

# Clinimetric properties of duty factor for temporomandibular disorder

## Propriedades clinimétricas da variável eletromiográfica duty factor para desordem temporomandibular

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### ABSTRACT

**Purpose:** To assess the reliability and responsiveness of the duty factor variable for assessing pain originating from temporomandibular disorders. **Methods:** The sample comprised 20 female volunteers, mean age 29 years 6 months ( $\pm 9.2$ ), with a diagnosis of myogenic temporomandibular dysfunction according to the Research Diagnostic Criteria for Temporomandibular Disorders. Electromyographic (EMG) signals were collected at three times: during mandibular rest; in the presence of moderate to severe pain; and when pain was reduced to mild or absent after 45 minutes of transcutaneous electrical nerve stimulation (TENS). Electromyographic signals during mandibular rest were processed to obtain values for muscle activation time greater than 10% of maximum bite force. Reliability was tested with intraclass correlation for repeated data before analgesia. Standard error of measurement (SEM) and minimum detectable change (MDC) were also computed to determine reliability. Responsiveness of duty factor was analyzed between EMG recordings, before and after analgesia, by calculating effect size (ES) and standardized response mean (SRM). **Results:** Duty factor presented intraclass correlation coefficient above 0.75 for all muscles. Standard error of measurement ranged from 4% to 8% and minimum detectable change from 5% to 12%. Regarding the responsiveness of duty factor to pain, effect size values fell between 0.2 and 0.5 and SRM values were greater than 0.8. **Conclusion:** Duty factor showed excellent reliability. However, responsiveness to TMD-related pain was low as expressed by effect size and excellent as expressed by standardized response mean.

**Keywords:** Electromyography; Temporomandibular joint dysfunction syndrome; Masticatory muscles; Pain; Transcutaneous electric nerve stimulation; Reproducibility of results

### RESUMO

**Objetivo:** Avaliar a confiabilidade e responsividade do *duty factor* à dor provinda da desordem temporomandibular. **Métodos:** Participaram 20 voluntárias, com média de idade de 29 anos e 6 meses ( $\pm 9,2$ ), portadoras de desordem temporomandibular miogênica, segundo o critério diagnóstico para pesquisa em Desordem Temporomandibular (RDC/TMD). Foram coletados sinais eletromiográficos nas condições de repouso dos músculos mastigatórios, na presença de dor moderada a severa e na diminuição ou eliminação desta dor após aplicação de Estimulação Elétrica Nervosa Transcutânea durante 45 minutos. Os sinais eletromiográficos de repouso foram processados para obtenção dos valores do tempo de ativação muscular acima de 10% do valor da máxima força de apertamento dentário. A confiabilidade foi testada pelo coeficiente de correlação intraclasse em dados repetidos antes da analgesia. Também foi calculado o erro padrão de medida e mínima mudança detectável. A responsividade da variável foi analisada entre as coletas eletromiográficas realizadas antes e após a analgesia pelo tamanho de efeito e média de resposta padronizada. **Resultados:** *Duty factor* apresentou valores de coeficiente de correlação intraclasse acima de 0,75 para todos os músculos. O erro padrão foi entre 4% e 8% e a mínima mudança detectável entre 5% e 12%. Na responsividade da variável para a dor, o tamanho de efeito obteve valores entre 0,2 e 0,5 e a média da resposta padronizada, valores acima de 0,8. **Conclusão:** O *duty factor* apresentou confiabilidade excelente e responsividade à dor da desordem temporomandibular baixa para tamanho de efeito e excelente para média da resposta padronizada.

**Descritores:** Eletromiografia; Síndrome da disfunção da articulação temporomandibular; Músculos mastigatórios; Dor; Estimulação elétrica nervosa transcutânea; Reprodutibilidade dos testes

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## INTRODUCTION

Duty factor is a variable that analyzes how much a muscle is active over a prescribed threshold of myoelectric activity, corresponding to a percentage of maximum voluntary contraction in teeth clenching<sup>(1)</sup>. Thus, this variable expresses muscle overload or hyperactivity by analyzing the percentage of time that the muscle, which should be at rest, produces myoelectric activity with respect to the amplitude, considered as a result of electrical noise or spontaneous motor unit activity.

The masticatory muscles of individuals with temporomandibular disorders (TMD) are more easily fatigued and hyperactivated when exposed to abnormalities of movement, structure, posture, or even worse, stress or pain<sup>(2)</sup>. In addition to fatigue and hyperactivity, an altered pattern of muscle activation occurs, according to the pain adaptation model. This model contends that the presence of pain alters patterns of muscle activation in order to protect masticatory muscles from painful stimuli. The vicious cycle theory, on the other hand, contends that pain generates a reflex that increases muscle activity. Such hyperactivity causes muscle fatigue and spasms, thus generating more pain<sup>(3)</sup>.

Several pain reduction techniques are used to treat TMD<sup>(4-10)</sup>. In physical therapy in particular, transcutaneous electric nerve stimulation (TENS) is one of the most utilized non-pharmacological analgesic resources<sup>(11)</sup>. Studies have demonstrated its effectiveness in promoting analgesia and reducing electromyographic muscle activity while resting<sup>(11)</sup>. In the literature, it has been shown that applying TENS in individuals with TMD produces some form of alteration in the activation patterns of masticatory muscles<sup>(12)</sup>. Researchers found a reduction in electrical activity of the muscles during the opening movement of the jaw after a TENS intervention, an indication that its pain inhibitory properties reduced the hyperactive reflex generated by pain in those muscles. When this reflex is inhibited, the vicious cycle of pain is broken<sup>(3,13)</sup>.

Considering the inclusion of duty factor as a variable for analyzing the activity of masticatory muscles and as a complement to the functional diagnosis of temporomandibular muscle disorder, it is important that tests on the clinimetric properties of reliability and responsiveness be conducted. Lack of studies on such properties can lead to biased results and decreased reliability<sup>(14)</sup>.

The aims of this study were to test the reliability of the duty factor variable for helping to diagnose TMD, as well as to test duty factor responsiveness to muscle pain resulting from TMD.

## METHODS

### Sample

The sample comprised 20 female participants, with a mean age (standard deviation) of 29 years and 6 months ( $\pm 9.2$ ). Eligibility criteria were having a Type 1a TMD diagnosis

(myofascial pain without limited opening), according to diagnostic criteria (RDC/TMD)<sup>(15)</sup>, and a minimum pain level of moderate intensity (from 4 to 10) on the Visual Numeric Scale (VNS) at the time of the first EMG data collection.

Exclusion criteria were: absence of molars, a history of temporomandibular joint (TMJ) or facial injury and/or tumors, and pregnancy. Furthermore, we also excluded individuals who were undergoing any form of dental treatment, speech-language or physical therapy, taking muscle relaxants or antidepressants, or who did not report any pain at the time of data collection.

Before data collection began, all participants signed Free and Informed Consent Forms. The study was approved by the research ethics committee of the teaching hospital affiliated with the School of Medicine of the *Universidade de São Paulo* (HCFMRP-USP), in accordance with resolution 196/96 of the Brazilian National Health Council, process number 1051/2013. Participants were assessed using Axis I and specific Axis II questions to compose the diagnosis, according to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD)<sup>(15)</sup>.

### Procedures

First, maximum bite force values were collected. Participants were seated in a chair with their backs against the support, eyes open, feet on the floor and arms resting on legs. Furthermore, they were instructed to look straight ahead at a fixed point horizontal to their line of sight, so that the inferior wall of the acoustic meatus and the inferior margin of the orbit were in alignment<sup>(16)</sup>.

Silver chloride surface electrodes from EMG System of Brazil® (São José dos Campos, Brazil) were placed on volunteers after cleaning skin with cotton soaked in 70% ethanol. The silver bars were placed perpendicular to the muscle fibers in order to maximize signal capture and minimize noise interference<sup>(12)</sup>. The EMG signals were then captured from the masseter, anterior temporal and suprahyoid muscles during maximum voluntary contraction (MVC) of the jaw (Figure 1).

The digital dynamometer used to measure bite force (model IDDK - Kratos®, Cotia-São Paulo, Brazil) was placed on the first molars to obtain the greatest bite force. Data from three repetitions of maximum voluntary contraction were collected, with a two-minute interval between repetitions. Lastly, peak force and electromyographic values for each collected sample were analyzed as indicated by the software. The mean value of the three values was considered for data analysis.

After recording bite force concomitant with EMG signals, the women were given the Visual Numeric Scale to measure pain and determine their inclusion in the next phase of the study. Participants were instructed to report what number on the scale represented the intensity of pain felt at the moment. Interpretation of the scale is based on the value provided by the person: no pain (0), mild pain (1-3), moderate pain (4-6)



**Figure 1.** Position of surface electromyography electrodes on the masseter and anterior temporal muscles, bilaterally, and suprahyoid muscles

and severe pain (7-10)<sup>(17)</sup>. Participants who reported moderate or severe pain continued in the study and underwent two 300-second EMG recording sessions of mandibular rest with a 10-minute interval between sessions.

During the interval between recordings, the researcher analyzed each participant's maximum voluntary contraction and maximum bite values using the software, and calculated the value for 10% of maximum bite force. The dynamometer was placed so that its digital display could easily be seen by participants, who were then instructed to maintain bite force at the previously calculated value with the help of the visual feedback provided by the dynamometer. The second EMG signal was obtained while this contraction was maintained.

On finishing the EMG recording, conventional TENS was applied (symmetrical biphasic square waveforms, 150 Hz 20  $\mu$ s, electrical paresthesia and 50% frequency modulation) for 45 minutes, stipulated by previous studies as sufficient time to generate analgesia<sup>(12)</sup>. Electrodes were placed on the masseter muscle and the anterior acoustic meatus<sup>(12)</sup>.

Immediately following the TENS intervention, participants were given the VNS once again to measure intensity of pain at that moment. Then another 300-second EMG recording was conducted on the same muscles during mandibular rest, as the electrodes had been kept in place during the TENS session.

### Data processing

We analyzed the EMG signal recorded during maximum bite force of the masticatory muscles. The root mean square (RMS) for each EMG collection was calculated, corresponding to 10% of the maximum force value applied on the dynamometer. This value was the basis for analyzing duty factor in the EMG session during mandibular rest. Duty factor variables for each of the analyzed muscles was determined by calculating the

sum of all the instances in which EMG amplitude values were equal to or greater than 10% of the maximum bite force with relation to total time of data collection during mandibular rest. The variables were estimated and compared among mandibular rest data collected before and after the analgesic intervention, disregarding laterality.

Reliability of the duty factor was tested based on intrasession analysis between the two 300-second EMG data collections during mandibular rest, considering the 10-minute interval between them. The two recordings were carried out before applying the analgesic recourse. Since participants presented painful points with palpation on both sides of the face, inferential analyses were conducted disregarding laterality, i.e., data from the left and right sides were included.

### Statistical analysis

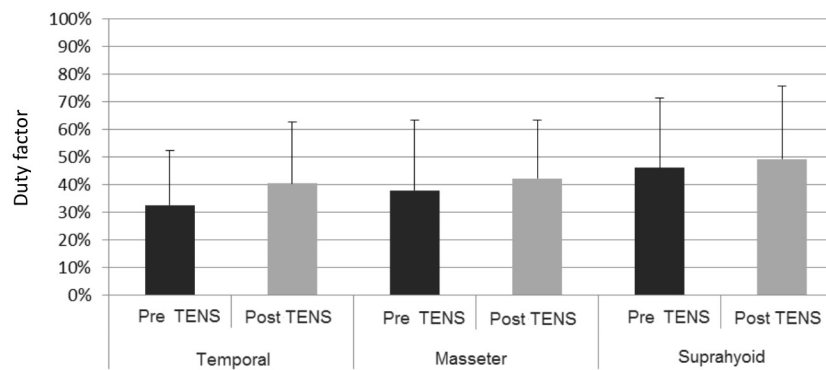
The intrasession reliability for each muscle was statistically analyzed using the result of  $ICC_{2,1}$ , with a confidence interval of 95%. Values of  $ICC_{2,1}$  were interpreted as "poor reliability" ( $<0.40$ ), "good or satisfactory reliability" ( $\geq 0.40$  and  $\leq 0.75$ ) and "excellent reliability" ( $>0.75$ )<sup>(18,19)</sup>. In addition to ICC, standard error of measurement (SEM) and minimum detectable change (MDC) were determined for duty factor. Values were separated by muscle.

The SEM was calculated using the equation:  $SEM = SD\sqrt{1-ICC}$ . MDC was estimated based on the SEM. The formula for calculating MDC was  $MDC = SEM\sqrt{2}$ <sup>(20)</sup>. The Student's t-test was applied to pain intensity values reported before and after the first EMG recording and after the TENS intervention, with the  $\alpha$  level set at 0.05.

The responsiveness of duty factor to TENS-induced analgesia for each muscle (laterality disregarded) was calculated based on the two 300-second EMG recordings during mandibular rest, one before and the other after the 45-minute analgesic intervention. Effect size (ES) and standardized response mean (SRM) was used to classify the responsiveness variable. Effect size is calculated by dividing the average difference by the standard deviation of the first measurement. Average difference is calculated by subtracting the final measurements from the initial measurements. The SRM is a coefficient and was obtained by dividing the mean change by the standard deviation of the change. Values under 0.2 indicate insignificant responsiveness, values between 0.2 and 0.5, low responsiveness, values between 0.5 and 0.8, moderate responsiveness, and values equal to or greater than 0.8, excellent responsiveness of the instrument<sup>(21-23)</sup>.

### RESULTS

In the first EMG assessment, when participants reported moderate to severe pain, mean duty factor values were 33% of the total resting time for the temporal muscle, 38% for the masseter muscle, and 46% for the suprahyoids. After analgesia,



**Note:** TENS = transcutaneous electrical nerve stimulation

**Figure 2.** Mean values and standard deviation of the duty factor obtained in the evaluations performed before and after analgesia in 20 participants with temporomandibular disorder

**Table 1.** Mean (standard deviation) of duty factor to 20 participants in the first and second session

	Temporal muscle	Masseter muscle	Suprahyoid muscle
1 <sup>st</sup> Session pre TENS	33% (±20)	38% (±25)	46% (±25)
2 <sup>nd</sup> Session pre TENS	39% (±22)	37% (±22)	47% (±24)
ICC <sub>2,1</sub>	0.83*	0.97*	0.96*
SEM	8%	4%	5%
MDC	12%	6%	7%

\* Significant values ( $p < 0.05$ ) – Correlation coefficient

**Note:** TENS = transcutaneous electrical nerve stimulation; ICC<sub>2,1</sub> = intraclass correlation coefficient (2,1); SEM = standard error of the measurement; MDC = minimum detectable change

when participants reported mild or no pain, mean duty factor values for the same muscles, respectively, were 40%, 42% and 49% of total resting time. No statistically significant differences ( $p > 0.05$ ) were found between pre- and post-analgesia values (Figure 2).

Analysis of pre-analgesia mean and standard deviation values for duty factor in all 20 participants revealed that the temporal muscle presented a 6% increase in activation between one recording and the other. The masseter and suprahyoid muscles presented a 1% increase as compared to initial activation ( $p > 0.05$ ) (Table 1).

The application of the analgesia intervention was successful for all participants. Initially, after the assessment and before the first EMG session, the 20 participants reported pain above 4 on the VNS, considered of moderate or severe intensity. After applying the analgesic technique, a significant difference ( $p < 0.05$ ) was observed in the VNS, as all volunteers reported mild or no pain, i.e., pain below 4. Even with the standardization obtained in the assessment of all participants and the efficacy of analgesia, the muscle hyperactivity response during mandibular rest was not the same for all women.

In 13 participants, EMG activation of the masseter and anterior temporal muscles increased after analgesia and, in 7, activation during mild or no pain was less than during moderate or severe pain. We must clarify that the 13 participants who presented increased EMG activation of the masseter muscles

were not the same as those who presented increased temporal muscle activation. The same is true for the volunteers with reduced activation. With regards to the suprahyoid muscles, 10 participants presented lower EMG activation after analgesia, and the other 10 presented greater EMG activation.

The responsiveness of duty factor was tested for participants who displayed the expected resting electric activity response after analgesia, i.e., decreased muscle activity. Of these, 7 presented a 6% reduction in EMG activity of the temporal muscles when compared to the initial measurement. The suprahyoid muscles of the 10 participants presented a 14% decrease in electrical activation after analgesia. These data, together with the responsiveness values of duty factor, are presented in Table 2.

**Table 2.** Mean values of the difference of electromyographic activation and responsiveness values of duty factor in volunteers whose myoelectric activity reduced after analgesia

Reduction of activation after analgesia	Temporal muscle	Masseter muscle	Suprahyoid muscle
Mean	- 6%	- 9%	- 14%
ES	0.28	0.48	0.50
SRM	1.21	1.17	1.19

**Note:** ES = effect size; SRM = standardized response mean

## DISCUSSION

Despite the homogeneity obtained in the selected sample, duty factor presented different responses among the assessed individuals. In other words, after applying the analgesic intervention, different EMG activation responses were observed using the variable, such as the absence of any significant variation or increased/reduced EMG amplitude.

According to the adaptation to pain theoretical model adopted in this study<sup>(12,24,25)</sup>, the expected behavior of muscle activity during pain relief, in the absence of voluntary muscle function, that is, in mandibular rest, would be reduced hyperactivity of mandibular elevator muscles among all participants. The presence of muscle pain, according to the theory, generates an afferent signal, known as a reflex, which increases muscle activity, generating stress or fatigue, which would cause the muscle to present more pain and thus feed the pain-spasm-pain cycle. Reduced muscle electrical activity after analgesia is the expected result when using this resource, breaking the cycle to which the muscle is submitted<sup>(3)</sup>.

Such a heterogeneous response to analgesia has been observed in the literature<sup>(11,12)</sup>, the authors of one study conducted one 45-minute session of conventional TENS with 35 volunteers, using the same parameters as in the current study. The results, much like in this study, displayed the effectiveness of the therapy in reducing muscle pain and a variety of muscle responses to analgesia during rest.

However, there are studies that have found homogeneous results. In one study, 60 volunteers with TMD were submitted to TENS for 60 minutes and the results showed reduced EMG activity in the masticatory muscles<sup>(25)</sup>. Another study compared the application of two types of TENS in individuals with TMD. In 60-minute TENS sessions, using different parameters than those used in the current study, both motor- and sensory-level stimulation resulted in reduced activation of muscles during rest<sup>(26)</sup>.

One possible explanation for the heterogeneity of responses found in the present study is the muscle interaction of the analgesic recourse. Conventional TENS with the parameters used and sensory-level stimulation may not have been capable of producing tissue stimulation sufficient to generate altered levels of masticatory muscle activation, or altered levels of muscle activity or inactivity. Transcutaneous electrical nerve stimulation is frequently used in physical therapy to treat diseases, including TMD. When used conventionally, it acts on the neuromodulation of pain, preferably stimulating afferent A-beta fibers, which are superficial cutaneous nervous fibers<sup>(27,28)</sup>. This would explain why TENS was an excellent tool for relieving muscle pain in all patients, according to the results of the VNS, but was not efficient to alter the activation patterns of muscles during rest of individuals with Type 1a TMD.

Regardless of the post-analgesia results, the analyzed measurement properties demonstrated excellent reliability

of duty factor, with ICC<sub>2,1</sub> values greater than 0.80 for all the tested muscles. Minimum detectable change (MDC) is a very commonly analyzed measurement, especially in clinical practice, as it corresponds to the level of clinical importance for individuals. Considering temporal muscle duty factor, 10 participants presented a difference greater than 12% after the TENS intervention. Fourteen individuals presented a difference in masseter duty factor greater than 6%, and 12 participants presented a 7% difference in suprahyoid duty factor post-intervention. Thus, in clinical practice, this is the minimum difference in duty factor that would be expected after undergoing TENS therapy.

As the purpose of this study was to analyze the capacity of the variable to analyze the magnitude of change in given measurements, the responsiveness of duty factor was tested in participants who presented reduced myoelectric activity after analgesia, as expected. Responsiveness of each participant's duty factor was quantified through ES and SRM and the results allowed us to categorize all the tested muscles as presenting low responsiveness as expressed by ES and excellent responsiveness as expressed by SRM.

Even though the analysis of responsiveness was compromised by the variability of EMG responses found in participants after TENS, all of the analyzed groups consisted of at least seven participants. This sample size validates the analysis, as stated by Nickel et al.<sup>(1)</sup>, who after conducting sample size calculations in their study, concluded that the minimal number for duty factor analysis is seven participants per diagnostic group<sup>(1)</sup>.

The results support the introduction of EMG and muscle duty factor as a possible part of clinical history and physical examination for Type 1a TMD (myofascial) patients, so as to reliably measure activation time relative to a threshold of masticatory muscle effort. Muscle activation time, whether voluntary or involuntary, during muscle rest or contraction, can help identify situations of hyperactivation or hypoactivation that are a result, for example, of the pain inhibition reflex or a protective spasm<sup>(13)</sup>. This variable could be considered when formulating therapeutic conduct with the goal of altering the duration of a certain level of muscle activation.

However, due to the contradictory results regarding responsiveness, the use of duty factor may not be recommended in the follow-up of clinical responses to pain relief induced by high- and low-frequency TENS. Low effect size indicates that the variable presents poor capacity for identifying changes in muscle activation patterns after TENS. On the other hand, the excellent standardized response mean values found in this study can be interpreted coefficients demonstrating the effectiveness of TENS in reducing pain in the group of assessed myogenic TMD patients.

Other techniques for treating myogenic TMD can be considered for assessing the responsiveness of duty factor, such as the use of muscle relaxants or the contract-relax technique,

being as the measurement differentiates asymptomatic individuals from those with myogenic TMD<sup>(2)</sup> and presents excellent intrasession reliability.

## CONCLUSION

Duty factor presented excellent reliability. Responsiveness was low for effect size, and excellent for standardized response mean. The variable was considered to be a reliable tool for EMG analysis. Further studies are suggested to confirm the responsiveness of the variable.

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