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Neurophysiological aspects of isotonic exercises in temporomandibular joint dysfunction syndrome

Efeito de exercícios isotônicos para redução da dor da musculatura orofacial em indivíduos com disfunção temporomandibular: aspectos neurofisiológicos

ABSTRACT

Purpose: The aim of the study was to investigate the electroneurophysiological aspects of volunteers with temporomandibular disorders before and after performing isotonic exercises for pain relief and self-care guidelines. **Methods:** The study was a parallel controlled randomized controlled trial under protocol 1,680,920. The inclusion criteria were age between 18 and 60 years, muscle temporomandibular dysfunction with or without limitation of mouth opening and self-reported pain with scores between 4 and 10. The individuals were randomized into experimental group and control. Twenty-three volunteers participated in the study, most of them were female. Control group had 11 and experimental group 12 individuals. Dropouts occurred in both groups, two in the experimental group and three in the control group. Since there were an intergroup imbalance the power density was analysed just in experimental group. Electroencephalographic recording was performed before and after the interventions, using the 32-channel apparatus, with sample frequency of 600 Hz and impedance of 5 kΩ. The data were processed through the MATLAB computer program. The individual records filtered off-line, using bandpass between 0.5 and 50 Hz. Epochs of 1,710 ms were created and the calculation of the absolute power density calculated by means of the fast Fourier transform. The statistical approach was inferential and quantitative. **Results:** The alpha power density analyzed presented a difference, but not significant, when compared in the two moments. **Conclusion:** According to this study, isotonic exercises performed to reduce pain provided a small increase in alpha power density in the left temporal, parietal and occipital regions.

RESUMO

Objetivo: O objetivo do estudo foi investigar os aspectos eletroneurofisiológicos de voluntários com disfunção temporomandibular antes e após realização de exercícios para redução de dor e orientações de autocuidado. **Método:** Foi realizado ensaio clínico randomizado controlado paralelo, aprovado por um Comitê de Ética. Os critérios de inclusão foram idade de 18 a 60 anos, disfunção temporomandibular muscular, com ou sem limitação de abertura de boca, e dor autorreferida com escores entre 4 e 10. Os indivíduos foram distribuídos, por sorteio, em grupo experimental ou controle. Participaram do estudo 23 voluntários, 11 controles e 12 do grupo experimental sendo a maioria do sexo feminino. Desistências ocorreram, sendo duas no grupo experimental e três no controle. Houve desbalanceamento entre grupos e apenas o experimental foi analisado. Foi realizado registro eletroencefalográfico antes e depois das intervenções, por meio de aparelho com 32 canais, frequência amostral de 600 Hz e impedância de 5 kΩ. Os dados foram processados por meio do programa computacional MATLAB. Os registros individuais filtrados off-line, utilizando passa banda entre 0,5 e 50 Hz. Épocas de 1,710 ms foram criadas e o cálculo da densidade de potência absoluta calculada por meio da transformada rápida de Fourier. A abordagem estatística foi inferencial e quantitativa. **Resultados:** A densidade de potência alfa analisada apresentou diferença, porém não significativa, quando comparada nos dois momentos. **Conclusão:** Pode-se concluir que, com base nesse estudo, os exercícios isotônicos realizados para redução de dor proporcionaram pequeno aumento na densidade de potência alfa nas regiões temporal, parietal e occipital esquerdas.

Study conducted at Universidade Federal da Bahia – UFBA - Salvador (BA), Brasil.

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INTRODUCTION

Pain reduction is an issue to be considered in rehabilitation⁽¹⁾. Among orofacial pathologies with this symptom the most frequently is temporomandibular dysfunction (TMD)⁽²⁾. Clinicians and researchers commonly aim to reduce pain and improve the quality of life of individuals with TMD. The noxious stimulation results in activation of afferent fibers which conduct to the brainstem resulting on neurochemicals releases and activation of neurons in the brain⁽³⁾. Changing this pathways and working through peripheral conduction, the central nervous system (CNS) undergoes changes that are explained by neural plasticity⁽⁴⁾. Among the strategies used to achieve these goals is the use of isotonic exercises in the painful region⁽⁵⁾. Some strategies have already been described to benefit individuals with chronic pain^(1,6). Studies have shown that relaxation exercises of the mandibular musculature reduced the pain of individuals with TMD^(7,8). In association with orientation, exercises, and rehabilitation of the stomatognathic functions, improvements were noted in volunteers with TMD versus the control group after the use of occlusal splints⁽⁹⁾. On the contrary, Wirianski et al.⁽¹⁰⁾ detected no differences between the control and intervention groups after isotonic resistance exercise. One of the limitations of this study was intra-subject variability during the primary outcome evaluation.

Most of results showed by relaxation exercises, home orientations are measure by clinical outcomes^(5,7-10). In addition to that, complementary exams enable the objective measurement of subjective issues such as pain⁽¹¹⁾. Electroencephalogram (EEG), first described by Berger in 1929, is a method that enables recording of the spontaneous electrical changes that occur in the cerebral cortex and analysis in relation to amplitude, frequency, and spatial location in the scalp⁽¹²⁾. Every recording is performed by the placement of electrodes in different regions of the head, which pick up the electrical signals, transduce them through the equipment, and store them in the computer. In the qualitative analysis of the records, the different frequencies are analyzed, the most frequently studied in the pain-related cases being alpha (8-12 Hz), beta (13-20 Hz), and gamma (>20 Hz) power densities^(12,13).

In a trial of nociceptive thermal stimulation in healthy volunteers, an increase in alpha power density was observed in the resting state; after stimulation, a reduction in this frequency was noted⁽¹⁴⁾. The authors also observed reduced alpha and beta power densities in addition to increases in theta and gamma power densities soon after the painful stimulus, but this was equivalent to acute pain. It should be noted that all changes occurred in the medial prefrontal region. These results suggested that changes in gamma power density were associated with longer-lasting pain. Changes in beta power density were associated with stimulus intensity⁽¹⁵⁾. In another study analyzing the desynchronization related to events in the alpha and beta bands, the authors observed changes at the beginning and end of isometric movements of the knee and ankle.

However, for isotonic movements of the same joints, desynchronization was observed during all executions⁽¹²⁾. In a study of athletes, a change in the alpha 1 power density

(7.5-10 Hz) was observed, with an increase in this density shortly after a low-intensity run and a 15-minute decrease after aerobic activity⁽¹⁶⁾. In the same study, the power density was also analyzed after a high-intensity run, when a reduction was observed only 15 minutes after the end of the activity. In a meta-analysis performed in 2004 synthesizing data from studies that tested the association between aerobic and cortical activity data, the authors verified that the alpha band increased during and after exercise with moderately large and statistically significant effects. The alpha activity was also higher in the tests that were performed in the morning or when the collection was always performed at the same time in all volunteers⁽¹⁷⁾. Although described in the literature, knowledge about cortical changes following therapeutic interventions in individuals with pain remains restricted. The aim of this study was to identify the alpha power density before and after isotonic exercise in subjects with TMD and chronic pain and test the superiority of this intervention compared to the self-care guidelines. To do so, a parallel randomized controlled trial was performed with volunteers with TMD.

METHOD

This research started after approval was received from the ethics committee (protocol 1,680,920) and was registered in the Brazilian Clinical Trials Registry.

The data were collected from January to December 2017 at Functional Stimulation Laboratory. There was no referral center for volunteers. The participants were made aware of the studies by posters distributed at the university, in dental centers of the city, and in social networks. All of the volunteers provided written informed consent and filled out a questionnaire regarding their sociodemographic data. Thereafter, they were randomized to the intervention or control groups. Inclusion criteria were age 18-60 years; diagnosis of muscular TMD with or without opening limitations according to the Brazilian version of the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD), Axis I⁽¹⁸⁾ and a reported pain score of 4-10 in the last six months, where 0 was no pain at all and 10 the most pain ever. The RDC/TMD was applied by a blinded previously trained researcher graduated in Speech and Language Pathology and pain was measure in the face and intra oral regions according to the protocol for the further analysis. Individuals who self-reported temporomandibular joints with disc displacement without reduction, arthralgia, osteoarthritis and osteoarthritis, or psychiatric and neurological disorders were excluded. Occlusal splints and medications could be used as they needed. Any type of myotherapy during data collection were not allowed. The randomization was performed at randomization.com. The volunteers in the experimental group performed two days of intervention per week for four weeks through pain reduction exercises adapted from the model proposed by de Felício et al.⁽⁵⁾ and given them the orientations to avoid movement and mandibular hyperfunction controlling the wide of opening with the tongue in the papilla incisiva. All the exercises proposed by Felício et al.⁽⁵⁾ were done but interventions in estomatognathic functions were not included in this protocol. Accompaniments were performed

twice a week in the same laboratory with 30-minute sessions on days and times previously agreed between the researcher and the volunteer.

The exercises were performed under researcher supervision with the purpose of making adjustments during the execution and requests for the participants to perform them at home every day, those performances were not controlled by the researchers. All exercises were performed in the same way without regard to individuality since the sample had differences in occlusion, age, sex, facial typology and if the pain was uni or bilateral. The control group was only oriented toward self-control of the movement and mandibular hyperfunction controlling the wide of opening with the tongue in the papilla incisive and instructed to undergo a new evaluation 30 days later. For the acquisition of the initial and final neurological data, the volunteers of the experimental and control groups were submitted to EEG performed with the BrainNet BNT 36, Lynx 32-channel device with impedance maintained below 5 k Ω and a sampling rate of 600 Hz and notch filter of 60 Hz. The electrodes were positioned according to the international 10X20 system using the electrode positioned in vertex as reference. Only 30 of 32 channels were used. The registration was performed at a previously agreed time between the volunteer and a researcher without control at the same time for the initial and final evaluations. The subject was asked to remain seated within Faraday's cage and rest for three minutes with the eyes closed. The acquisition process was interrupted when artifacts were verified. The preprocessing of the data was performed using the MATLAB computer program (The MathWorks Inc., Natick, MA, USA) using the EEGLAB tool. Each recording was filtered offline using band passes of 0.5-50 Hz. Epochs of 1,710 ms were created and the absolute power density was calculated using the fast Fourier transform.

The absolute power density of the alpha frequency in the regions of interest was then obtained (left and right channels): left front (channels FP1, FPZ, FZ, F3, F7, FT7, FC3, and FCZ), right front (channels FP2, FPZ, FZ, F4, FT8, T4, T4, T8, and T6 channels), right temporal (channels C4, FC4, FCZ, CZ, CP4, and CPZ), left temporal (FT7, T3, TP7, and T5 channels), left parietal (CPZ, CP3, P3, and PZ channels), right parietal (CPZ, CP4, P4, and PZ channels), right occipital (O2 and OZ channels), and left occipital (O1 and OZ channels). The electrodes positioned between areas were analyzed in one region as in the other. In both groups, the initial findings were compared with the final records performed 30 days after the first evaluation. Twenty-three volunteers were selected; of them, EEG records of two (one in each group) were not register due to study dropout after signing the consent form and conducting the clinical evaluations. Among those interested, 11 were allocated to the control group and 12 to the experimental group. However, after treatment to remove the artifacts from the EEG records, one volunteer from the control group and one from the experimental group were excluded because the initial and final data had very small temporal registers for the power density analysis. The scan of another volunteer of the experimental group presented artifacts in the initial registry; therefore, imputation of the data was done in this registry (Figure 1).

Statistical analysis

The statistical analysis was performed after imputation of losing data. This was done was performed by calculating the mean of the other volunteers in each EEG channel. The unpaired Cohen d test was used to compare the control and intervention groups. The paired Cohen d test was used for intragroup comparisons, while the unpaired Student's t test was used to detect the existence of significant differences between the means of the initial and final moments. In all cases, values of $p \leq 0.05$ were considered statistically significant. All statistical calculations were performed using the free statistical program R.

RESULTS

During the analysis of the individual EEG records, a high number of artifacts in four exams required their elimination. To avoid reducing the sample size, imputation of data from one of the volunteers who had a final record without artifacts; this value was also calculated from the means of each channel of the other volunteers (Figure 1). The statistical analysis was done with both groups, but when performing the Cohen d test,

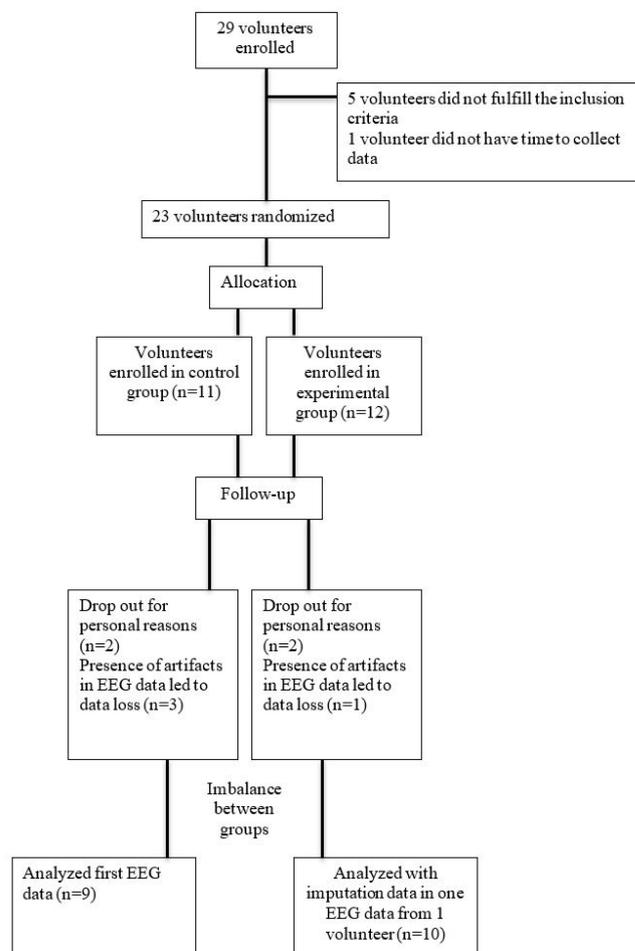


Figure 1. Study Design Flowchart
Source: Study data

to verify difference in the means of the alpha power densities, there were an intergroup imbalance of 1.02-1.29. The control group presented a lower alpha power density than the intervention group. These values for the test in question are considered high, indicating a strong deviation between the means of the groups studied (Figure 2). An imbalance occurred as a function of pain degree and age. In the intervention group, older people

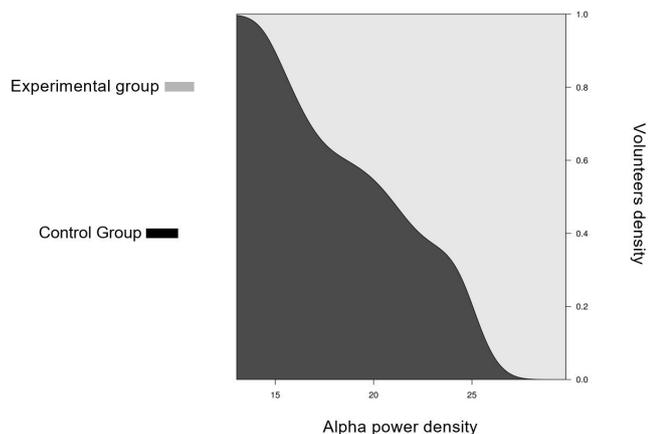


Figure 2. Graph comparing the differences of the means between groups in relation to alpha power density
Source: Study data

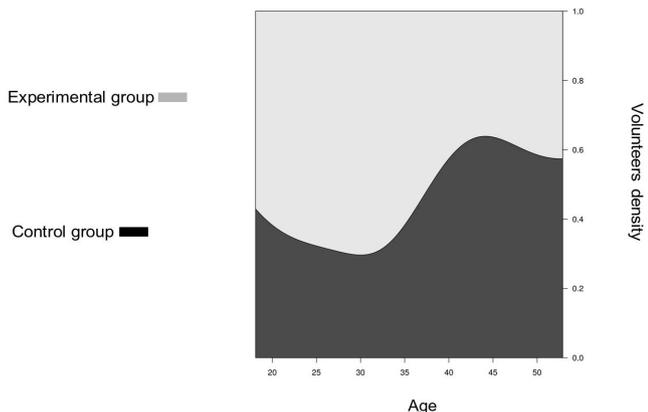


Figure 3. Graph comparing the differences of means between groups in relation to age
Source: Study data

were included compared to the control group (Figure 3). The intervention group presented weaker and more intense pain, while the control group reported medium pain intensities (Figure 4). With regard to alpha power density, in all regions, variation of 17.06-28.08 μV in the right hemisphere and 17.18-27.19 μV in the left hemisphere were observed. As a result of these imbalances, the study continued only with the experimental group as shown in the flowchart (Figure 1) described in the CONSORT study⁽¹⁹⁾, the effect size of the isotonic exercises under the alpha power density was calculated.

The experimental group had nine volunteers; the sociodemographic characteristics of the sample are described in Table 1. After the intervention, was found a small increase in alpha power density. However, it was statistically non-significant due to the small sample size and subject dropouts (Figure 4).

The power density was verified with values between the regions (Table 2). Although there were no statistically significant differences, those findings showed differences in means between the measurements collected before and after the intervention; specifically, they were larger in the temporal, parietal, and left occipital areas post-intervention (Figure 5).

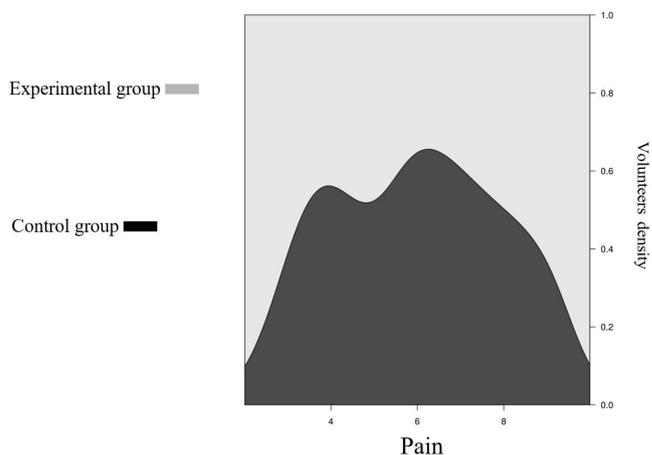


Figure 4. Graph comparing the differences of the means between the groups in relation to the pain
Caption: Right Central (RC), Left Central (LC), Right Temporal (RT), Left Temporal (LT), Right Frontal (RF), Left Frontal (LF), Right Parietal (RP), Left Parietal (LP), Right Occipital (RO) e Left Occipital (LO). **Source:** Study data

Table 1. Sociodemographic data

		Experimental group	
		n (%)	Average
Age			34.36
Gender	Male	3(27.0)	10.4
	Female	8(73.0)	
Race	White	2(18.0)	
	Black	3(27.0)	
	Brown	5(46.0)	
	Did not declare	1(9.0)	
Pain numeric scale			6.6
			2.6

Caption: n = sample size; SD = standard deviation. **Source:** Study data

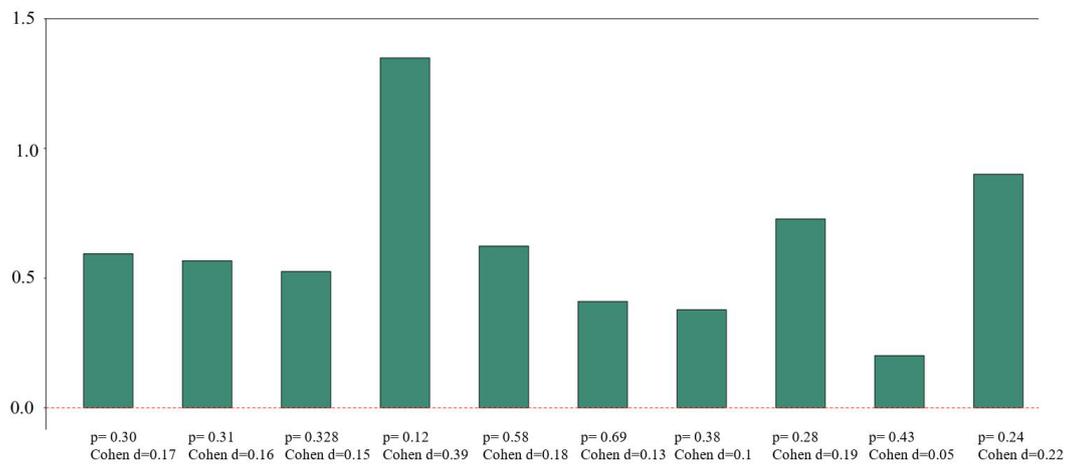


Figure 5. Graph of power density in regions of interest

Table 2. Records of alpha power density in regions of interest before and after the intervention

Region of interest	Absolute power density before (μV)	Absolute power density after (μV)	<i>p</i> value
Right Frontal	22.23	22.86	0.34
Left Frontal	22.51	22.92	0.34
Right Central	20.93	21.53	0.30
Left Central	21.05	21.62	0.31
Right Parietal	21.86	22.24	0.38
Left Parietal	21.63	22.36	0.28
Right Temporal	23.02	23.54	0.32
Left Temporal	22.63	23.98	0.12
Right Occipital	28.08	28.28	0.43
Left Occipital	27.19	28.09	0.24

Source: Study data

DISCUSSION

Randomized clinical trials are considered the gold standard for evaluating clinical intervention efficacy⁽²⁰⁾. Choosing this study type was the best way to test the hypothesis of the superiority of the isotonic exercises for reducing pain compared to self-care alone using an electroneurophysiological examination. After randomization, any volunteer may be chosen for one of the groups, and their characteristics may be similar to those of the sample represented in randomization clinical trials. The objective of randomization is to prevent bias in relation to known and unknown characteristics. At the end of the study, this makes it possible to attribute intergroup differences to the intervention performed. However, among the difficulties and risks inherent to a randomized clinical trial with a small sample, imbalances in the group characteristics were found⁽²¹⁾. This was the major initial limitation of this study. When analyzing the mean intergroup differences, the control group presented a lower alpha power density than that of the experimental group in addition to differences in ages and pain degrees. The possibility of a statistically inadequate analysis follows since the power density in the experimental group was already high at the beginning of the study compared to the control group.

When the results of the experimental group were analyzed, there were a larger number of female volunteers with an average age of 35 years, corroborating with the literature describing a higher prevalence in women aged 18-44 years⁽²²⁾. The findings of quantitative EEG data are rare in the TMD literature. The results obtained in this study were contrary to those found by Narita et al.⁽²³⁾. In that study, a registry was performed of volunteers with TMD using rigid and flexible myorelaxant splints during dental tightening. The authors observed a reduction in alpha in the right posterior temporal region. However, it occurred in a non-linear way, increasing and decreasing over time. This corroborates the data presented by Liu et al.⁽²⁴⁾, who found an increase in alpha soon after the start of the isometric contraction and a reduction soon after the end of the task, also demonstrating non-linear responses when alpha wave was analyzed. During sustained contractions, alpha reduction occurs, which confirms the hypothesis of changes in cortical signals only during this type of contraction, which is responsible for muscle fatigue. The variability found in the registers of alpha power densities may be associated with the different types of pain and moments of EEG capture. Acute pain reduces the alpha frequency in healthy people⁽²⁵⁾ but increases in those with chronic pain⁽²⁶⁾. It is unknown whether the EEG records of patients with TMD were initially equal to those of healthy people and changed over

time with the presence of constant muscle contraction. They may present similar patterns to those individuals with chronic pain in whom differentiated cortical functioning is justified by the constant presence of pain⁽²⁷⁾. It has been reported, on patients with TMD, pain throughout a four months period which would classify as a chronic pain carrier. The main difference between cases could be that on TMD patients, despite the long period of occurrence the pain is not constant and ceases over time⁽²²⁾. This difference would justify the differentiated patterns in the EEG records. This reinforces one of the limitations of this study since we did not measure frequency, quality and the constancy of the pain.

In addition to the different patterns in the electroneurophysiological records observed in individuals with TMD, the scheduled exam time may have contributed to the variability of the results. This is explained by the presence of night bruxism in some patients with TMD, which may increase in the morning and caused different results in those volunteers which EEG was done by the morning. Another factor worth discussion is the moment of the exam since it was performed after doing RDC/TMD, which lasted an average of two hours, rather than during them as described in the literature⁽²⁸⁾. This may have modified the pattern of power densities, rendering the actual recording caused by the execution of isotonic exercises impossible. Despite these limitations, an increase in alpha power density in the left temporal, parietal, and occipital regions after the intervention was found. This was demonstrated by the differences in mean elevations between the initial and final moments. The regions in which the modifications were found were similar to the findings of Korotkov et al.⁽²⁹⁾, which showed activation on positron emission computed tomography (CT) after muscle fatigue equivalent to the suppression of alpha in the EEG records⁽²⁹⁾, temporal regions, motor cortex, cingulate, and somatosensory areas. These last areas are equivalent to the parietal region according to the 10 × 20 system, the same used in the current study to mount the capture electrodes. During fatigue, when the individual experienced pain, a reduction in alpha power density was observed in the regions similar to those in which differences were detected in this study.

The increase of alpha densities in the temporal and parietal regions leads us to reflect in relation to the auditory symptoms present in TMD since the ascending auditory pathways finish their course in the temporal lobe⁽³⁰⁾. As auditory complaints were not the focus of discussion of this study, information was not sufficient to clarify this hypothesis.

Neurophysiological data is not very discussed in myology and speech and language therapy, this results showed us that a lot most to be study to understand all the changes and possibilities that occurs in the cortex while we focus in peripheral stimulation.

Once it is known how the electroencephalographic data can be used, the therapist will have a deeper knowledge about what happens from a neurological point of view. In this way,

clinical approaches will be based on more objective analyzes, which will facilitate decision before and during the treatment.

CONCLUSION

After performing isotonic exercises for 30 days, volunteers with TMD demonstrated increased alpha power densities in the left temporal, parietal, and occipital regions compared to the initial and final moments, although the differences were not statistically significant. This change may be associated with factors not controlled in this study. The present study opens the way to new research seeking a better understanding of TMD pain. The superiority of the performance of the isotonic exercises compared to self-care through the EEG findings could not be tested due to a lack of intergroup balance.

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Authors' contributions

RAFSB - project design, analysis and interpretation of data and writing of the article; *CMCM* - participated in the analysis and interpretation of the data; *TSL* - participated in the analysis and interpretation of the data; *RABF* - participated in the analysis and interpretation of data and writing of the article; *EPS* - participated in the condition of advisor, project design, analysis, data interpretation, writing of the article and final approval of the version to be published.