

Original Research

Influence of body posture on surface electromyographic functional indices during maximum voluntary clenching



Joana Cabrita¹ , João Caramês^{1,2,3} , Duarte Marques^{1,2,3,*} 

¹ Faculty of Dental Medicine, University of Lisbon, Lisbon, Portugal

² Biomedical and Oral Sciences Research Unit (UICOB), LIBPhys-FCT UIDB/04559/2020, Lisbon, Portugal

³ Instituto de Implantologia, Lisbon, Portugal

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ABSTRACT

Objectives: To evaluate the within-session repeatability of surface electromyographic functional indices obtained with the Teethan[®] wireless system and to determine the influence of body posture during maximum voluntary clenching.

Methods: Thirty-one healthy dentate participants with no self-reported temporomandibular pain or dysfunction were enrolled in a repeated-measures study. Bilateral electromyographic recordings of the masseter and anterior temporalis muscles were obtained with the Teethan[®] system in sitting, standing, and supine postures. For each posture, three consecutive clenching trials were recorded without removing the electrodes. Descriptive statistics, intraclass correlation coefficients, repeated-measures analysis of variance, Bonferroni-adjusted comparisons, and Pearson correlation coefficients were calculated as supplementary association analyses.

Results: No significant differences among body postures were observed for most indices, except for the masseter symmetry index, which showed higher values in sitting than in supine posture. Because postures were assessed in a fixed order, this difference should be interpreted cautiously. Most pairwise correlations between repeated trials were moderate to strong. Overall intraclass correlation coefficient values for average measures ranged from 92.2% to 96.8%, indicating excellent reliability. Single-measure reliability ranged from 79.8% to 91.0%, the within-subject coefficient of variation from 9.3% to 23.1%, and Bland-Altman analysis showed negligible systematic bias.

Conclusions: Within the limitations of this study, the evaluated indices demonstrated high within-session repeatability and were minimally influenced by body posture during maximum voluntary clenching in healthy adults. (Rev Port Estomatol Med Dent Cir Maxilofac. 2026;67(3):139-149)

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* Corresponding author.

E-mail address: duarte.marques@edu.ulisboa.pt (Duarte Marques).

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Introduction

The stomatognathic system plays a crucial role in postural control and consists of the temporomandibular joint (TMJ), dental and periodontal structures, and the masticatory neuromuscular system.¹ The TMJ forms part of the functional cranio-cervico-mandibular complex through anatomical, biomechanical, and neurophysiological connections with the cervical region.^{2,3} Variations in cervical posture can therefore influence mandibular movement patterns and masticatory muscle activity, owing to the continuity of the muscular and ligamentous chains between the mandibular and cervical region.²⁻⁵ Functional changes in head posture may influence occlusal parameters and mandibular function. Anterior head displacement is often associated with neck and shoulder tension, occlusal disturbances, and temporomandibular discomfort.⁶

Mastication, as an essential function of the stomatognathic system, depends on occlusal contact and force distribution.⁷⁻⁹ In clinical settings, occlusal adjustments are frequently required during restorative and rehabilitative procedures to ensure harmonious contacts and balanced loading.^{8,10,11} Although the stomatognathic system has significant adaptive capacity, some patients may experience discomfort or pain, particularly in the presence of occlusal interferences during dynamic mandibular movements.⁸

Occlusal stability is a physiological state that depends on the interplay among the TMJ, dentition, and masticatory muscles, with ideal contact occurring along the long axes of the teeth to maintain periodontal health and joint balance.^{6,12,13} Occlusal equilibration is a mechanical intervention that adjusts occlusal morphology to distribute stress, synchronize contacts, and harmonize muscle function and cusp relations, thereby optimizing muscular activity and establishing a stable, symptom-free masticatory system.^{6,14-16}

Advances in digital technology now offer sophisticated tools for occlusal evaluation and analysis.¹⁴ A novel approach to adjusting intraoral appliances and prostheses involves the analysis of masticatory muscle surface electromyography (sEMG) activity, facilitating the evaluation of muscle synergy and balance.¹⁷⁻¹⁹ Evidence suggests that symmetry in electromyography (EMG) activity is critical for oral and functional rehabilitation.^{19,20} A novel wireless sEMG device – Teethan® (Teethan® S.p.A., Milan, Italy) has been introduced to analyze temporalis and masseter muscle activity during clenching, providing standardized functional indices to assess it.²¹ Despite its potential, studies evaluating the use of sEMG in oral rehabilitation remain limited.

Because body posture may affect sEMG recordings, particularly during procedures commonly performed in the supine posture, such as oral rehabilitation and occlusal splint adjustment, it is important to determine whether posture influences Teethan-derived indices. Therefore, this study aimed to evaluate the within-session repeatability of these functional indices and to determine the influence of sitting, standing, and supine postures during maximum voluntary clenching in healthy dentate adults. The null hypothesis was that body posture would not significantly affect the recorded functional indices.

Materials and methods

This exploratory within-session reliability and agreement study employed a repeated-measures design across three body postures (sitting, standing, and supine). The sample included 31 healthy volunteers recruited from the students and staff at (Faculty of Dental Medicine, University of Lisbon, Lisbon, Portugal). We did not perform a formal a priori sample size calculation because the sample size was based on an internal pilot investigation conducted by the same group with 14 volunteers using the same device and the same three postures.²² A post-hoc sensitivity analysis confirmed the adequacy of the achieved sample: with 31 participants, the study had 80% power to detect a between-posture effect of Cohen's $f = 0.23$ (partial $\eta^2 = 0.052$) in a three-level repeated-measures analysis of variance (ANOVA) ($\alpha = 0.05$), and allowed the intraclass correlation coefficient (ICC) to be estimated with a 95% confidence interval (CI) width of approximately 0.12 for an expected value of 0.90.²³ A total of 279 sEMG recordings were obtained (31 participants $\times$ 9 trials); however, all inferential analyses were conducted at the participant level, accounting for the repeated-measures structure. We did not perform a formal a priori sample size calculation based on ICC because this investigation was designed as an exploratory reliability and agreement study.

All participants provided written informed consent before inclusion. The study protocol complied with the Declaration of Helsinki and was approved by the institutional ethics committee (approval no. CE-FMDUL202321; approved on 20/11/2025).

Eligibility criteria required a minimum age of 18 years, complete natural dentition, and absence of self-reported temporomandibular pain or dysfunction based on a validated temporomandibular disorder (TMD) pain screening questionnaire.²⁴ Individuals with tooth loss, prosthetic restorations affecting occlusal contacts, or TMD symptoms were excluded. A complete Diagnostic Criteria for Temporomandibular Disorders (DC/TMD) clinical examination was not performed. Moreover, participants' screening did not systematically assess or record specific occlusal characteristics, including crossbite, open bite, deep overbite, and dental crowding.

sEMG activity was recorded using the Teethan® wireless sEMG device, which comprises four differential electrodes connected to proprietary analysis software via USB transmission. Two electrodes recorded the activity of the anterior temporalis muscles (left and right), and two recorded the superficial masseter muscles (left and right). According to the manufacturer, the Teethan® system acquires surface electromyographic signals using differential electrodes with integrated amplification and digital processing. Muscle activity was expressed in microvolts (μV), and the software automatically processed it to generate a set of standardized functional indices under two conditions: calibration (clenching on cotton rolls) and test (clenching on natural dentition).^{21,24} The software (version 3.1.0) automatically filters, rectifies, and normalizes the signals from the calibration clenching performed on cotton rolls, and computes the functional indices from the most stable portion of each 5-second maximum voluntary clenching task. The manufacturer does not disclose the proprietary sampling frequency, filter characteristics, and signal-processing algorithms.

The following indices were analyzed:

- Percent Overlapping Coefficient (POC): Quantifies bilateral muscle symmetry for each pair of homologous muscles (masseter and temporalis). This index reflects imbalance in the evaluated muscle pairs, indicating the predominance of either the right or left temporalis muscles (POCt; corresponding to the anterior quadrants) or the right or left masseter muscles (POCm; corresponding to the posterior quadrants).^{21,24}
- Barycenter (BAR): Represents the occlusal barycenter position by evaluating the overlap between temporalis and masseter muscle activity. Unlike the POC, which compares analogous muscles, the BAR indicates occlusal force distribution. For example, posterior BAR values reflect greater molar contact and increased masseter activity.^{21,25}
- Torsion: Measures mandibular torsion in the horizontal plane, calculated from crossed muscle pairs (right temporalis vs. left masseter and left temporalis vs. right masseter).^{21,25,26}
- Impact (IMP): Reflects the overall muscular activity and is considered an indirect index related to clenching intensity, with normal reference values between 100% and 115%.^(21,27) Actual bite force was not measured directly in this study.

- Asymmetry (ASIM): Compares total right-side and left-side muscle activation. Positive values indicate right-side predominance; negative values indicate left-side predominance.^{21,27}

A single trained operator performed all recordings following the manufacturer's standardized protocol to ensure methodological consistency. Before electrode placement, the skin was cleaned with 70% isopropyl alcohol to reduce impedance and improve signal quality. The wireless differential electrodes were used according to the manufacturer's specifications and were positioned directly on the skin without additional conductive gel. The anterior temporalis muscle electrodes were placed by identifying the anterior bundle through palpation while the participant clenched. These electrodes were positioned near the coronal suture, approximately 2 cm from the zygomatic process. Similarly, the superficial masseter muscle electrodes were placed by palpating the muscle belly during clenching, positioning them parallel to the muscle fibers along the line connecting the outer corner of the eye to the mandibular angle. Symmetrical electrode positioning was maintained between the left and right sides, following the manufacturer's instructions (Figures 1 and 2).



Figure 1. Placement of the temporal and masseter muscle electrodes – frontal view.



Figure 2. Placement of the temporal and masseter muscle electrodes – right lateral view.

All recordings were performed in the same quiet clinical room under standardized environmental conditions, with participants tested at similar times of day to minimize potential circadian influences. The three body postures were assessed in a fixed sequence—seated, standing, and supine—for all participants. Before data acquisition, participants were familiarized with the task through practice attempts and standardized verbal instructions. They were also asked to avoid strenuous physical exercise and caffeinated beverages for at least 2 hours before testing.

Calibration was performed with participants in the sitting posture, in accordance with the manufacturer's instructions. Two cotton rolls were placed bilaterally in the posterior region (premolar–molar area), and participants were instructed to maintain maximal voluntary clenching for 5 seconds. They were instructed to perform each clench in maximum intercuspation and received standardized verbal instructions during all recordings, including verbal encouragement to ensure maximum effort. The same operator repeated this calibration procedure three times to ensure accuracy. The manufacturer does not disclose the algorithm by which the proprietary software combines the three calibration acquisitions to derive the normalization reference.

Following calibration, the same trained operator recorded a total of nine 5-second maximal voluntary contraction trials. Participants clenched without cotton rolls in three consecutive trials in each of the three evaluated postures:

1. Sitting: The participant was seated with their torso perpendicular to the floor, legs uncrossed, hands resting on their knees, and head aligned in a neutral position.
2. Standing: The participant stood upright with feet shoulder-width apart, arms relaxed alongside their body, and head straight.
3. Supine: The participant lay in a fully reclined dental chair (backrest angle approximately 180°) without the use of additional pillows. The chair headrest was adjusted individually to support the head and maintain a comfortable neutral cervical posture, with the face oriented upward.

In all postures, participants were instructed to maintain a relaxed, natural head and neck position without intentional flexion or extension. A standardized rest interval of approximately 1 minute was allowed between consecutive trials and posture changes to minimize muscle fatigue. Perceived fatigue and discomfort were not formally assessed using a standardized scale; however, no spontaneous complaints of pain, discomfort, or fatigue were reported during the experimental session. The sEMG electrodes remained attached throughout all nine trials across the three postures. Intra-observer agreement was not formally evaluated.

Following each recording session, the software generated a comprehensive report containing all the indices described above, minimizing the influence of external factors.⁽²¹⁾ A total of 279 sEMG recordings were obtained across the three body postures (sitting, standing, and supine).

Before statistical analysis, the exported data were checked for transcription errors, implausible values, missing data, and

outliers. Range checks and visual inspection of distributions were performed to confirm the plausibility of the descriptive results. These checks did not exclude any recordings, and all 279 acquisitions were retained for analysis.

Descriptive statistics were calculated from participant-level averages across trials for each posture, whereas reliability and repeated-measures analyses used all individual trials. Body postures were assessed in a fixed sequence (sitting, standing, and supine) to maintain a consistent experimental workflow. Descriptive statistics included mean, standard deviation, minimum, maximum, median, and interquartile range calculated for each index by body posture. Data distribution and plausibility were assessed visually using boxplots.

Reliability was assessed using ICCs based on a two-way mixed-effects model, absolute agreement, and average-measures interpretation across the three repeated trials, with corresponding 95% CIs. Because the intended clinical application corresponds to the mean of repeated trials rather than a single trial, average-measures coefficients [ICC(3,k)] were selected as the primary reliability estimate; accordingly, these values reflect the reliability of the mean of three trials, not a single measurement. The ICC values were interpreted as follows: excellent (> 90%), good (71–90%), moderate (51–70%), fair (31–50%), and poor (< 31%). Measurement error was characterized by the standard error of measurement (SEM; calculated as the within-subject standard deviation), the minimal detectable change at the 95% confidence level ($MDC_{95} = 1.96 \times \sqrt{2} \times SEM$), and the within-subject coefficient of variation. Single-measure ICCs [ICC(3,1)] were derived alongside the average-measure coefficients. Within-session agreement across repeated trials was assessed with Bland–Altman limits of agreement.

A 3 × 3 repeated-measures factorial ANOVA was performed for each functional index, with body posture (sitting, supine, and standing) and trial repetition (trials 1–3) as within-subject factors. Main effects of body posture and trial repetition, as well as the posture–trial interaction, were evaluated. Sphericity was verified with Mauchly's test; when violated, Greenhouse–Geisser corrections were used. Pairwise comparisons were adjusted using the Bonferroni correction as needed. Effect sizes were reported using partial η^2 . Residual normality was inspected using Shapiro–Wilk tests and Q–Q plots. When normality assumptions were markedly violated, non-parametric Friedman tests with Holm-adjusted Conover post-hoc comparisons were conducted as sensitivity analyses. Pearson's correlation coefficients were calculated as supplementary analyses to describe pairwise associations between repeated trials within each body posture. These correlations were not interpreted as agreement estimates.

Paired mean differences and 95% CIs were calculated for the statistically significant posture comparisons. Statistical significance was set at $\alpha = 0.05$. All analyses were performed using SPSS Statistics software, version 29.0 (IBM Corp., Chicago, USA).

Results

Thirty-one healthy participants were included in the analysis: 22 women and 9 men, with a mean age of 37.0 ± 11.0 years (range, 21–60 years). All participants exhibited complete natu-

ral dentition and reported no temporomandibular pain or dysfunction based on the screening questionnaire. A total of 279 sEMG recordings were obtained across the three body postures (sitting, standing, and supine).

Table 1 summarizes the mean (μ) and standard deviation (σ) for age and each functional index, overall and according to body posture, using participant-level averages across the three repeated trials within each posture. Table 2 presents the median, interquartile range, minimum, and maximum values for all functional indices according to body posture. Median values were highly comparable across sitting, supine, and standing postures, with only POCm showing a modest reduction in the supine posture and IMP exhibiting greater dispersion and higher extreme values. Overall, these descriptive statistics support the substantial overlap and clinical stability of the evaluated sEMG indices across postures.

Figure 3 displays boxplots of the six functional indices according to body posture. The plots demonstrate considerable overlap in medians and interquartile ranges among postures, confirming similar distributions across variables. IMP showed greater variability and several upper outliers, whereas POCm showed a slight downward shift in the supine posture.

Overall ICC values were excellent for all measured indices, ranging from 92.2% to 96.8%, indicating high within-session reliability of the average of the three repeated trials. When

analyzed by body posture, POCm and ASIM maintained excellent ICC values across all postures, while the remaining indices showed good-to-excellent ICC values depending on posture (Table 3).

Table 4 presents the results of the 3×3 repeated-measures factorial ANOVA used to evaluate the effects of body posture, trial repetition, and the posture-trial interaction on POCT, POCm, BAR, TORS, IMP, and ASIM. No significant main effect of trial repetition or posture-trial interaction was observed for any functional index, indicating no evidence of systematic fatigue or learning effects across repeated clenching trials. A significant main effect of body posture was observed only for POCm ($F(2,60) = 5.02$, $p = .010$, $\eta^2p = .143$), with higher values in the sitting posture than in the supine posture ($p = .017$). No statistically significant body-posture effects were observed for POCT, BAR, TORS, IMP, or ASIM.

Pearson correlation coefficients were calculated as supplementary analyses to describe pairwise associations between repeated trials within each body posture (Table 5). Most pairwise correlations were positive and statistically significant, indicating moderate-to-strong associations among repeated measurements. The lowest association was observed for TORS in the sitting posture, with a correlation range of 0.32–0.69 and one non-statistically significant pairwise comparison. Because correlation does not assess agreement, these results were in-

Table 1. Mean and standard deviation of age and surface electromyographic functional indices.

Index	Mean (μ)				Standard deviation (σ)			
	Overall	Sitting	Supine	Standing	Overall	Sitting	Supine	Standing
Age	37.03	–	–	–	11.03	–	–	–
POCT	68.24	70.74	66.54	67.42	21.28	17.35	23.35	23.10
POCm	61.46	64.18	58.43	61.79	28.34	25.44	29.74	30.23
BAR	63.50	63.33	62.82	64.36	17.45	16.99	18.28	17.59
TORS	75.57	77.33	74.05	75.33	17.28	12.88	18.57	19.99
IMP	127.06	122.15	123.91	135.13	81.38	64.58	79.88	98.26
ASIM	-8.06	-7.38	-7.49	-9.30	31.53	28.69	32.64	34.01

Values for POCT, POCm, BAR, TORS, IMP, and ASIM were calculated from participant-level averages across the three repeated trials within each body posture. Overall values were calculated across participant-level posture averages. ASIM – asymmetry index; BAR – barycenter index; IMP – impact index; POCm – masseter symmetry index; POCT – temporal symmetry index; TORS – torsion index.

Table 2. Median, interquartile range, minimum, and maximum values of surface electromyographic functional indices.

Index	Sitting (median [IQR], min-max)	Supine (median [IQR], min-max)	Standing (median [IQR], min-max)
POCT	78.82 [24.44], 16.37–88.92	79.94 [32.05], 2.14–88.62	80.50 [29.13], 2.84–88.26
POCm	76.99 [30.89], 0.81–88.57	66.69 [40.19], 0.14–88.48	77.21 [42.45], 0.09–88.26
BAR	63.03 [17.74], 23.24–90.03	58.87 [27.11], 27.37–88.58	67.24 [27.18], 23.48–90.62
TORS	81.87 [14.78], 46.49–91.36	79.50 [16.60], 2.82–91.16	82.60 [17.42], 4.29–92.10
IMP	101.73 [83.19], 24.74–314.99	111.53 [79.36], 22.06–425.97	117.81 [91.14], 14.04–535.75
ASIM	-1.57 [41.10], -80.58–52.00	-4.58 [37.99], -87.52–72.78	-7.70 [41.51], -85.15–74.77

Values were calculated from participant-level averages across the three repeated trials within each body posture. ASIM – asymmetry index; BAR – barycenter index; IMP – impact index; IQR – interquartile range; POCm – masseter symmetry index; POCT – temporal symmetry index; TORS – torsion index.

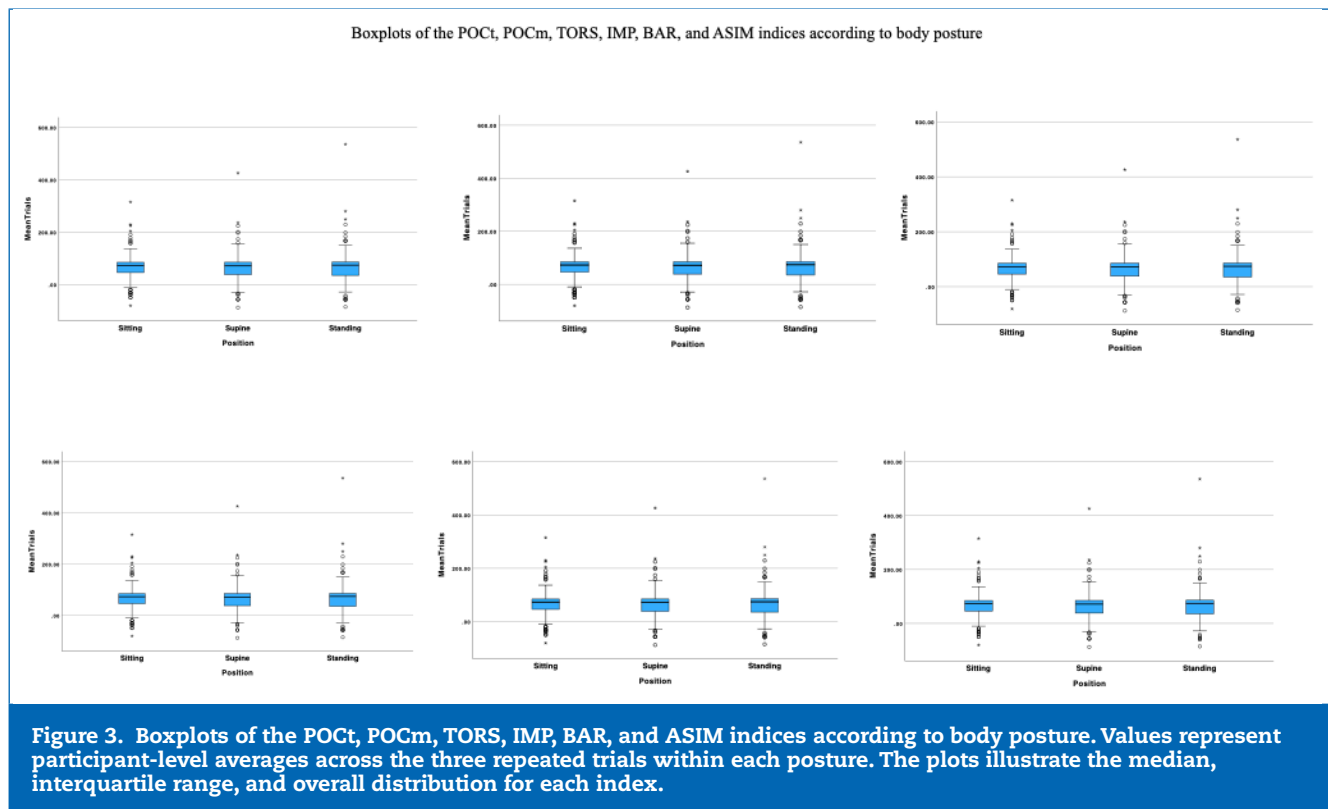


Table 3. Intraclass correlation coefficients and corresponding 95% confidence intervals.

Index	ICC			
	Overall	Sitting	Supine	Standing
POct	94.6% [92.4; 96.3] / 85.4% [80.2; 89.7]	81.7% [66.8; 90.6] / 59.8% [40.1; 76.3]	98.1% [96.6; 99.0] / 94.5% [90.4; 97.1]	98.4% [97.0; 99.2] / 95.3% [91.5; 97.6]
POCm	96.5% [95.1; 97.6] / 90.2% [86.6; 93.1]	92.2% [85.9; 96.0] / 79.8% [67.0; 88.9]	97.0% [94.5; 98.5] / 91.5% [85.1; 95.6]	99.4% [99.0; 99.7] / 98.2% [97.1; 99.1]
BAR	92.2% [89.0; 94.6] / 79.8% [73.0; 85.4]	81.8% [66.9; 90.6] / 60.0% [40.3; 76.3]	96.7% [94.0; 98.3] / 90.7% [83.9; 95.1]	97.5% [95.4; 98.7] / 92.9% [87.4; 96.2]
TORS	94.5% [92.2; 96.2] / 85.1% [79.8; 89.4]	78.1% [60.2; 88.7] / 54.3% [33.5; 72.3]	97.5% [95.5; 98.7] / 92.9% [87.6; 96.2]	98.7% [97.7; 99.4] / 96.2% [93.4; 98.2]
IMP	95.6% [93.9; 97.0] / 87.9% [83.7; 91.5]	88.2% [78.6; 93.9] / 71.4% [55.0; 83.7]	96.6% [93.8; 98.2] / 90.4% [83.5; 94.8]	98.3% [96.9; 99.1] / 95.1% [91.2; 97.3]
ASIM	96.8% [95.5; 97.8] / 91.0% [87.6; 93.7]	91.3% [84.2; 95.5] / 77.8% [64.0; 87.6]	98.7% [97.6; 99.3] / 96.2% [93.1; 97.9]	99.2% [98.5; 99.6] / 97.6% [95.6; 98.8]

ICC values refer to average measures across the three repeated trials and are presented overall and according to body posture. ASIM – asymmetry index; BAR – barycenter index; CI – confidence interval; ICC – intraclass correlation coefficient; IMP – impact index; POCm – masseter symmetry index; POct – temporal symmetry index; TORS – torsion index. Within each cell, values are presented as average-measure ICC(3,k) / single-measure ICC(3,1), each with its 95% CI.

interpreted as supplementary association analyses rather than primary reliability estimates.

Single-measure reliability [ICC(3,1)] ranged from 79.8% to 91.0% overall, consistent with the average-measure estimates [ICC(3,k)] reported above. Measurement error was small relative to each index's range. Overall, the SEM (defined as the within-subject standard deviation) ranged from 7.0 (TORS) to 29.4 (IMP), the MDC95 from 19.4 to 81.6, and the within-subject

coefficient of variation from 9.3% to 23.1% for the magnitude-based indices. The signed asymmetry index (ASIM) was excluded from the coefficient of variation. Table 6 presents the corresponding single-measure coefficients and error metrics by body posture.

Bland-Altman analysis of the repeated trials showed negligible systematic bias for all indices, with the limits of agreement displayed in Figure 4. The significant body-posture effect

Table 4. Results of the 3 × 3 repeated-measures factorial ANOVA.

Variable	Effect	F(df)	p value	Partial η^2
POCt	Body posture	F(2,60) = 1.43	.247	.045
	Trial repetition	F(2,60) = 0.17	.846	.006
	Posture-trial interaction	F(4,120) = 0.58	.677	.019
POCm	Body posture	F(2,60) = 5.02	.010	.143
	Trial repetition	F(2,60) = 1.44	.245	.046
	Posture-trial interaction	F(4,120) = 1.61	.175	.051
BAR	Body posture	F(2,60) = 0.31	.738	.010
	Trial repetition	F(2,60) = 2.14	.127	.067
	Posture-trial interaction	F(4,120) = 0.75	.562	.024
TORS	Body posture	F(2,60) = 0.84	.438	.027
	Trial repetition	F(2,60) = 0.99	.377	.032
	Posture-trial interaction	F(4,120) = 0.49	.747	.016
IMP	Body posture	F(2,60) = 1.62	.207	.051
	Trial repetition	F(2,60) = 0.68	.509	.022
	Posture-trial interaction	F(4,120) = 0.30	.876	.010
ASIM	Body posture	F(2,60) = 0.34	.710	.011
	Trial repetition	F(2,60) = 0.07	.933	.002
	Posture-trial interaction	F(4,120) = 1.15	.336	.037

The model evaluated the effects of body posture, trial repetition, and posture-trial interaction on each functional index. Body posture included sitting, supine, and standing conditions; trial repetition included trials 1–3 within each posture. ASIM – asymmetry index; BAR – barycenter index; df – degrees of freedom; IMP – impact index; POCm – masseter symmetry index; POCt – temporal symmetry index; TORS – torsion index. For the significant main effect of body posture on POCm, the paired mean difference between the sitting and supine postures was 5.75 percentage points (95% CI, 1.82 to 9.67).

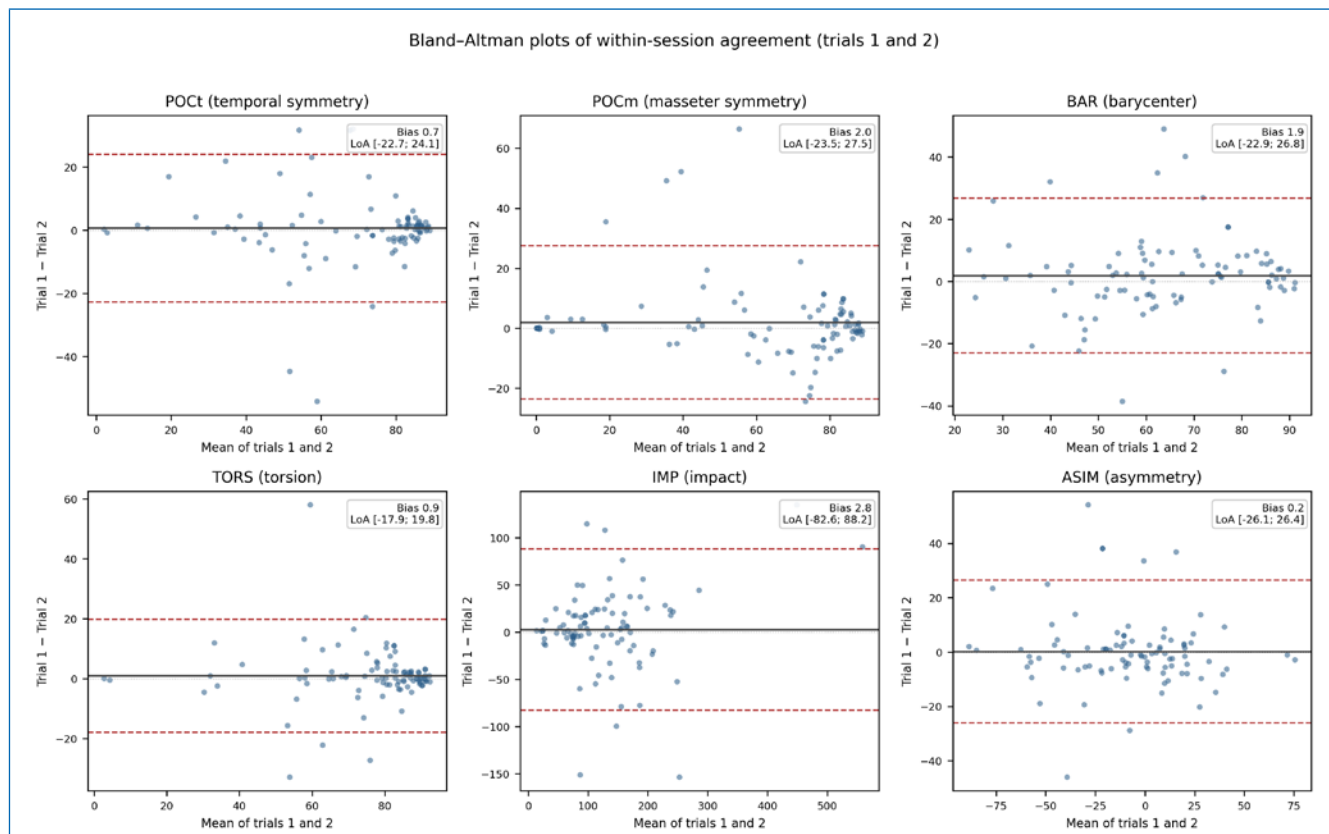


Figure 4. Bland-Altman plots of within-session agreement between the first two repeated trials for the six functional indices (POCt, POCm, BAR, TORS, IMP, and ASIM). The solid line denotes the mean difference (bias), and the dashed lines denote the 95% limits of agreement.

Table 5. Pearson correlation coefficients between repeated trials within each body posture.

Variable	Body posture	r range	p value range
POCt	Sitting	0.44–0.75	<.001–.013
	Supine	0.93–0.96	<.001
	Standing	0.95–0.96	<.001
POCm	Sitting	0.72–0.96	<.001
	Supine	0.85–0.96	<.001
	Standing	0.98–0.99	<.001
BAR	Sitting	0.42–0.85	<.001–.018
	Supine	0.87–0.95	<.001
	Standing	0.92–0.94	<.001
TORS	Sitting	0.32–0.69	<.001–.082
	Supine	0.91–0.96	<.001
	Standing	0.95–0.97	<.001
IMP	Sitting	0.60–0.90	<.001
	Supine	0.89–0.94	<.001
	Standing	0.95–0.98	<.001
ASIM	Sitting	0.66–0.89	<.001
	Supine	0.96–0.97	<.001
	Standing	0.97–0.98	<.001

Values represent the range of pairwise Pearson correlation coefficients between trials 1–3 for each functional index and body posture. ASIM – asymmetry index; BAR – barycenter index; IMP – impact index; POCm – masseter symmetry index; POCt – temporal symmetry index; TORS – torsion index. Pearson correlation coefficients describe associations between repeated trials and should not be interpreted as agreement estimates.

on POCm corresponded to a paired mean difference of 5.75 percentage points (95% CI, 1.82 to 9.67) between the sitting and supine postures. Single-measure reliability was posture-dependent: in the sitting posture it decreased to the moderate range for several indices (e.g., POCt 59.8%, BAR 60.1%, TORS 54.6%), whereas it remained good to excellent in the supine and standing postures (Table 6). The impact index (IMP) showed the largest measurement error, with an overall MDC95 of 81.6 and a within-subject coefficient of variation of 23.1%.

Discussion

The present study investigated the within-session repeatability of a wireless sEMG system (Teethan®) and the potential influence of body posture on masticatory muscle activity during maximum voluntary clenching. The results demonstrated excellent overall within-session reliability for all functional indices, with ICC values exceeding 90%. The only statistically significant variation was in POCm, which was slightly higher in the sitting posture than in the supine. These findings indicate that the evaluated functional indices demonstrated high within-session repeatability and were minimally influenced by body posture under the conditions of this study. Because no comparison with a conventional multichannel electromyography system was performed, the present results should not be interpreted as evidence of criterion validity.

The high repeatability observed is consistent with a previous report demonstrating acceptable within-session repeatability of these functional indices.⁽²¹⁾ However, repeatability

Table 6. Standard error of measurement (SEM), minimal detectable change (MDC95), and within-subject coefficient of variation (CV%) of the functional indices, overall and by body posture.

Index	Body posture	SEM	MDC95	CV%
POCt	Overall	8.54	23.67	12.5%
	Sitting	12.74	35.31	18.0%
	Supine	5.51	15.29	8.3%
	Standing	5.01	13.88	7.5%
POCm	Overall	9.15	25.36	14.9%
	Sitting	12.22	33.87	19.4%
	Supine	8.83	24.48	15.2%
	Standing	4.01	11.12	6.6%
BAR	Overall	8.42	23.34	13.3%
	Sitting	12.46	34.54	19.8%
	Supine	5.70	15.81	9.4%
	Standing	4.77	13.22	7.6%
TORS	Overall	7.00	19.40	9.3%
	Sitting	10.36	28.71	13.4%
	Supine	5.04	13.96	6.9%
	Standing	3.90	10.82	5.1%
IMP	Overall	29.45	81.64	23.1%
	Sitting	38.01	105.35	31.0%
	Supine	25.27	70.03	20.7%
	Standing	21.96	60.88	16.5%
ASIM	Overall	9.73	26.98	–
	Sitting	14.53	40.26	–
	Supine	6.38	17.67	–
	Standing	5.22	14.46	–

ASIM – asymmetry index; BAR – barycenter index; CV% – within-subject coefficient of variation, computed as the within-subject standard deviation divided by the grand mean; IMP – impact index; MDC95 – minimal detectable change at the 95% level ($1.96 \times \sqrt{2} \times \text{SEM}$); POCm – masseter symmetry index; POCt – temporal symmetry index; SEM – standard error of measurement (equal to the within-subject standard deviation); TORS – torsion index. CV% is not reported for ASIM, a signed index centered near zero. Values are expressed in the native units of each index.

reflects measurement consistency and should not be equated with validity or diagnostic utility. A previous pilot study⁽²¹⁾ revealed strong within-subject correlations across repeated trials, consistent with the present results.

By extending the evaluation to three body postures, the present study expands on previous evidence, demonstrating that sEMG functional indices exhibit robust repeatability and are largely unaffected by postural variations. These results suggest that body posture had limited influence on most Teethan®-derived indices under the present experimental conditions. The only exception was a modest increase in POCm in the sitting posture compared with the supine posture ($F(2,60) = 5.02$, $p = 0.010$, $\eta^2p = 0.143$). This difference may reflect posture-related variation in masseter recruitment and cervico-mandibular co-activation, consistent with previous electromyographic studies describing postural modulation of jaw and neck muscle activity in healthy adults.^{25,29} Nevertheless, because a fixed posture sequence was implemented, potential order, learning, or accommodation effects cannot be ruled out.²⁶

Prior work established that standardized protocols, operator consistency, and accurate electrode placement are critical

for reliable sEMG of masticatory muscles and that standardized indices can improve analytical reliability.^{25,26,28} The pilot investigation evaluating the repeatability of Teethan® indexes during maximum voluntary clenching reported generally high within-subject repeatability of the device, although with variability across indices, and confirmed the usefulness of pairwise correlations for quantifying within-session stability.²¹

The literature on the clinical discriminative validity of sEMG for TMDs remains inconsistent. Some investigations have reported asymmetry or activity differences between TMD patients and controls, whereas others have not identified significant asymmetry despite variations in overall muscle activity.³⁰⁻³³ A recent systematic review highlighted that methodological heterogeneity, particularly regarding electrode positioning and data processing, contributes to divergent results.³⁴ In this context, the present investigation was intentionally limited to assessing repeatability and posture effects in healthy, fully dentate volunteers, representing a necessary step before exploring diagnostic or prognostic applications.

Methodologically, the present study followed a strict within-session design (three trials per posture, electrodes kept stable), in accordance with prior recommendations stressing the importance of operator expertise and electrode positioning for reproducibility.^{26,34} ICC estimates were used as the primary reliability measure, while Pearson correlations were interpreted only as supplementary descriptions of associations among repeated trials. Compared with previous studies restricted to a single posture during maximum clenching²¹, the present three-posture framework suggests that the evaluated indices can be recorded consistently across standardized body postures within a single session. However, these findings should not be interpreted as evidence that posture standardization is unnecessary.

Despite its strengths, this study has several limitations to consider when interpreting its findings. The sample consisted exclusively of healthy dentate adults without self-reported TMD symptoms. Participants were screened for temporomandibular pain or dysfunction using a validated questionnaire rather than a complete DC/TMD clinical examination; therefore, subclinical or undiagnosed temporomandibular disorders cannot be fully excluded. The unequal sex distribution may have contributed to interindividual variability and may limit the generalizability of the findings. Although the repeated-measures design reduced the influence of between-participant characteristics on posture comparisons, the study was not specifically designed or powered to investigate sex-related differences in the electromyographic indices.

The investigation was limited to within-session repeatability, so it did not evaluate between-session or inter-operator reliability. Previous sEMG studies also highlight the importance of assessing repeatability across serial or repeated maximum voluntary contraction recordings.^{35,36} The results, therefore, apply primarily to controlled, short-term conditions. Although a single trained operator performed all measurements during the same session and without electrode repositioning, intra-observer agreement was not formally assessed. Therefore, residual operator-related measurement variability cannot be completely excluded.

The electromyographic recordings were obtained only during maximum voluntary clenching and cannot be extrapolated to other functional tasks or mandibular activities. Body postures were assessed in a fixed sequence rather than in randomized order; therefore, potential learning, accommodation, or fatigue effects cannot be excluded and may have contributed to the modest positional difference observed for POCm. Because body posture and measurement order were inherently confounded in this design, the positional effect observed for the masseter symmetry index cannot be causally attributed to posture alone. Finally, because no comparison was made with a reference electromyography system, the present findings do not establish criterion validity.

From a measurement-error standpoint, single-measure reliability was posture-dependent, decreasing to the moderate range in the sitting posture for several indices, while remaining good to excellent in the supine and standing postures. Together with the comparatively large minimal detectable change and within-subject coefficient of variation of the impact index, these findings reinforce the recommendation to base clinical interpretation on the average of repeated acquisitions rather than on a single clench, particularly for impact-related readings and when recording in the sitting posture.

Future research should extend the analysis to symptomatic populations, including patients with temporomandibular disorders, bruxism, or complex prosthetic rehabilitations, to determine whether postural influences or neuromuscular asymmetries become more pronounced under pathological or functionally altered conditions.³⁷⁻⁴⁰ Moreover, integrating sEMG with digital occlusal mapping or three-dimensional kinematic analysis could enhance understanding of how muscle coordination relates to occlusal force distribution and joint loading. Longitudinal research assessing sEMG indices before and after prosthodontic treatment would clarify whether improved muscle symmetry correlates with clinical outcomes such as comfort, masticatory efficiency, and prosthesis longevity. Whether such measurements improve diagnostic accuracy, treatment decisions, or clinical outcomes in prosthodontic rehabilitation remains to be established.

Conclusions

Within the limitations of this study, surface electromyographic functional indices derived from the evaluated system demonstrated excellent within-session repeatability during maximum voluntary clenching in healthy dentate adults. Body posture did not significantly influence most indices, except for a modest difference in the POCm between sitting and supine postures. These findings do not establish criterion validity, between-session reliability, or applicability to symptomatic or prosthodontically rehabilitated populations.

Conflict of interest

The authors have no conflicts of interest to declare.

Ethical disclosures

Protection of human and animal subjects. The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Joana Cabrita: Conceptualization; Formal analysis; Investigation; Methodology; Writing – original draft. **João Caramês:** Conceptualization; Supervision; Writing – review & editing. **Duarte Marques:** Formal analysis; Methodology; Supervision; Writing – review & editing.

ORCID

Joana Cabrita  0000-0002-4869-1053

João Caramês  0000-0002-5544-3744

Duarte Marques  0000-0003-1966-8281

REFERENCES

- Faralli MM, Calenti CC, Ibba MC, Ricci GG, Frenguelli AA. Correlations between posturographic findings and symptoms in subjects with fractures of the condylar head of the mandible. *Eur Arch Otorhinolaryngol*. 2009;266(4):565-70.
- Cuccia A, Caradonna C. The relationship between the stomatognathic system and body posture. *Clinics (Sao Paulo)*. 2009;64(1):61-6.
- Seth-Johansen C, Gotfredsen K. Validity and reliability of digital occlusal analyzing methods in Dentistry. A systematic review. *J Dent*. 2025;163:106124.
- Kitsoulis P, Marini A, Iliou K, Galani V, Zimpis A, Kanavaros P, et al. Signs and symptoms of temporomandibular joint disorders related to the degree of mouth opening and hearing loss. *BMC Ear Nose Throat Disord*. 2011;11:5.
- Kang JH. Effects on migraine, neck pain, and head and neck posture, of temporomandibular disorder treatment: study of a retrospective cohort. *Arch Oral Biol*. 2020;114:104718.
- Haralur SB, Al-Gadhaan SM, Al-Qahtani AS, Mossa A, Al-Shehri WA, Addas MK. Influence of functional head postures on the dynamic functional occlusal parameters. *Ann Med Health Sci Res*. 2014;4(4):562-6.
- Martinez-Gomis J, Lujan-Climent M, Palau S, Bizar J, Salsench J, Peraire M. Relationship between chewing side preference and handedness and lateral asymmetry of peripheral factors. *Arch Oral Biol*. 2009;54(2):101-7.
- Rovira-Lastra B, Khoury-Ribas L, Flores-Orozco EI, Ayuso-Montero R, Chaurasia A, Martinez-Gomis J. Accuracy of digital and conventional systems in locating occlusal contacts: a clinical study. *J Prosthet Dent*. 2024;132(1):115-22.
- Lujan-Climent M, Martinez-Gomis J, Palau S, Ayuso-Montero R, Salsench J, Peraire M. Influence of static and dynamic occlusal characteristics and muscle force on masticatory performance in dentate adults. *Eur J Oral Sci*. 2008;116(3):229-36.
- Mpungose SK, Geerts GA. Analyzing complete denture occlusal contacts: accuracy and reliability. *Int J Prosthodont*. 2016;29(1):50-2.
- Turkistani KA, Alkayyal MA, Abbassy MA, Al-Dharrab AA, Zahran MH, Melis M, et al. Comparison of occlusal bite force distribution in subjects with different occlusal characteristics. *Cranio*. 2023;41(3):204-11.
- Kerstein RB, Radke J. Masseter and temporalis excursive hyperactivity decreased by measured anterior guidance development. *Cranio*. 2012;30(4):243-54.
- Reinhardt R, Tremel T, Wehrbein H, Reinhardt W. The unilateral chewing phenomenon, occlusion, and TMD. *Cranio*. 2006;24(3):166-70.
- Elboraey AN, Dehis WM, Eissa SM, El-Hotieby MM, Abdelkader OK. Occlusal equilibration and muscle activity in fixed versus removable mandibular implant supported overdenture. *Clin Oral Investig*. 2024;28(3):160.
- Akacsos SR, Kis M, Szekeley M, Popsor S, Dorner K. Jaw relationship assessment for removable complete dentures using the t-scan computerised system - a case report. *Med Pharm Rep*. 2019;92(Suppl 3):S85-90.
- Homsí G, Kumar A, Almotairy N, Wester E, Trulsson M, Grigoriadis A. Assessment of masticatory function in older individuals with bimaxillary implant-supported fixed prostheses or with a natural dentition: a case-control study. *J Prosthet Dent*. 2023;129(6):871-7.
- Klasser GD, Greene CS. Oral appliances in the management of temporomandibular disorders. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2009;107(2):212-23.
- Ferrario VF, Sforza C. Coordinated electromyographic activity of the human masseter and temporalis anterior muscles during mastication. *Eur J Oral Sci*. 1996;104(5-6):511-7.
- Tecco S, Quinzi V, Nota A, Giovannozzi A, Abed MR, Marzo G. Electromyography-guided adjustment of an occlusal appliance: effect on pain perceptions related with temporomandibular disorders. A controlled clinical study. *Diagnostics (Basel)*. 2021;11(4):667.
- Tecco S, Mummolo S, Marchetti E, Tete S, Campanella V, Gatto R, et al. sEMG activity of masticatory, neck, and trunk muscles during the treatment of scoliosis with functional braces. A longitudinal controlled study. *J Electromyogr Kinesiol*. 2011;21(6):885-92.
- Saracutu OI, Pollis M, Cagidiaco EF, Ferrari M, Manfredini D. Repeatability of Teethan(R) indexes analysis of the masseter and anterior temporalis muscles during maximum clenching: a pilot study. *Clin Oral Investig*. 2023;27(9):5309-16.
- Alves A, Cabrita J, Alves R, Casado S, Caramês J, Marques D. Concordância do Teethan® na medição da intensidade muscular mastigatória – Estudo Clínico [poster]. Congresso Anual da Sociedade Portuguesa de Estomatologia e Medicina Dentária; 2023; Oeiras, Portugal.
- Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behav Res Methods*. 2009;41(4):1149-60.
- Gonzalez YM, Schiffman E, Gordon SM, Seago B, Truelove EL, Slade G, et al. Development of a brief and effective temporomandibular disorder pain screening questionnaire: reliability and validity. *J Am Dent Assoc*. 2011;142(10):1183-91.

25. Ferrario VF, Sforza C, Colombo A, Ciusa V. An electromyographic investigation of masticatory muscles symmetry in normo-occlusion subjects. *J Oral Rehabil.* 2000;27(1):33-40.
26. Ferrario VF, Tartaglia GM, Galletta A, Grassi GP, Sforza C. The influence of occlusion on jaw and neck muscle activity: a surface EMG study in healthy young adults. *J Oral Rehabil.* 2006;33(5):341-8.
27. Castroflorio T, Icardi K, Torsello F, Deregiibus A, Debernardi C, Bracco P. Reproducibility of surface EMG in the human masseter and anterior temporalis muscle areas. *Cranio.* 2005;23(2):130-7.
28. Ferrario VF, Sforza C, Zanotti G, Tartaglia GM. Maximal bite forces in healthy young adults as predicted by surface electromyography. *J Dent.* 2004;32(6):451-7.
29. Ferrario VF, Sforza C, D'Addona A, Miani A Jr. Reproducibility of electromyographic measures: a statistical analysis. *J Oral Rehabil.* 1991;18(6):513-21.
30. Naeije M, McCarroll RS, Weijs WA. Electromyographic activity of the human masticatory muscles during submaximal clenching in the inter-cuspal position. *J Oral Rehabil.* 1989;16(1):63-70.
31. Tartaglia GM, Moreira Rodrigues da Silva MA, Bottini S, Sforza C, Ferrario VF. Masticatory muscle activity during maximum voluntary clench in different research diagnostic criteria for temporomandibular disorders (RDC/TMD) groups. *Man Ther.* 2008;13(5):434-40.
32. Tartaglia GM, Lodetti G, Paiva G, De Felicio CM, Sforza C. Surface electromyographic assessment of patients with long lasting temporomandibular joint disorder pain. *J Electromyogr Kinesiol.* 2011;21(4):659-64.
33. Manfredini D, Cocilovo F, Stellini E, Favero L, Guarda-Nardini L. Surface electromyography findings in unilateral myofascial pain patients: comparison of painful vs non painful sides. *Pain Med.* 2013;14(12):1848-53.
34. Massaroto Barros B, Biasotto-Gonzalez DA, Bussadori SK, Gomes CA, Politti F. Is there a difference in the electromyographic activity of the masticatory muscles between individuals with temporomandibular disorder and healthy controls? A systematic review with meta-analysis. *J Oral Rehabil.* 2020;47(5):672-82.
35. Iwasaki S, Tokunaga T, Baba S, Tanaka M, Kawazoe T. Noninvasive estimation of the location of the end plate in the human masseter muscle using surface electromyograms with an electrode array. *J Osaka Dent Univ.* 1990;24(2):135-40.
36. Suvinen TI, Malmberg J, Forster C, Kempainen P. Postural and dynamic masseter and anterior temporalis muscle EMG repeatability in serial assessments. *J Oral Rehabil.* 2009;36(11):814-20.
37. Im YG, Han SH, Park JI, Lim HS, Kim BG, Kim JH. Repeatability of measurements of surface electromyographic variables during maximum voluntary contraction of temporalis and masseter muscles in normal adults. *J Oral Sci.* 2017;59(2):233-45.
38. Manfredini D, Winocur E, Ahlberg J, Guarda-Nardini L, Lobbezoo F. Psychosocial impairment in temporomandibular disorders patients. RDC/TMD axis II findings from a multicentre study. *J Dent.* 2010;38(10):765-72.
39. Manfredini D, Lobbezoo F. Sleep bruxism and temporomandibular disorders: A scoping review of the literature. *J Dent.* 2021;111:103711.
40. Câmara-Souza MB, Bracci A, Colonna A, Ferrari M, Rodrigues Garcia RCM, Manfredini D. Ecological momentary assessment of awake bruxism frequency in patients with different temporomandibular disorders. *J Clin Med.* 2023;12(2):501.

Influência da postura corporal nos índices eletromiográficos durante apertamento máximo voluntário

R E S U M O

Objetivos: Avaliar a repetibilidade intrassessão dos índices funcionais eletromiográficos obtidos com o sistema sem fios Teethan® e determinar a influência da postura corporal durante o apertamento dentário máximo voluntário.

Métodos: Foram incluídos trinta e um participantes saudáveis com dentição natural completa e sem dor ou disfunção temporomandibular autorreportada num estudo com medidas repetidas. Foram obtidos registos bilaterais dos músculos masséter e temporal anterior com o sistema Teethan® nas posturas sentada, em pé e em decúbito dorsal. Em cada postura foram registados três apertamentos consecutivos, sem remoção dos elétrodos. Foram calculadas estatísticas descritivas, coeficientes de correlação intraclasse, análise de variância para medidas repetidas, comparações com correção de Bonferroni e correlações de Pearson como análises suplementares de associação.

Resultados: Não se observaram diferenças significativas entre posturas para a maioria dos índices, exceto no índice de simetria do masséter, superior na posição sentada face ao decúbito dorsal. Como a ordem das posturas foi fixa, este resultado deve ser interpretado com precaução. A maioria das correlações entre repetições foi moderada a forte. Os valores globais dos coeficientes de correlação intraclasse para medidas médias variaram entre 92,2% e 96,8%, indicando excelente fiabilidade. A fiabilidade de medida única variou entre 79,8% e 91,0%, o coeficiente de variação intrassujeito entre 9,3% e 23,1%, e a análise de Bland-Altman revelou viés sistemático desprezável.

Conclusões: Dentro das limitações deste estudo, os índices avaliados apresentaram elevada repetibilidade intrassessão e foram minimamente influenciados pela postura corporal durante o apertamento máximo voluntário em adultos saudáveis. (Rev Port Estomatol Med Dent Cir Maxilofac. 2026;67(3):139-149)

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Palavras-chave:

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Postura

Prostodontia

Reprodutibilidade dos resultados