Cover page

Considerations

The current work is a pre-print, actually under review in the *Journal of Oral Rehabilitation* (ISSN: 1365-2842). This process does not imply further publication in the Journal, so readers are advised to exercise caution if using this reference.

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Relationship between mandibular position, activation of the masticatory musculature and free throw accuracy in female basketball players

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Abstract

Background: Current research relates jaw clenching and athletic performance, in terms of force and agility. However, the impact of jaw clenching on accuracy sports is unclear.
Objectives: To analyze the impact of jaw position and chewing type on free throw accuracy and electromyographic (EMG) activity of masticatory muscles during free throws.
Methods: Cross-sectional study with 25 female basketball players aged 18-44. Each participant executed 18 free throws under three different jaw conditions: mandibular rest, maximum intercuspation, and with interdental cotton rolls, in randomized order.
Results: Chewing type and jaw position were not associated with shooting accuracy ($p = 0.106$; $p = 0.778$). There was a positive correlation between EMG activity of the right masseter and free-throw accuracy at maximum intercuspation ($r_s = 0.402$; $p = 0.046$). In contrast, negative correlations were found with other muscles when the occlusal vertical dimension was altered ($r_s = -0.619$, $p = 0.001$; $r_s = -0.490$; $p = 0.013$; $r_s = -0.534$; $p = 0.006$). The chewing type affected the EMG of the left masseter in the altered occlusal vertical dimension ($H = 6.969$; $p = 0.031$). Significant differences in EMG recordings were observed across different mandibular positions during free throws ($p < 0.001$).
Conclusions: While jaw positioning and chewing type do not impact free throw accuracy in amateur female basketball players, the EMG activity of masticatory muscles is linked to shooting performance. This highlights the need for further research on motor behavior of masticatory muscles in precision sports, especially for athletes using intraoral devices.
Keywords: accuracy, basketball, electromyography, free throw, masticatory muscles.

1 INTRODUCTION

Numerous studies have shown the possible effects of jaw-clenching on athletic performance[1,2]. Certain authors point out that increased activation of the masseter muscles may increase force in other muscles[3], thus improving the biomechanics and economy of the sporting gesture through resulting neuromuscular responses[1,3]. This is known as the concurrent activation potentiation phenomenon (CAP)[4,5], which is thought to promote greater cortical activation, increased efficiency in motor neuron activity, and enhanced reflex responses[4,6].

Several theories advocate the possible neuromuscular benefits associated with jaw clenching[4]. The first focuses on the integrative function of the motor cortex and the connections between different motor areas of the brain. When one part of the motor cortex is activated by jaw clenching, neural centers in other brain areas co-activate, sending impulses to other motor centers to precisely coordinate the initiation of specific actions. The second theory suggests that the contraction of the masticatory muscles produces increased excitability in alpha motor neurons, gamma loops, and neuromuscular spindles, along with decreased cortical and afferent stimulus inputs. Jaw clenching has been linked to greater facilitation of the H-reflex in certain muscle groups[7]. This facilitation comes from the descending influence in the cerebral cortex and the afferent inputs in the orofacial region. Research using both surface and deep electromyography has demonstrated the activation of cervical muscles and shoulder girdles during different voluntary dental clenching tasks[8–11], and decreased EMG activity of the trapezius and sternocleidomastoid (SCM) muscles in the mandibular resting position[12,13].

Shooting accuracy is essential in basketball where game rules stipulate a fixed shooting distance and no defensive opposition for a free throw[14]. Basketball coaches emphasize that the movement pattern of free throws should be sequenced (placing hands on the ball, bringing it to forehead height, bending the upper and lower limbs to throw while extending them) since it can affect the success of the shot[14–16].

It has been described that the kinematics of the ball, the throwing speed[17] and the angle of release all determine the success of a free throw[18]. Repeated practice improves control and we now know that improved postural control impacts on free throws[19]. Researchers point out that dental occlusion and jaw position may affect postural control depending on certain external interferences especially in conditions of instability, muscle fatigue or both[20,21], yet there is still controversy due to the heterogeneity of results[22,23].

Masticatory muscle contraction may improve the neuromuscular responses of the main muscles involved in a sporting action or gesture due to the CAP phenomenon, which may impact free throw accuracy. This relationship has not yet been investigated despite the existing evidence on other performance-related parameters for professional basketball players wearing mouthguards[1,24].

The objectives of this study are: 1) To analyze the impact of jaw position and EMG activity of masticatory muscles on free throw accuracy in amateur female basketball players. 2) To study whether chewing type influences EMG activity of the masticatory muscles in a free throw. 3) To analyze the effect of different jaw positions on EMG activity in the masticatory muscles.

2 METHODOLOGY

2.1 Study design

A cross-sectional observational study was carried out following the STROBE guidelines. Chewing type, EMG activity of the masseter and temporalis muscles, and free-throw accuracy were assessed at 3 different mandibular positions: the mandibular rest position (RP), maximal intercuspation position (MIP), and increased occlusal vertical dimension position (OVD) (Figure 1). All assessments were made in one single session.

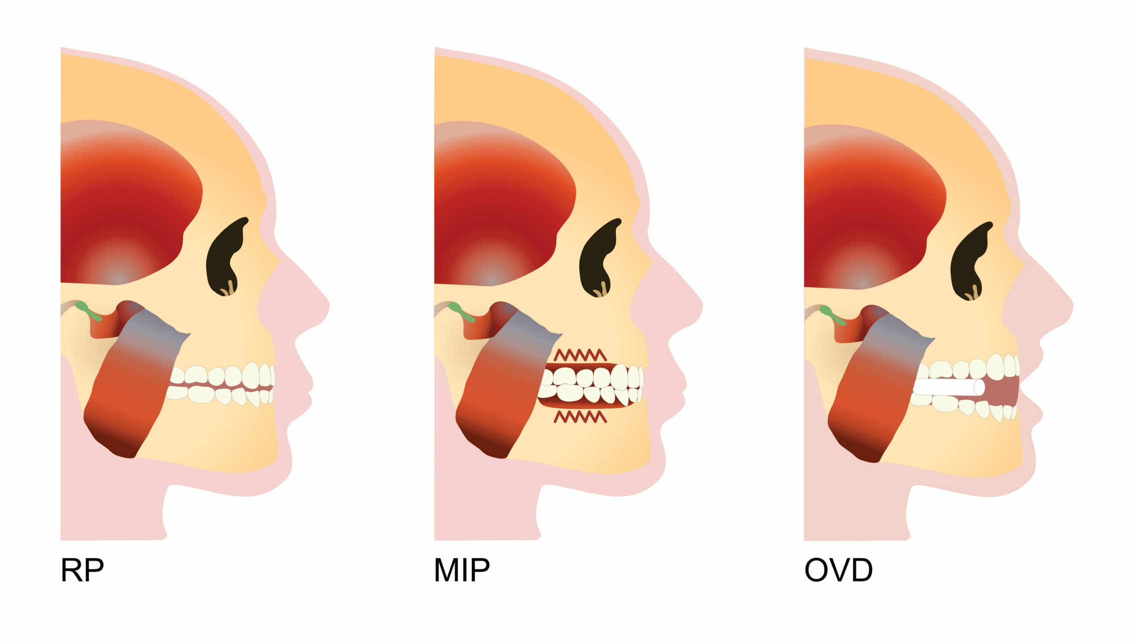

FIGURE 1 Mandibular posi.ons. Abbrevia.ons: RP, rest posi.on; MIP, maximal intercuspa.on posi.on; OVD, ver.cal dimension posi.on.

The study was approved by the Institutional Ethics Committee at Camilo José Cela University (code number 09_22_UEMDTT) following the guidelines of the Declaration of Helsinki. All sample subjects read and signed written informed consent before participating in the study.

2.2 Participants

Twenty-five federated amateur female basketball players from different teams in the Madrid Region, aged between 18 and 44 were recruited to participate in the study. The recruitment period and data collection period took place between February and March 2024.
Participants under 18 years of age, with missing teeth, periodontal disease, temporomandibular disorder, bruxism, those undergoing orthodontic treatment or wearing occlusal splints were excluded. Participants were also excluded if they had suffered trauma such as mandibular or cranial fractures, postsurgical conditions affecting the craniomandibular region, had undergone previous orthognathic surgery, had received treatment with botulinum toxin in the masticatory muscles in the previous 6 months, had received physiotherapy treatment in the study area in the previous 15 days or had taken a muscle relaxant in the 48-72 h before the start of data collection[25]. After verifying the inclusion and exclusion criteria, the participants freely and voluntarily signed an information sheet and an informed consent form explaining the study hypothesis and procedure, as well as other issues related to data processing and protection of privacy under current state regulations. We then collected personal, sociodemographic, and anthropometric variables using a Google Forms questionnaire.

2.3 Sample size calculation

The minimum sample size of free throws was calculated for a bilateral repeated measures test with a 95% confidence level (alpha error = 0.05), a beta error of less than

0.2, a standard deviation of 5, and a minimum detectable difference of 4 units, adjusting for 15% losses. Fifteen shots were required for each round.

2.4 Assessments and measuring instruments

2.4.1 Assessment of chewing type

The unilateral chewing test was used to determine chewing type[26,27]. Participants were asked to chew a piece of sugarless chewing gum and to open their mouths to show which side of the mouth the gum was on (right or left side). This procedure was repeated 7 times with a time interval of 5 seconds each. Participants were classified according to the following criteria: predominant unilateral chewer when they registered 7/7 cycles on the same side, consistent unilateral chewer when they registered 5/7 or 6/7 cycles on the same side, and bilateral chewer (also called alternating unilateral chewer) when they registered same side[27].

2.4.2 EMG measurement

Bilateral EMG measurements were taken in one single session, with several measurements of muscle activity in the masseter and the anterior bundle of the temporalis muscles using an mDurance R surface EMG device (mDurance Solutions SL, Granada, Spain)[28]. There are three parts to the system, a portable Shimmer3 EMG unit (Realtime Technologies Ltd., Dublin, Ireland), a mobile application called "mDurance" (Android), which receives data from the Shimmer3 unit and the mDurance cloud service, where EMG signals are stored, filtered and analyzed[28]. EMG sampling cuts were made starting at 0.5 seconds before the EMG peak coincided with the shot and ending 0.5 seconds later. This recording method allows us to consider the anticipatory postural adjustments (APAs), secondary to the action (ASAs) and consecutively (CPAs)[29–31]. Raw EMG data were filtered through a fourth-order lowpass Butterworth filter. Raw parameters for Mean muscle fiber recruitment (RMS) and maximum voluntary contraction (MVC) data were collected and are expressed as percentages (%RMS and %MVC).

2.4.3 Assessment of free throw accuracy

The evaluation of accuracy was carried out on official international basketball courts, where the free throw is 4.60 meters from the backboard and 5.80 meters from the baseline. The basketball hoop height is 3.05 meters. We used the regulation ball for women's competitions, with a circumference of between 72.4 and 73.7 centimeters, weighing between 510 and 567 grams (size 6)[32].

All study participants shot the throws with no instruction or imposition on how to execute each personal routine.

Free throw accuracy was measured in 3 distinct positions at the mandibular level: RP (lip competition and no dental contact between both dental arches), MIP (lip competition and maximum dental clenching) and OVD (with interposition of cotton rolls 0.8 mm in diameter x 3.8 mm in length between the premolar and molar teeth of both dental arches). Before the throws, all participants were instructed on the randomly assigned order of each mandibular position to be adopted while shooting.

2.5 Study protocol

Once the form was completed by each of the participants, chewing type was evaluated, and results were registered on a recording sheet.

To reduce impedance, each participant's face was cleaned with a 90 % alcohol solution. The main investigator placed the electrodes on the masseter muscles and anterior bundles of the temporalis muscles according to SENIAM protocol[33], using two separate channels for each (right and left), as shown in Figure 2, with reference electrode placed on the surface of the frontal bone[25]. These electrodes were connected by wires to each of the EMG electrodes.

FIGURE 2 Electrode placement according to SENIAM protocol.

Maximum voluntary contraction (MVC) of the masseter and temporalis muscles (anterior beams) was recorded. Participants were asked to perform a maximum dental clench in a maximum intercuspation position for 6 seconds, followed by a rest time of 2-3 seconds[25,34]. The procedure was repeated 6 times. The mean RMS and MVC obtained were used as the gold standard for each player´s maximal muscle activation. The %RMS and %MVC are expressed as percentages. EMG activity of the masticatory muscles was recorded during the free throws in the different jaw positions. The players made 54 free throws, 18 in each randomized jaw position for each participant. Before each set of throws, the players were instructed on the procedure to follow in each jaw position. One of the evaluators recorded the number of shots through the hoop in each jaw position on a record sheet, and the total percentage of successful hoops was then calculated. Players rested for one minute between each series of 18 shots. No recordings were made for each first, ninth and eighteenth shot making a total of 15 study significant shots for each jaw position (Figure 3).

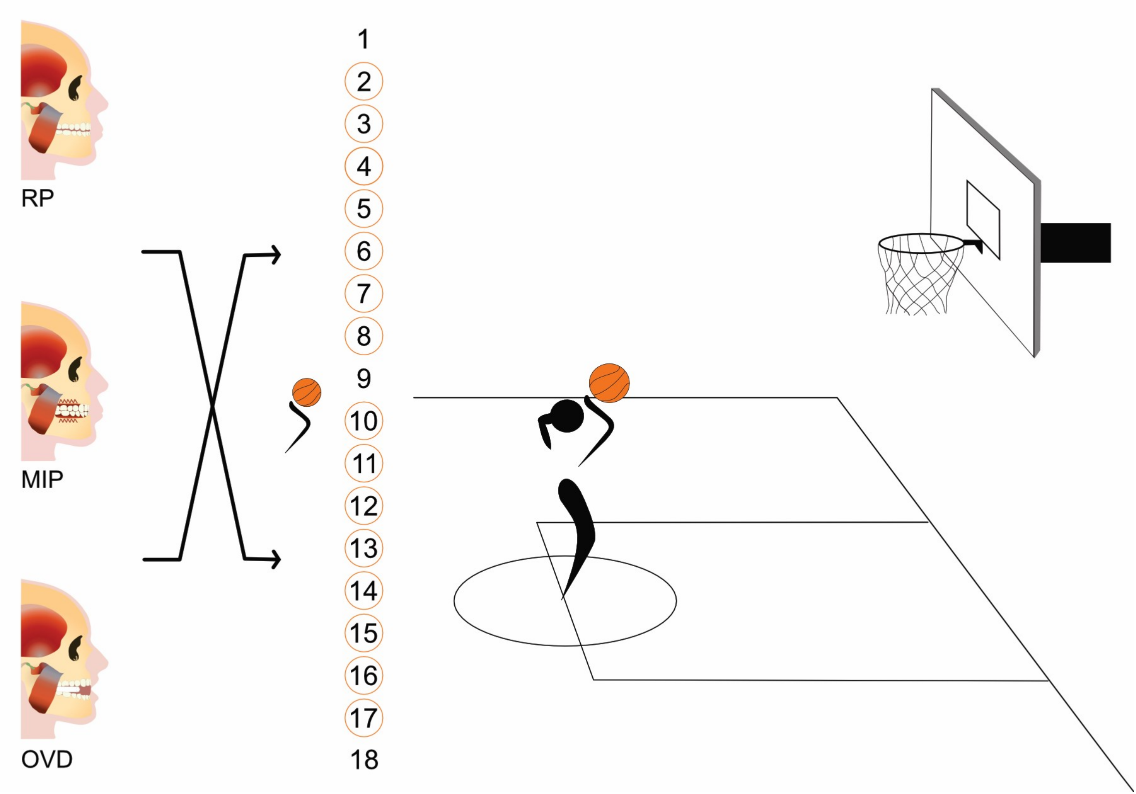

FIGURE 3 Free throw in the different randomized mandibular posi.ons. Abbrevia.ons: RP, rest posi.on; MIP, maximal intercuspa.on posi.on; OVD, ver.cal dimension posi.on.

2.6 Statistical analysis and data processing

The Shapiro–Wilk test was used to test normality of data distribution. When the data were normally distributed, repeated-measure ANOVA parametric tests were used. Nonparametric tests (Spearman's correlation coefficient, Kruskal–Wallis H test, and Friedman's test) were used for non-normal distribution data. The chi-square test was used for the analysis of associations with qualitative variables. The significance level was set at $p \leq 0.05$. All statistical analyses were carried out using the SPSS package (IBM SPSS Statistics for Macintosh, Version 25.0. Armonk, NY, USA: IBM Corp).

3 RESULTS

3.1 Descriptive results and normality analysis

Descriptive results (mean ± standard deviation) are shown for age, weight, height, BMI, foot size (European size), and percentage of free throw accuracy in each jaw position, in normal distribution. Most of the electromyographic data collected were not normally distributed. Both initial MVC and RMS parameters and those derived from the tests in the different jaw positions are not normally distributed (see Table 1 and Table 2 for ranges and medians).

[TABLE 1 here]

[TABLE 2 here]

3.2 Inferential analysis

The repeated-measure ANOVA showed no significant within-subject differences in free throw accuracy among the different jaw positions analyzed ($F_{(2, 48)} = 2.354$; $p = 0.106$). The intrasubject chewing type did not influence accuracy ($F_{(2, 44)} = 2.354$; $p = 0.778$) (Supplementary Table 1).

For the RMS parameter of electromyographic activity, there was a positive relationship between the maximal intercuspation of the right masseter and the accuracy of the free throw in this mandibular position ($r_s(23) = 0.402$; $p = 0.046$) and a negative relationship between the right masseter ($r_s(23) = -0.619$; $p = 0.001$), right temporal ($r_s(23) = -0.490$; $p = 0.013$) and left temporal ($r_s(23) = -0.534$; $p = 0.006$) in the OVD position and percentage of success in that mandibular position. For the MVCs, there was a negative relationship between the activity of the right masseter ($r_s(23) = - 0.557$; $p = 0.004$), right temporal ($r_s(23) = -0.451$; $p = 0.024$), and left temporal in OVD ($r_s(23) = -0.436$; $p = 0.029$) in relation to the accuracy of the free throw in the OVD position (Table 3). In the percentage of maximum muscle activation, we observed an inverse correlation between the %RMS of the right masseter at rest and the accuracy of the free throw in resting position ($r_s(23) = -0.431$; $p = 0.031$) and between the accuracy in OVD position and the %RMS of the right masseter ($r_s(23) = -0.558$; $p = 0.004$), right masseter %MVC ($r_s(23) = -0.534$; $p = 0.006$), left masseter %MVC ($r_s(23) = - 0.432$; $p = 0.031$), right temporal %RMS ($r_s(23) = -0.458$; $p = 0.021$), left temporal %MVC ($r_s(23) = -0.432$; $p = 0.031$) and right temporal %MVC ($r_s(23) = -0.489$; $p = 0.013$) in OVD (Table 3).

[TABLE 3 here]

No significant differences were found in the electromyographic activity of the different muscles studied during free throws regarding chewing type, except for the RMS of the left masseter in OVD position ($H(2) = 6.969$; $p = 0.031$), the %RMS of the left masseter ($H(2) = 7.544$; $p = 0.023$) and the %MVC of the same muscle ($H(2) = 6.410$; $p = 0.041$) (Supplementary Table 2).

A nonparametric Friedman's test for differences between repeated measures of the RMS, MVC, %RMS and %MVC of the scanned muscles was carried out, yielding a chi-square value of 29.360 ($p < 0.001$) for the right masseter RMS, right temporal RMS ($\chi^2 = 31.760$, $p < 0.001$), left masseter RMS ($\chi^2 = 34.880$, $p < 0.001$) and left temporal RMS ($\chi^2 = 37.520$, $p < 0.001$). The MVCs of the right masseter ($\chi^2 = 15.440$), right temporal ($\chi^2 = 29.354$), left masseter ($\chi^2 = 27.455$), and left temporal ($\chi^2 = 29.360$) muscles were also significantly different ($p < 0.001$). In activation percentages, the χ^2 values were 29.360 for right masseter %RMS ($p < 0.001$), right temporal %RMS ($\chi^2 = 31.760$, $p < 0.001$), left masseter %RMS ($\chi^2 = 34.880$, $p < 0.001$), left temporal %RMS ($\chi^2 = 37.520$, $p < 0.001$), right masseter %MVC ($\chi^2 = 15.440$, $p < 0.001$), right temporal %MVC ($\chi^2 = 29.354$, $p < 0.001$), left masseter %MVC ($\chi^2 = 27.455$, $p < 0.001$) and left temporal %MVC ($\chi^2 = 29.360$, $p < 0.001$).

4 DISCUSSION

Our results show that neither jaw position nor chewing type affects free throw accuracy. To the best of our knowledge, there are no data from similar studies on the relationship between free throw accuracy and different mandibular positions, where vertical dimension of occlusion is altered[35]. In similar studies on putt accuracy in golf, no significant differences have been reported among professional golfers with varying molar contact through mouthguards and stabilization splints[36]. A significant increase in both club head speed and drive distance, however, was observed when these types of devices were worn. Dias et al., analyzing the shot accuracy of pistol shooters at 10 m, found no significant differences when comparing occlusal splints versus placebo splints, although a nonsignificant decrease in shot dispersion was found[37]. Schulze and Busse[2] compared the accuracy of passing, defensive reception, and serving in a group of volleyball players with and without dental guards, observing an increase in the EMG activity with intraoral devices. Unlike our research, EMG measurements of the masseter, temporalis, "cervical group" (not specified), and digastric muscles were taken while the players were seated measuring RP, MIP, and OVD with interdental cotton rolls in place before the sports activity, not during it.

What is generally observed with the use of intraoral devices in sporting activity is an increase in strength in non-masticatory muscles, both in jumping and in explosive strength, maximum strength, and running kinematics[4,24,38]. This increase in strength is thought to be derived from the CAP described by Ebben[4], where an increase in cortical activation produced by the action of the masticatory musculature would lead to activation of other areas of the cortex. Although shooting accuracy is highly dependent on the subject's visuomotor afferents and the decrease of or interruption in motor activity[39], other physical factors such as shot preparation, postural control, the distance between the ball and the ground as it leaves the player's hand, the angle of the shot, the frequency of backward ball spin, and the smoothness of the executed movements have been described[14]. These same authors point out that the timing and variability of muscle activation of the players' biceps and triceps brachii muscles influence free throw accuracy, observing that expert players show higher scores for both parameters than intermediate and novice players. However, factors such as postural control, exerted strength, balance, or muscle response to fatigue may be influenced by masticatory muscle activity[20,21,40]. The impact of cognitive processes such as motivation, selfcontrolled practice, and attention has also been described in the study of accuracy of free-throws[41]. We found that increased electromyographic activity of the muscles explored in the altered OVD position significantly worsened free throw accuracy. Greater accuracy, however, is observed in the activity of the right masseter in MIP position. Although this may be associated with the PAC mechanism, the worsening of free throw accuracy in OVD seems to be associated with muscular hyperactivation, which should not be the case. This relationship could be supported by a different neuromuscular response due to the influence on trigeminal proprioception through afferent connections of the V pair in the CNS, since changes in dynamic and static body balance, posture, and muscle tone of the masseters, SCOM, and spinal erectors have been observed when dental occlusion is modified[21,38]. Possible relationships between the viscoelastic properties of certain muscle groups and the dental interposition of cotton rolls have also been described through the temporomandibular system-body fascia interrelation[42,43]. This relationship has still to be certified, and some authors believe that all information passes through and is regulated by the CNS[9]. These possible interactions are becoming more relevant as the use of mouthguards in contact sports to avoid the risk of orofacial injury is common[38,44,45]. Depending on the type of mouthguard or splint used, there are variations in the vertical dimension of the athlete's occlusion as well as the force and velocity exerted by different muscle groups[46,47]. The relationship between trigeminal afferents and the vestibular nuclei has been demonstrated in mammals, observing their role in the stabilization of gaze and postural control through the integration of this information in the CNS with that from the cervical spine and the proprioception of the oculomotor muscles[48,49]. Suvinen and Kemppainen[50] argued that EMG activity of the masticatory muscles in healthy subjects does not differ, with only moderate changes in OVD position. Dysfunctional subjects treated with intraoral devices tend to have lower activation rates of masseter and temporalis muscles. In our study, we did not use interdental devices other than cotton rolls, but it would be interesting to study EMG activity in players wearing mouthguards or splints during precision activities, monitoring effect at the time of the sporting act. Finally, different EMG activities observed in each mandibular position only confirmed that the players understood what was asked of them in each free throw, since the highest activation peaks and RMS were reflected during MIP compared to the other mandibular positions. The relationships between electromyographic activity recorded in the masticatory muscles and accuracy in free-throw shooting need further attention, with more in-depth studies differentiating sample groups by level of play (beginner, intermediate, elite), the presence/absence of temporomandibular disorders, different game/shooting situations or even by analyzing other sports where accuracy is a key factor.

Limitations

The main limitations of the study derive from the sample selection, since although the initial questionnaire asked the participants to comment on the presence or absence of pain in the temporomandibular region, this alone does not determine the presence of a disorder. Certain occlusion parameters, such as crossbite, scissor bite, or mediotrusive interference, which could alter the activation patterns of the masticatory muscles, were not considered. Another limitation is that the free throw measurements were not taken in real competition context but during training sessions and the presence of electrodes and wiring necessary for the electromyographic recording may have impacted on the throw.

5 CONCLUSIONS

Jaw position is not associated with free throw accuracy in amateur female basketball players. The chewing type presented by each player did not influence the percentage of free throw accuracy. Electromyographic activity collected in the masseter and temporalis muscles is associated with accuracy, with a positive relationship at MIP and a negative relationship in the OVD position. Further study of the impact motor behavior of the masticatory musculature may have on shooting in basketball or other precision sports is needed, especially for individuals who use intraoral devices.

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Institutional Review Board Statement: This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the human research committee of Universidad Camilo José Cela, Madrid, Spain.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Raw data will be made available upon request to the corresponding author.

Declaration of competing interest: The authors declare that they have no competing interests.

Supplementary materials

Supplementary material associated with this article can be found in the online version at

TABLE 1 Descriptive statistics data.

Variable	Mean	SD	95% CI
Age	29.28	8.40	25.81 - 32.75
Weight	62.64	6.58	59.92 - 65.36
Height	1.72	0.07	1.68 - 1.74
BMI	21.28	1.99	20.45 - 22.09
Shoe size	39.64	1.72	38.93 - 40.34
% Accuracy RP	59.78	21.41	50.94 - 68.62
% Accuracy MIP	51.56	16.55	44.72 - 58.39
% Accuracy OVD	58.23	22.69	48.86 - 67.59

Abbreviations: BMI, body mass index; RP, rest position; MIP, maximal intercuspation position; OVD, vertical dimension position.

TABLE 2 Descrip.ve sta.s.cs data (non-normal).

Variable		MVC Test		FT RP		FT MIP		FT OVD	
		Median	Range	Median	Range	Median	Range	Median	Range
RMS	Right	177.77	670.26	29.25	128.35	151.33	522.69	33.38	113.04 masseter
	Right	171.98	593.51	21.35	319.41	136.82	332.07	24.14	57.13 temporal
	Left masseter	174.48	725.91	23.00	296.63	161.53	926.45	23.89	112.43

	Left temporal												
MVC	Right masseter												
	Right temporal	242.43	1008.72	53.12	1298.19					235.76	492.28	69.79	293.42
	Left masseter												
	Left temporal			1156.10	291.40	4945.52	61.73	474.05					
				382.76	309.64	424.44	117.94	470.50					
		167.16	441.69	28.97	112.83	153.93	233.31	33.35	110.11				
		266.43	1196.26	100.21	579.00	259.88	966.83	111.78	517.67				

Abbreviations: MVC, maximum voluntary contraction; FT, Free throw; RP, rest position; MIP, maximal intercuspation position; OVD, vertical dimension position; RMS, muscle fiber recruitment.

TABLE 3 Spearman’s correla.ons between EMG parameters and accuracy percentage in the different mandibular posi.ons.

			% Accuracy RP	**% Accuracy MIP**	**% Accuracy OVD**
Masseters	RMS	R	-0.306	**0.402**	**-0.619**
		Sig.	0.136	**0.046**	**0.001**
		L	-0.113	0.293	-0.304
		Sig.	0.591	0.155	0.139
	% RMS	R	**-0.431**	0.101	**-0.558**
		Sig.	**0.032**	0.629	**0.004**
		L	-0.197	-0.076	-0.334
		Sig.	0.345	0.719	0.102
	MVC	R	-0.258	0.296	**-0.557**
		Sig.	0.212	0.151	**0.004**
		L	-0.043	0.243	-0.232
		Sig.	0.839	0.241	0.265
	% MVC	R	-0.364	0.086	**-0.534**
		Sig.	0.074	0.683	**0.006**
		L	-0.133	0.184	**-0.432**
		Sig.	0.525	0.380	**0.031**

Temporalis muscles	RMS	R	-0.265	0.233	**-0.490**
		Sig.	0.201	0.263	**0.013**
		L	-0.356	0.096	**-0.534**
		Sig.	0.081	0.649	**0.006**
	% RMS	R	-0.232	0.073	**-0.458**
		Sig.	0.265	0.727	**0.021**
		L	-0.316	-0.140	**-0.432**
		Sig.	0.124	0.505	**0.031**
	MVC	R	-0.279	0.281	**-0.451**
		Sig.	0.177	0.173	**0.024**
		L	-0.307	0.020	**-0.436**
		Sig.	0.135	0.925	**0.029**
	% MVC	R	-0.170	0.108	**-0.489**
		Sig.	0.416	0.607	**0.013**
		L	-0.250	-0.309	-0.359
		Sig.	0.228	0.133	0.078

Abbreviations: RMS, muscle fiber recruitment; MVC, maximum voluntary contraction; RP, rest position; MIP, maximal intercuspation position; OVD, vertical dimension position; R, right; L, left.