography (SEMG) is controversial in the diagnosis and subsequent treatment of temporomandibular disorders (TMD), although there is some evidence that the pattern of the masticatory muscles in TMD patients differs from controls. The aim of this study was to compare relative time of mandibular elevator muscle activation at different levels of activity and median frequency (MF) during sustained clenching. *Methods*: Twenty-two women, aged between 18 and 48 years, volunteered to participate in the study. The TMD group had 14 participants diagnosed as group Ia muscle disorders (RDC/TMD). The control group had eight healthy individuals. SEMG records were obtained from masseter and temporal muscles during 10 s of sustained clenching. Normalized SEMG amplitudes were classified as minimal, moderate and maximal and time of activation in each level of activity was calculated and compared using two-way ANOVA (groups versus time). A slope of the linear regression line that fits MF values over time was calculated as a fatigue index for elevator muscles. *Results*: Only the temporal muscles of the TMD group showed longer activation time at moderate and minimal activity levels compared to controls. Fatigue indexes were greater for the TMD group compared to controls. *Conclusion*: Results showed motor control strategies during sustained clenching that differentiate controls from TMD patients.

1. Introduction

Temporomandibular disorder (TMD) is a complex, chronic and recurrent painful musculoskeletal disorder that involves the temporomandibular joint and associated structures, such as the soft tissues around it (Okeson and Franco, 1998; Dworkin and LeResche, 1992). The current gold standard for the diagnosis of TMD is still a combination of anamnesis and clinical examination (Dworkin and LeResche, 1992; Chaves et al., 2008b,a) and, when appropriate, radiographic evaluation (Schiffman et al., 2010; 2014). Its etiology is multifactorial and probably due to muscular hyperfunction, parafunctional habits, traumatic injury, hormonal influence or internal joint derangement (Tartaglia et al., 2011; Suvinen and Kemppainen, 2007; Liu and Steinkeler, 2013).

As the stomatognathic system of TMD patients is dysfunctional, the muscular activity of such individuals may present differences in comparison to healthy individuals (Tartaglia et al., 2011). A painful muscle may present reduced electromyographic activity and reduced motor unit discharge rates in dynamic contractions (Murray and Peck, 2007). This reduction is due to changes in the agonist–antagonist activation pattern of masticatory muscles. Differences in affected muscles between control and TMD individuals become more evident when maximum clenching effort is required (Ardizone et al., 2010).

The recruitment of a motor unit results in the generation of several action potentials with extent, shape and frequency characteristics. Over the time needed to establish electromyographic fatigue, such as in sustained clenching, changes in muscle sarcolemma permeability occur with consequent reduction in muscle fiber conduction velocity and increase in recruitment of motor units. These changes are detected by SEMG in raw signal power spectral density analysis and interpreted as signs of fatigue (De Luca, 1997).

Thus, studies show that the functional changes reported by TMD patients are related to changes in muscle activity, such as hyperactivity and fatigue (Tartaglia et al., 2011; Santana-Mora et al., 2009) and surface electromyography (SEMG) could contribute to the diagnosis of TMD. However, the diagnostic role of SEMG is extensively questioned in the literature (Klasser and Okeson, 2006).

A pilot study proposed the evaluation of the duty factor, i.e., masseter and temporal muscle activation time over subject-specific thresholds for muscle activity per 20 N bite-force during sleep-

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http://dx.doi.org/10.1016/j.jelekin.2015.04.010
1050-6411/

wake cycles. Eleven individuals with bruxism were classified into three groups. All myoelectric activities of the masseter and temporal muscles above the threshold were recorded for three consecutive nights with the use of portable electromyographic devices. No statistically significant difference was found for comparison of duty factor variable values among the groups in this study. However, it was established that it would be necessary to include at least seven volunteers in each group of the study to reach conclusions based on an appropriate sample size ($\alpha = 0.05$, $\beta = 0.80$) (Nickel et al., 2011). Therefore, duty factor is the relative duration of myoelectric activation above or below a predetermined threshold of the electromyographic record and may represent the motor strategy adopted during a contraction.

The presence of chronic and recurrent pain in TMD patients was previously related to changes in masticatory myoelectric patterns and habitual jaw position (Ries and Bérzin, 2008; Tartaglia et al., 2008; Peck et al., 2008; Murray and Peck, 2007). However, it is unclear whether, during clenching in TMD patients, there is a strategy to control muscle activation time by which the system partially reduces activated time to moderate and relatively lower levels of muscle activity while attempting to maintain a sustained contraction.

Thus, this study aimed to compare the relative activation time of jaw elevator muscles of controls and TMD patients at different levels of myoelectric amplitude in relation to the maximum bite force during clenching maintenance. As a secondary objective, the median frequency (MF) was also described and compared among these groups. The hypothesis of the study was that TMD volunteers would have a higher percentage of activation time than control volunteers in levels classified as relatively low amplitude due to the agonist inhibition described in the pain-adaptation model (Peck et al., 2008). It was also hypothesized that the MF of the electromyographic signal for muscles of the TMD group would present higher reduction of contractions over time in comparison to the control group, since the muscles affected by the disorder are more prone to fatigue (Tartaglia et al., 2011; Santana-Mora et al., 2009).

2. Method

2.1. Volunteers

This study was approved by the Research Ethics Committee of the Clinic Hospital of the Ribeirão Preto Medical School of the University of São Paulo, Brazil (Process HCRP number 12979/2011) in accordance with resolution 196/96 CNS/MS. All participants, who were between 18 and 48 years old, freely agreed to participate and signed the Free and Informed Consent form.

The recruitment of TMD-free control group volunteers was carried out through verbal invitation to participate among university students. Inclusion criteria for the control group were no RDC/TMD diagnosis, normal occlusion (Angle class I, normal overjet and overbite, absence of cross-bite), and no periodontal disease, tooth pain, extensive caries, or dental mobility.

The volunteers for the TMD group were recruited from a dental care service of the public oral health system who had been diagnosed with orofacial pain. They were contacted by telephone and asked to answer questions regarding the exclusion criteria. Those who reported meeting the eligibility criteria and agreed to participate in a physical examination for inclusion attended the research setting to confirm whether they: (1) met the research diagnostic criteria for TMD (RDC/TMD) (Dworkin and LeResche, 1992) Axis I diagnosis only for Group Ia muscle disorders (no multiple-diagnosis); and (2) had experienced masticatory muscle pain for more than six months.

The following were the exclusion criteria for both control and TMD groups: use of muscle relaxant medications or antidepressants; reports of other comorbidities, such as frequent headaches or neck pain; presence of Angle's Class III malocclusion, missing teeth, dental implants, removable prosthetics or braces; history of facial and temporomandibular joint trauma or dislocation in the course of dental treatment. An experienced dental surgeon checked inclusion and exclusion criteria for both groups.

Eight women volunteers (24.7 ± 3.5 years old) were included in the control group. Seventeen women from the public oral health system showed up for the physical exam. Three volunteers were excluded for multiple RDC/TMD diagnoses after conclusion of the physical examination. Thus, 14 women (28.5 ± 8.6 years) were included in the TMD group. Pain intensity related on visual analogue scale of pain, during RDC/TMD muscle palpation protocol, was severe. The Interpretation of EVN is according to the value suitable for the person, where no pain (0), mild pain (1–3), moderate pain (4–6) and severe pain (7–10) (MacCaffery and Beebe, 1989).

2.2. Electromyography and bite force

SEMG signals were collected using surface differential electrodes (two Ag–AgCl bars, $10 \times 2 \times 1$ mm, with 10 mm interelectrode distance, gain of 20, input impedance of 10 GΩ and common mode rejection ratio of 130 dB). The electrodes were placed over clean skin with 70% alcohol. Sensor bars were placed parallel to the muscle fibers of the temporal and masseter muscles, bilaterally (Rodrigues et al., 2005). A 3 cm^2 stainless steel reference electrode (Bio-Logic Systems Corp., Mundelein, Illinois, USA) was also used, located in the manubriosternal region, with the function of reducing the effect of electromagnetic interference and other acquisition noises in the electromyographic signal.

EMG signals were sampled by a 12 bit A/D converter board of dynamic resolution, bandwidth -10 V to +10 V, and band-pass filtered at 10 Hz to 5 Hz. The sampling rate per channel was 2 kHz. MyosystemBr1 version 3.5.4 software (DataHominis® Tecnologia Ltda, Uberlândia, Minas Gerais, Brazil) was used for viewing and processing. SEMG signals were digitally filtered with a 20–500 Hz band-pass.

Maximum bite force was obtained with a model IDDK digital dynamometer (Kratos®, Cotia, São Paulo, Brazil) with a capacity of up to 100 kgf and two stems (each bar with 6 mm, separated by 3 mm) protected by Teflon™ disks adapted to oral conditions where the bite force is applied.

2.3. Procedure

Volunteers remained seated with their upper back resting against a backrest, feet flat on the floor, and arms lying on the armrests. They were verbally instructed to keep looking at the horizon (Tôrres et al., 2006).

The dynamometer bars were placed between the first molars of the preferred side of mastication to measure peak forces during a 5-s maximum clenching; three trials were made. EMG signals were recorded simultaneously during the clenching contraction. A two-minute resting interval between peak force records was allowed.

Three electromyographic records of clenching sustained for 10 s were conducted (MyosystemBr1, DataHominis®, Uberlândia, Minas Gerais, Brazil) against Parafilm M® (BRAND GMBH Wertheim, Germany) between the premolars, and upper and lower primary and second molars on both sides. The individuals were verbally encouraged to exert maximum effort. A three-minute resting period between the contractions was allowed. The captured signal was saved on a hard drive for future analysis and processing.