RESEARCH ON FATIGUE IN FACIAL AND JAW MUSCLES: REVIEW OF THE LITERATURE

Pesquisa da fadiga nos músculos faciais e mastigatórios: revisão de literatura

Angela Ruviaro Busanello-Stella [1], Ana Maria Toniolo da Silva [2], Eliane Corrêa [3]

ABSTRACT

The purpose of this study was to deepen the knowledge about muscle fatigue of masticatory and facial muscles through analysis of scientific literature. The search strategy was based on the statements of the Cochrane Library. Articles were selected through the PubMed database, using the descriptor "muscle fatigue" in conjunction with the following descriptors: "speech therapy", "facial muscles", "jaw muscles", "mastication", "chewing" , "lip" and "clenching". Articles from the last ten years were included, regardless of the language. The texts were analyzed, at first, in its abstract and those that did not fit the study`s objective were excluded. Then, the full texts were analyzed, being considered: aim, study design, control and study groups, criteria and methodological rigor, applied protocols, results and discussion about the presence of fatigue in the targeted muscles. In a last stage, studies that were not in accordance with the purpose of the study, were excluded. Thus, out of 138 articles found, 54 were excluded due to the repetition by crossing key-words and 84 were analyzed. In the abstract analysis, 46 were excluded and 38 were fully analyzed. 24 articles were maintained and 14 were excluded because they do not fit the study`s criteria. Despite there are some studies regarding the analysis of fatigue, their methodology is very varied, making difficult the comparison and detailing. While some studies have found, for example, greater fatigue of the masseter and orbicularis oris muscles, others have not found the same results, which may have influenced the target population for each study.

KEYWORDS: Muscle Fatigue; Facial Muscles; Masticatory Muscles

INTRODUCTION

Muscle fatigue is defined by the incapability of the musculature to maintain high levels of force in time[1]. It happens due to the accumulation of substrate, such as lactic acid, within the muscle cells, which interferes on the concentration of intracellular pH and, consequently, in the conduction of the action potentials necessary for the activation of muscles [2]. It may be considered a natural muscle-defense process [2-5] which activates prior to the occurrence of any damages to the organic and cellular levels [6].

Its occurrence will depend on the type, length and intensity of the exercise; on the typology of the recruited muscle fibers; on the level of training of the individual and on the environmental conditions for the performance of the exercise [7]. In addition, the study of muscle fatigue may show limitations due to its multifactorial nature and complexity [6].

The investigation about this mechanism in facial and jaw muscles has drawn the attention of researchers in the field of health, who carry out studies in humans, with and without alterations, and in animals. In relation to Speech Therapy, knowing how muscle fatigue occurs in specific diseases such as temporomandibular disorders (TMD) [8,9], sleep apnea [10], degenerative diseases [11] and mouth breathing, for instance, appears to be an important

(1) Post-graduation Program in Human Communication Disorders at Universidade Federal de Santa Maria – UFSM, Santa Maria, RS, Brazil.

(2) Speech Therapy Degree and the Post-graduation in Human Communication Disorders at Universidade Federal de Santa Maria, UFSM, Santa Maria, RS, Brazil.

(3) Physical Therapy Department and Post-graduation Program in Human Communication Disorders at Universidade Federal de Santa Maria – UFSM, Santa Maria, RS, Brazil.

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parameter for therapeutic procedures. Nevertheless, the protocols of these studies are rather divergent, what may hamper the comparisons among them.

Thus, this study aims at deepening the knowledge in relation to muscle fatigue of facial and masticatory muscles through the analysis of scientific literature.

METHODS

basis to define the steps of the study [12]. The first step was to formulate the study problem; the second to locate and select the studies from the database; and the third to assess the studies found in a critical way.

Works referring to the past ten years, regardless the language, were selected in the Pubmed database. The descriptor "*muscle fatigue*" was put together with the following descriptors: "*speech therapy*", "*facial muscles*", "*jaw muscles*", "*mastication*", "*chewing*", "*lip*" and "*clenching*".

Along this step, 138 works were found, as illustrated in Table 1.

Table 1 - Distribution of the articles found in the Pubmed database, the first stage of the study, as the intersection of the descriptors

Key-words	Number of articles found
"muscle fatigue" and "speech therapy"	12
"muscle fatigue" and "facial muscles"	23
"muscle fatigue" and "jaw muscles"	34
"muscle fatigue" and "mastication"	19
"muscle fatigue" and "chewing"	29
"muscle fatigue" and "lip"	8
"muscle fatigue" and "clenching"	13
Total articles	**138**

In this step the works which repeated in the crosschecking of the descriptors were excluded. Subsequently, the analysis of *abstracts* was carried out and those that did not present the use of fatigue protocols in relation to facial and/or jaw muscles were also excluded. Finally, the works selected were fully read and underwent analysis of the following aspects: objective, study design, formation of control and study groups, criteria and methodological strictness, applied protocols, results found and discussion about fatigue in the muscles concerned. In this last step, those that were not in accordance with the purpose of this study were excluded. These steps are illustrated in Figure 1.

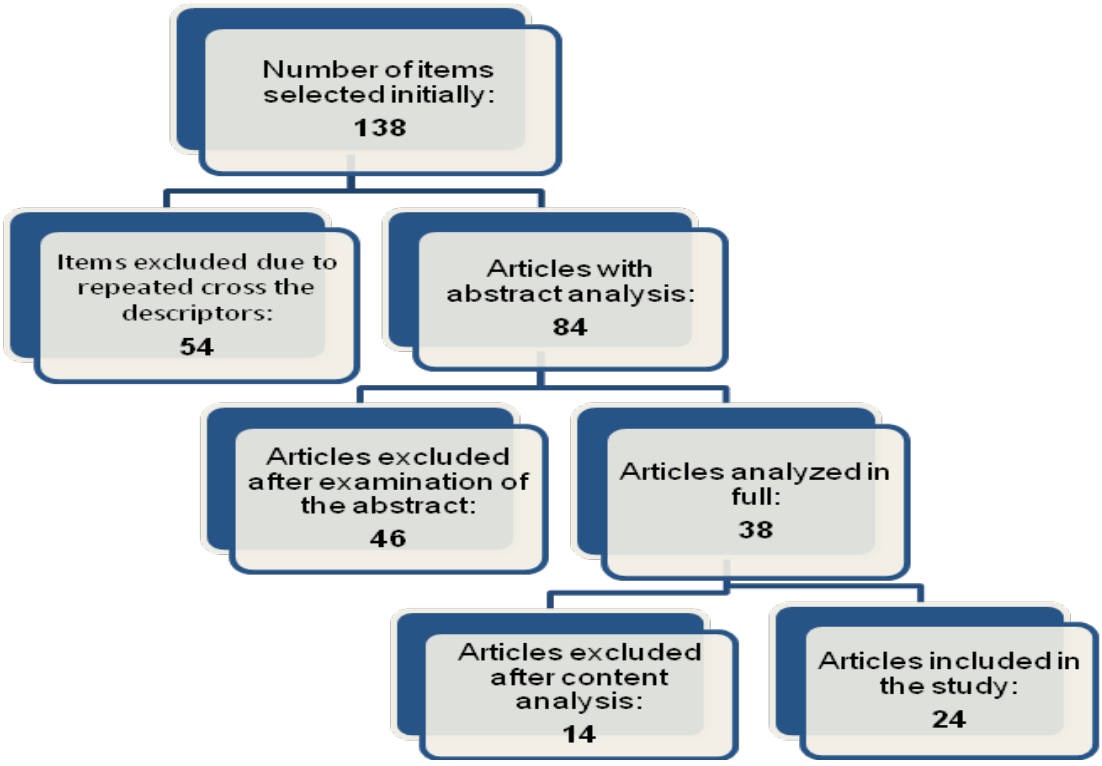

Figure 1 - Number of selected items throughout the stages of the study

REVIEW LITERATURE

From the 38 works that were fully analyzed, 14 were excluded for their content did not match with the criteria previously described, and 24 were included in the final step. The textual reasons that excluded these 14 studies were:

- fatigue was not considered the objective of the study but a symptom indirect to other diseases;
- the muscles studied were not specified (e.g.: masseter, temporalis, orbicularis oris, orbicularis oculi, among others) or did not refer to the facial and jaw muscles;
- important methodological aspects did not present a detailed description such as selection, subjects, criteria for group formation and procedure for muscle fatigue evaluation.

The studies were subsequently organized into two parts: studies developed with humans and experimental research (with animals). Within each session, the works were presented by the relevance of their topics.

Research on fatigue in facial and jaw muscles in humans

A study regarding thickness, tolerance and induction of pain of the masseter was carried out in 2003 with individuals with different types of craniofacial morphology [13]. Thirty young adults at average ages between 23 and 25 years old were divided into two groups: short faced individuals and normal-long faced individuals according to Ricketts analysis [14]. The variables analyzed were: (a) thickness of right masseter; (b) outset and tolerance to pain and; (c) report of pain and fatigue. Thickness was measured once through ultrasound and the other variables were measured after gum mastication for 10 minutes at four times (immediately after, five minutes after, ten minutes after and 24 hours after mastication ended). The researchers observed that individuals with short faces had greater thickness in the masseter, whereas individuals with normal to long faces had greater tolerance and outset of pain. They reported the Mechanical Advantage Theory as a plausible justification for the differences observed, where the individuals with longer faces would have less mechanical advantage in jaw elevator muscles. Therefore, individuals with short faces would have greater occlusal force and, consequently, greater intramuscular pressure, which may limit the blood flow through the muscles, something that is necessary for the maintenance of force.

It is believed that the findings of these researchers match the literature bases although the gum, which was used as food in this study, may have influenced the results.

A study [15] aiming to examine the effects of muscle fatigue on the short latency reflex of the jaw was carried out with healthy men and women, with and without induction of muscle pain with hypertonic saline solution (HS). According to the researchers, the administration of intramuscular substances, especially HS, causes similar effects of pain observed in individuals with TMD and, for this reason, it becomes a useful way of studying the interaction between the dysfunction, pain and motor control. Fifteen men and thirteen women at average of 24 years old conducted a protocol of induction of muscle fatigue (mastication of chewing gum for six minutes), followed by the injection of HS and isotonic saline (IS) in the left masseter, with an interval of 45 minutes between them. Reports of pain and fatigue by degree scales as well as the amplitude of the electromyographic signal of the masseter and anterior temporalis muscles, right and left sides, were analyzed in three situations (prior to, immediately after and 15 minutes after administration of HS). In this case, the amplitude of the electromyographic signal was used for the analysis of the jaw jerk reflex. Although researchers observed that there was an increase in the amplitude of the signal after the fatigue protocol followed by HS, there was no statistical significance. The only difference observed was between sexes in relation to reflex triggering which, according to the authors, may have occurred due to the difference between the muscle structure of men and women.

Another study was developed in a similar way about the administration of intramuscular substances to induce pain [16]. The research considered the effect of muscle fatigue induced by low-level isometric contraction and subsequent muscle pain triggered by the administration of glutamate on the response of exteroceptive suppression and the electromyographic activity at rest in healthy humans in order to investigate whether the glutamate would act specifically on the condition of fatigue. In this study, the masseters and anterior temporalis muscles (right and left sides) of 23 individuals (11 women and 12 men at ages between 25 and 23 years old, respectively) without any signs or symptoms of TMD, headaches or clenching were assessed. The procedure consisted of a sustained isometric contraction at 10% of the maximum voluntary contraction (MVC) for 30 minutes in order to induce fatigue, followed by an injection of glutamate or isotonic saline solution (IS) (two different times) and subsequent rest. Considering this routine, the following aspects were analyzed at four times (outset, post-contraction, post-injection and post-rest):

(a) electromyographic activity at initial rest;

(b) amplitude and frequency of electromyographic signal during isometric contraction;

(c) duration and degree of exteroceptive suppression;

(d) pain and fatigue levels at pressure (measured in degree scales).

The researchers concluded that exteroceptive suppression was associated with the presence of fatigue and pain (in this case, induced by the administration of glutamate), once the degree of inhibition increased. They also emphasized that the muscle activity at rest captured by electromyography also suffered influence, in a distinct way, once an initial increase was observed followed by a decline.

Studies such as the ones cited above prove to be innovative and daring, once they make an attempt at reproducing, in an induced way, what would happen in natural pathological conditions, even though they analyze the electromyographic signal mainly from the perspective of amplitude. It is believed that information regarding the reduction of median frequency (MF) as used for the analysis of muscle fatigue in the studies cited below would enrich the electromyografic findings reported so far.

A second study carried out by the same authors [17] using the same sample and methodology compared the relationship between fatigue and muscle pain with the electrical activity of the jaw musculature in relation to gender (male and female). They did not observe differences between genders for these aspects, though they inferred that, clinically, women could be considered more vulnerable to pain and fatigue triggering, presumably due to the fact that the differences in their neuromuscular system contribute to a greater propensity to developing chronic problems of skeletal muscle pain.

Another study which considered the influence of fatigue and muscle pain on jaw muscles [18] aimed at investigating the effect of intense masticatory exercises on fatigue and muscle pain induction and, consequently, in the masticatory system. Forty men who should perform 20 five-minute masticatory sessions were included. Fatigue and muscle pain scores and amplitude of mandibular stretch reflex of the left masseter were measured at the end of each session, 20 minutes and 24 hours after the mastication ended, by means of the visual analogue scale (VAS). In addition, signs of TMD and threshold of pressure-muscle pain were measured prior to, 20 minutes and 24 hours after the total exercise time, based on the tool Research Diagnostic Criteria for TMD (RDC/TMD). Researchers observed that fatigue and pain increased, reflex amplitude remained unaltered and threshold of pressure-muscle pain decreased with the performance of exercises. Despite of the fact

that the study showed some limitations according to the authors themselves, they concluded that intense and prolonged masticatory exercises may induce fatigue, pain, and decrease of the pain threshold of pressure-masticatory muscles, without interference of the amplitude of the mandibular stretch reflex.

Studies have shown that factors such as pain and fatigue are better detected in isometric contractions [3,4]. This is because in these situations intracellular substrates would accumulate more easily, thus impairing the passage of potentials of muscular action and more rapidly yielding pain and fatigue conditions. However, it is believed that studies involving research on pain and fatigue in dynamic contractions are extremely relevant, once they depict what most commonly occurs in the routine of the population.

The relation between the masseter and the sternocleidomastoid (SCM) was investigated by Japanese researchers [19]. This study aimed at investigating the relation between the activity of the masseter and the SCM and the head and jaw movements during mastication in the protocol of muscle fatigue. The sample consisted of 12 adults (ten men and two women) with normal occlusion that should perform gum mastication for 30 seconds at three different times: prior to the performance of maximum clenching, immediately after it, and three minutes after clenching. The electrical activity of masseters and right SCM was captured simultaneously during mastication (through an electromyographic test), as well as the head and jaw movements (through the motion capture system), being ten masticatory cycles selected for analysis. In the electromyographic analysis, the fields of amplitude and frequency were taken into consideration. In order to ascertain the occurrence of fatigue during mastication, the median frequency of the signal was estimated. With reference to electrical activity, the masseter had lower activity after clenching, whereas the activity of the SCM increased. As for muscle fatigue, both muscles had a reduction in MF after clenching, being it restored after three minutes. For the movements, stability was observed for jaw movement and head movements increased after clenching. Therefore, the researchers concluded that there is a relation between jaw muscles and head and neck muscles.

The influence of vibrotactile stimulation in the masseter on the late perception of pain and fatigue in healthy individuals has been recently investigated[20]. Twenty-five healthy women participated in this study, receiving vibratory stimuli for 15 seconds, sequentially performing contractions at 10%, 20% and 40% of MVC. Fatigue was investigated, as well as pain, through visual scales. Researchers observed that vibratory stimuli did not interfere in the outset of pain and fatigue.

Studies investigating muscle fatigue in specific occupations such as wind instrument players and goldsmiths were also found.

Another group of Japanese researchers [21] carried out a study to investigate the influence of tonal change of wind instruments in muscle activity, and the effects of sustained blows on fatigue. Thirty-three individuals assessed while playing their instruments were selected, being analyzed the masseter, temporal, orbicularis oris and digastric muscles of the left side. The study developed two testing steps:

Step 1 – individuals playing their instruments for three seconds in the habitual tone and then an octave above. Electromyographic signal was measured at rest, while the musicians played, during maximum dental clenching and during maximum mouth opening.

Step 2 – individuals playing their instruments for 90 minutes. Electromiographic signal was measured prior to and after blowing activity and analyzed through MF analysis.

Researchers observed that the electrical activity of the masseter and temporal muscles while playing the instrument was slightly higher than at rest, yet extremely lower in comparison to dental clenching. As for orbicularis and digastric muscles, the activity was relatively higher while playing the instrument. Higher notes were followed by an increase in the electrical activity only in part of the sample. Regarding the analysis of MF there was no difference prior to and after prolonged activity. Thus, the authors concluded that the activity of jaw muscles was low, regardless the note played, and prolonged blow activity was not enough to induce fatigue in the studied muscles.

The study with goldsmiths was carried out in India [22] and aimed at measuring the effect of air tubes used in their work on fatigue of facial muscles and respiratory stress in daily work routine. One hundred male goldsmiths were included and answered a questionnaire, underwent a pulmonary function test, peak expiratory flow measurement, as well as the electromyographic evaluation of left and right buccinators and orbicularis oris, for they are, in principle, the most engaged muscles during their work. The electromyographic evaluation was carried out throughout their workday, respectively in the beginning, the middle and at the end, allowing the analysis of muscle fatigue through MF. Results evidenced reduced lung volume and peak expiratory flow, possibly due to the great pressure needed for their activity (the use of air tubes) and the exposition to certain chemical compounds. Fatigue was observed in all the muscles studied at the end

of the goldsmiths' workday. For these reasons, the researchers concluded that the implementation of a new and more ergonomic air tube may reduce facial fatigue and respiratory stress.

With the proposal for improvements and greater ease in studies with muscle fatigue research, Italian researchers carried out a study in which fatigue was researched under conditions of continuous levels of submaximal muscle contraction [23]. These researchers stated that the use of pre-established and fixed force levels brings benefits when compared to the use of termed force of MVC of the individuals, once they would reduce the possibility of dental fractures, pain and discomfort. Ten healthy individuals underwent electromyographic evaluation of the masseter and anterior temporal, performing right unilateral clenching in a 13 kg load cell (127N) until exhaustion. In this context, MF was estimated in the outset, after one minute and at the end of the test. The resistance time observed varied from one to eight minutes, and there was a reduction of MF in the masseter and temporal, being more significant in the masseter. It led the researchers to conclude that research with fixed submaximal loads may induce muscle fatigue and would be a more accessible protocol, regardless the population assessed.

In a study about fatigue in the upper airway muscles, researchers in the United States developed a force transducer for the nasal muscle [24]. They assessed the nasal dilator muscles in order to test the hypothesis that central mechanisms would contribute to fatigue in these muscles, in conditions of sustained submaximal contractions. Eleven individuals were selected, five men and six women who were able to control the mobility of the nasal muscle and did not have any respiratory intercurrence. Three types of procedures were performed, with the following analyses: (a) submaximal contractions of the muscles at 20, 35 and 65% of the MVC until the force reduced in 90%, being the signal analyzed in microvolts (μV) and MF; (b) stimuli of the facial muscle and subsequent analysis of maximum potential evoked; (c) 15 nasal contractions of 10 minutes each, being analyzed the signal in μV and MF after each cycle. Despite the lack of clarity in presenting the results, the authors observed that the electromyographic activity in μV increased with time, the MF decreased approximately 25% in all experiments, and paradoxically the maximum potential evoked did not alter, what according to them indicates that fatigue (especially observed for the decrease of MF) is mainly due to the mechanisms close to the neuromuscular junction. In their opinion, these data show that central fatigue may have been present even though the central nervous system failed to completely activate the nasal dilator muscles during submaximal contractions evoked. In addition, it was not possible to quantify its magnitude or where it starts (e.g. suprabulbar motor centers, facial motor neurons, among others).

The obstructive sleep apnea was the aim of a study [10] in which researchers tested the use of a treatment for apneic individuals (intra-oral device for the functional reordering of the occlusion) as a preliminary way, in normal individuals. The sensation of occlusal alteration caused by the use of the device at night was assessed in 12 healthy individuals. The variables considered were sensation of occlusal alteration, masticatory force, occlusal contact area and muscle fatigue, all measured every fifteen minutes during the first four hours after removal of the device. The same procedures were repeated on another day after the individuals had slept without the device. Occlusal sensation was quantified through VAS; masticatory force and occlusal contact area were measured by a computer program during three seconds of clenching; and muscle fatigue of the masseters was investigated through MF accessed by surface electromyography (sEMG). Researchers observed that the sensation of occlusal alteration was detected by the individuals up to 75 minutes after removal of the device and interference in masticatory force was detected right after removal. Muscle fatigue was associated to the altered sensation in only two individuals and with masticatory force in only one individual. Thus, it was concluded that the most recurrent variable, alteration in occlusal perception, was probably due to the non-physiological shift of the temporomandibular joints (TMJs) that happens with the use of the intra-oral device.

Other diseases such as Amyotrophic Lateral Sclerosis (ALS) have also been the object of studies that investigate musculature [11]. This is a progressive disease characterized by significant muscle fatigue and reduced response to repeated nerve stimulation, especially in the limbs. Nevertheless, these signs may appear in facial muscles, so that, initially, the disease may be misdiagnosed as Myasthenia Gravis, which is, for the researchers, the reason for this study. It aimed at investigating the occurrence of muscle fatigue and the response to repeated nerve stimulation in facial muscles of individuals with ALS of the oropharyngeal type, in other words, with complaints about dysarthria, dysphagia and/or hypernasal voice. The stimulation of the orbicularis oculi (OO), trapezoid and nasal muscles was performed in ten patients. Six patients reported muscle fatigue while performing the tests of the muscles concerned; three presented abnormal reduction of stimulation in facial muscles, but not in the muscles of legs and arms; two presented

abnormal reduction in stimulation of OO and nasal muscles; one presented reduction only for OO. According to these findings, researchers stated that facial muscles may be affected, as one of the first manifestations of some types of ALS, even though facial weakness is not yet evident.

Among the cervical diseases associated to the stomatognathic system there is the whip-lash syndrome (WLS). This disease generally emerges associated to car accidents and is due to an abrupt movement of acceleration and deceleration in the neck, causing a series of symptoms and sequelae. Other studies also investigate muscle fatigue in jaw muscles in this population [25,26].

The responses of the autonomic nervous system were studied in individuals with cervical diseases associated with the stomatognathic system [25], including muscle fatigue. The study investigated autonomic reactions theoretically more significant in these individuals when compared to normal individuals in masticatory conditions. Two groups with 21 individuals each had cardiovascular aspects, perception of fatigue and pain, and muscle fatigue through EMG evaluation, tested in a situation of alternated unilateral mastication with chewing gum. In fact, more intense responses were observed in the group affected by the disease, and more than half prematurely interrupted the test due to exhaustion; cardiac frequency and blood pressure were higher, pain and fatigue sensation also, although there was no perception of change in electromyographic aspects of fatigue for the masseter (amplitude and frequency of the signal). According to the authors, more intense responses of the autonomic nervous system in individuals with cervical disease during masticatory stimulation show an overload in the mandibular motor system and may indicate central regulatory mechanisms, once the muscular parameters for fatigue were not observed.

Another group of researchers investigated the masticatory resistance of the same population, and its relation with cervical lesions [26]. Three groups with 50 individuals each were formed: the ones affected by cervical lesions, with TMD and/or healthy. All of them underwent a protocol of unilateral mastication of chewing gum in a five-minute section and data referring to the report of sensation of pain and fatigue in masticatory musculature, resistance time and outset of symptoms were analyzed. The individuals with associated cervical lesions showed fatigue and pain more easily and earlier, evidencing lower resistance during mastication.

A recent study [27] investigated the difference in electromyographic patterns, including muscle fatigue, of women with sporadic and chronic headaches. Forty-two women grouped in three sectors were selected considering the type of headache and its absence. The analysis of MF was carried out through electromyography throughout the MVCs, and, a distinctive aspect of this research, as well as the following was a mold of masticatory cells specific for each individual. The authors observed that, among the muscles assessed, the masseter was the most fatigable while comparing individuals with headaches in general with the control group. In addition, women with chronic headaches showed a more rapid decrease in MF, compared to others.

TMD patients have also been the focus of other studies[8,9]. One of them, carried out in Brazil[8], looked for signs of muscle fatigue in individuals with TMD, during mastication. Twenty women participated in the study, diagnosed by the RDC as clinically normal or with TMD of the myogenic type. The masticatory muscles (masseter and temporal) were analyzed EMG during 15 seconds of mastication. Fatigue was investigated through the analysis of median frequency throughout mastication, not showing significant alteration. According to the authors, the lack of electromyographic signals of fatigue, in all individuals, may be have happened because of the elevation of blood flow due to the masticatory movement, an aspect that may hinder the deposition of substrates within the muscles that induce fatigue.

Another study, carried out in Italy[9], focused on: (a) assessing the use of EMGs as an objective measurement of fatigue of jaw elevator muscles; (b) comparing the EMG manifestations of fatigue of the masseter and temporal right and left; (c) assessing the recovery of the investigated muscles after testing their resistance; (d) comparing fatigue and recovery of jaw elevator muscles between healthy individuals and TMD patients. Twenty healthy individuals and TMD patients participated in it, performing submaximal isometric contractions at 20%, 40% and 60% of MVC for 30 seconds, and at 80% until exhaustion (resistance test) and recovery. A force transducer was used for these quantifications. According to the authors, the decrease of MF was a good indicator of fatigue in the muscles assessed, masseter and temporal (independently of the side) showed the same myoelectric manifestations of fatigue and recovery; and the muscles assessed showed lower values in TMD patients. Finally, they concluded that myoelectric evaluations, the way they were remarked in this study, may help in the clinical evaluation of TMD patients.

The influence of food texture on muscles and masticatory movements, as well as on fatigue of this musculature was investigated by other authors [28]. They analyzed, in a sample of 28 individuals, the oxygenation of the masseter, as well as the

mandibular movement during mastication of chewing gum for 80 seconds with three different textures. They concluded that the harder the chewing gum, the greater the velocity of mandibular movements and the lower the intramuscular oxygenation, suggesting that it would lead to an increase of the anaerobic metabolism and, consequently, to a greater probability for emergence of muscle fatigue.

There are a number of protective reflexes against potential damage to oral structures. One of them is the inhibitory mandibular reflex[29], of which some studies were found, relating it to muscle fatigue. It is characterized by the exteroceptive suppression of activity of jaw closing muscles, likely to be evoked by mechanical or electrical stimulation of oral structures.

One example of these studies was one carried out in Holland in 2009[29]. Researchers assessed the effect of muscle fatigue induced by exercises on the inhibitory mandibular reflex in healthy individuals. Hence, eight individuals without signs of TMD and dental flaws were assessed, performing two experimental sessions that aimed at investigating the reproducibility of effects. In each session the individuals were supposed to perform intense mastication for 30 seconds. The subjective assessment of fatigue (VAS) and the research of inhibitory reflex (through evocation of electrical stimulation caused in the lips during mastication) were carried out in the beginning of mastication, after and in two moments following it. As a result, it was observed that the sensation of muscle fatigue caused a reduction of 50% in the inhibitory reflex, with total recovery in the first retesting.

Another study also focused on the inhibitory reflex[30], used a methodology similar to the previous one and aimed at investigating whether experimentally controlled conditions, such as fatigue and pain, which simulated TMD symptoms, could interfere in the mandibular inhibitory reflex. Eighteen healthy individuals participated, being previously examined with RDC to investigate the occurrence of symptoms. Methodological procedures were based on the previous study, though pain sensation concomitantly to fatigue was included. As well as the other authors, these ones observed a reduction in the inhibitory reflex after induction, at 30% instead. This condition was considered a positive feedback, mainly when performed in TMD patients, once inhibition decrease would cause masticatory muscles to be more active in their closing, pain and fatigue would enhance and reflex would consequently remain decreased, epitomizing a cycle.

Scientific research often relies on specific variables to evaluate capacity and efficiency of certain apparatus. This was the case of a study that used the research on muscle fatigue to test a device for induction of eccentric contractions in masticatory muscles and, consequently, late pain in these muscles[31]. Eccentric contractions happen when the muscle performs the contraction in a contrary direction to the movement executed, what is very hard to be reproduced in practice, especially in the masticatory muscles. The researchers remarked that in the majority of studies about this musculature fatigue is induced by other types of contraction and, maybe for this reason, classify this musculature as resistant. The apparatus developed by authors had two metal axes connected by an articulating axis which the participants should bite. The eccentric property of contraction occurred when, by clenching the device, it was programmed to exert force against. For its testing, six individuals performed a series of eccentric contractions, 5 minutes each, with rest intervals of one minute. Sixty movements of opening and closing the mouth were performed in each series. They analyzed sensation of fatigue and pain (through VAS); maximum mouth opening without pain; sensibility to palpation; and MVC before exercise, immediately after, as well as 24, 48 hours, and one week after exercise. The researchers concluded that the device had fulfilled its function, once the levels of pain and fatigue in musculature were high, maximum mouth opening had decreased after 24 and 48 hours of exercise and, within 24 hours, MVC had also been lower.

Based on the idea that repeated dental clenching would be likely to cause pain and muscle damage, even at low intensities, another study was developed focusing on pain [32]. Authors emphasized that individuals with pain in the masticatory musculature generally maintain the same teeth clenched for longer periods than individuals without pain, suggesting that habits such as bruxism could emerge, even in these conditions. Thus, ten healthy women participated in the study and were supposed to perform, on distinct days, voluntary contractions until exhaustion, at 7.5%, 10%, 15%, 25% and 40% of MVC. The variables analyzed were: (a) perception of pain and (b) fatigue, (c) actual fatigue onset, as well as (d) threshold of painful pressure for the masseters and temporal muscles in three times: prior to, immediately after and one day after exercise. The moment in which the individual would not be able to remain exercising would be considered the actual onset of fatigue. Thus, the levels of masticatory force and resistance (exercise outset until fatigue onset) widely varied among individuals, though pain threshold in the masseter decreased considerably immediately after and one day after exercising for the 7.5% load. For the temporal muscle, pain threshold was still reduced

one day after exercising at 7.5% of MVC. It led the authors to understand that low levels of dental clenching, in a prolonged way, induce late pain in masticatory muscles of healthy women.

Research of fatigue in facial and masticatory muscles in studies with experimental patterns

The study of fatigue in facial and masseter muscles with tests in animals was also developed. A Japanese study [33] aimed at analyzing peripheral fatigue and damage to masseter caused by prolonged low-frequency stimulation. Thirty male mice were used, divided into five groups: S1, S2, S4, DanTr and Sham (placebo). The left masseters were chosen as experimental muscles, being the right masseters for the control group. Stimulation was performed in the left side of the neck, next to the musculature concerned, throughout 2 hours, characterizing a session. In group S1, a session was performed, in S2 two sessions, and in S4 four sessions (all of them with a three-minute interval between sessions). Four sessions were also performed in group DanTr, though Dantrolene was administered in order to determine whether there were artifacts of electrical current. The group Sham (placebo) was characterized as a control group in which there was no electrical stimulation. In the other groups it occurred in the right masseter only. The peak of maximum force during stimulation was considered in the assessment of fatigue, and for the assessment of the histological damage to the masseter, it was dissected. The results showed that, in each session, the maximum force of mandibular closing increased within one minute of stimulation followed by a drastic decline and became stable after it. In addition, the peak of maximum force decreased as each session developed. With reference to histological analysis, it was observed that the stimulated masseter became larger and with a more irregular arrangement of fibers, as well as the increase in the interstitial space and infiltration of mononuclear cells in the fibers, including the control groups (Sham and DanTr). It led the researchers to the conclusion that prolonged low-frequency stimulation in masticatory muscles may induce fatigue and damage to muscle fibers.

Another study with mice investigated the relation of muscle fibers and the functions muscles perform[34]. According to the authors, skeletal muscles have a heterogeneous structure of fiber types that reflects the functional demand of each muscle. This relation has been investigated in larger animals, but not in small ones and, for this reason, the authors defended the hypothesis of a positive relation between the amount of muscle fibers resistant to fatigue and the daily demand of use. Fourteen adult male mice participated in the study which had the activity of masseter, digastric and temporal muscles monitored by means of radiotelemetry throughout one day (time quantification). For the analysis of fiber types in muscles, a immunohistochemical staining was performed where it was possible to analyze the fiber content of heavy chains of myosin. The researchers validated their initial hypothesis, once the muscle which had greater activation time, though at lower intensity, was the one which contained the greater number of slow fibers (Type I and Type I + II), in the digastric muscle in this case. In addition, all muscles showed a positive relation between activation time and percentage of fibers type IIX, which have intermediary physiological property in relation to types IIA and IIB.

From the 24 studies analyzed, it was observed that a great majority was directed to the masticatory muscles (22 studies), followed by orbicularis oris and digastric muscles (two studies each), and orbicularis oculi, buccinators and nasal muscle (only one reference each). It is understood that masticatory muscles are the most studied once they are easily located, contribute to most of the stomatognathic functions and, consequently, influence on the other orofacial structures, relating to a number of pathologies of the stomatognathic system. In addition, it is possible to quantify the force in these muscles, an alternative that is widely employed in analysis of fatigue, a fact that is yet not possible for swallowing muscles, for instance.

In reference to the measurement of muscle fatigue, 12 works used EMG, 10 were based on the participants' reports and three performed histochemical analyses. All in all, the report of individuals was based on the use of VAS as a way of quantification, what implies in a great subjectivity of the findings. The use of EMG counterpoints this reality once it contributes with objective data regarding muscle fatigue, though it yet offers more than one way of analysis. In this context it is possible to perform the analysis of force peak or amplitude as well as the median frequency of the signal. In many works found in this study, researchers opted for the investigation of fatigue through analyzing the decrease of MF, a praxis that has been well accepted and defended in national and international scientific literature.

In addition, the great variability of protocols employed in the research about muscle fatigue was evident. Some used static contractions, either at maximum or sub-loads, while others used dynamic contractions, aiming at researching fatigue during muscle function. The variability also refers to the difference in determining the phenomenon of fatigue. There are studies which refer to fatigue as

the first sign of "something different" in the muscle, as well as the incapability of maintaining contractions. These factors have certainly influenced in the diversity of results found in this study.

CONCLUSION

The analysis of scientific literature about fatigue in facial and masticatory muscles has allowed the conclusion that, though there are works which focus on the analysis of fatigue, their methodology is widely varied, either in relation to the tools used or the protocols employed, hindering a deeper analysis of the subject and the possibility to compare.

Due to this variability, findings referring to muscle fatigue were also divergent. The masseter, for instance, appeared to be more fatigable associated to certain diseases such as TMD, chronic headache and cervical lesions, in some studies, while in others it was unaltered. The orbicularis oris was more fatigable in certain occupations, as with gold-workers. In addition, the masticatory muscles of women were more fatigable than men's.

From the data collected it is suggested that further studies are developed in order to investigate increasingly more diverse populations and muscles, with complete and appropriate methodological designs for the diverse situations.

RESUMO

O objetivo deste estudo foi aprofundar os conhecimentos acerca da fadiga muscular dos músculos faciais e mastigatórios por meio da análise da literatura científica. A estratégia de pesquisa baseou-se nas indicações da Biblioteca Cochrane. Os artigos foram selecionados por meio da base de dados PubMed, utilizando-se o descritor "*muscle fatigue*" em conjunto com os seguintes descritores: "*speech therapy*", "*facial muscles*", "*jaw muscles*", "*mastication*", "*chewing*", "*lip*" e "*clenching*". Foram incluídos artigos dos últimos dez anos, independente de idioma. Os textos foram analisados inicialmente em seu *abstract*, sendo excluídos os que não se adequavam ao objetivo. Em seguida foram analisados os textos integralmente e considerou-se: objetivo, delineamento do estudo, formação dos grupos, critérios e rigor metodológico, protocolos aplicados, resultados encontrados e a existência de discussão sobre a fadiga nos músculos objetivados. Nesta última etapa, aqueles que não estavam de acordo com o propósito deste estudo também foram excluídos. Assim, foram encontrados 138 artigos, dos quais 54 foram excluídos devido à repetição mediante cruzamento dos termos e 84 foram analisados. Destes, 46 foram excluídos na etapa do *abstract* e 38 analisados na íntegra. Destes 38, 24 foram mantidos e 14 excluídos por não se adequarem aos critérios do estudo. Embora existam alguns trabalhos referentes à análise da fadiga, a metodologia dos mesmos é muito variada, dificultando a sua comparação e detalhamento. Enquanto alguns estudos observaram, por exemplo, maior fadiga dos músculos masseteres e orbiculares da boca, outros não encontraram os mesmos resultados, o que pode ter sofrido influência da população alvo de cada estudo.

DESCRITORES: Fadiga Muscular; Músculos Faciais; Músculos Mastigatórios

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Mailing address:
Angela Ruviaro Busanello-Stella
Av. Presidente Vargas 2355/8º andar, sala 801-
Policlínica Provedor Wilson Aita
Santa Maria/RS - Brasil
CEP: 97050-600
E-mail: angelafonoaudiologia@yahoo.com.br