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Research Article

Analysis of Bite Force, EMG, and Thickness of the Masticatory Muscles in Swimmers: Crawl Modality

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Abstract

Swimming is considered a primordial function that enables a professional swimmer to achieve better functional performance. The present study evaluated the stomatognathic system of professional swimmers with variations in breathing techniques during crawl swimming. Eighteen participants were divided into groups: sedentary (mean ± SD 15.0 ± 0.9 years; n = 6); professional swimmers who breathe to the left (mean ± SD 17.0 ± 2.4 years; n = 6) and professional swimmers who breathe to the right (mean ± SD 21.0 ± 2.4 years; n = 6). The molar bite force, thickness (rest and maximum voluntary contraction) and electromyographic activity (rest, right and left laterality and protrusion) of the masseter and temporalis muscles was evaluated. The professional swimmers' groups demonstrated lower normalized electromyographic activity in almost all mandibular tasks than the sedentary group, with statistically significant difference ($P \leq 0.05$) in right laterality for the left temporal muscle ($P = 0.04$). No statistically significant difference in muscle thickness and molar bite force was found among the groups. Based on the findings of this study, crawl swimming promotes positive changes in electromyographic activity of the masseter and temporal muscles in professional swimmers.

Keywords: Crawl Swimming; Electromyography; Ultrasound; Bite Force; Masticatory Muscles

Introduction

Periodontal infections cause chronic inflammation of the periodontium, which includes the gingiva, cementum, periodontal ligament (PDL), and the alveolar bone. This causes progressive alveolar bone loss and PDL destruction [1] and triggers an immune-inflammatory response [2].

There are numerous ways to perform regularly physical activities, which have health-related benefits [5]. Among the various sports, swimming enhances both physical and technical strength that are developed, in most of the time, inside the water, which is not considered a natural environment and has a density that is thousand times greater than that of air [6].

Crawling is considered the fastest technique of all swimming styles but requires greater physical ability of the swimmers who practice it regularly so that there are no errors when moving the head, which must be parallel to the water when the arm opposite to the breathing side enters water [7,8]. Considering the set of functions that make up the stomatognathic system, it is important to understand whether functional and morphological changes can occur in this complex system during regular crawl swimming practice.

Because of the lack of studies in the literature on the function of the stomatognathic system in Professional Swimmers using variations of crawl breathing techniques, this study aimed to evaluate molar bite force, electromyographic activity, and thickness of the masseter and temporalis and to determine if professional swimmers in the crawl modality would present significant changes in the stomatognathic system compared to the sedentary individuals.

Material and Methods

Study design and Participants

The study was approved by the Local Research Ethics Committee at the (process# 53174516.7.0000.5419) according to Resolution 466/12 of the National Health Council. This study was conducted in accordance with the Declaration of Helsinki. The preparation of the participants and the data collection were performed in the Laboratory of Electromyography, School of Dentistry. All participants were informed about the objectives and stages of the research and were asked to sign a free and informed consent form; for subjects below 18 years, their legal guardians signed the form.

From a total of 70 participants evaluated, 18 healthy participants aged 15 - 25 years, of both genders, normal occlusion (Angle's Class I), and without temporomandibular dysfunction according to the Research Diagnostic Criteria for Temporomandibular Disorders (RDC-TMD) were included in this study.

The participants, 12 of whom were professional crawl swimmers with at least 2 years of practice and 6 who were sedentary individuals, were divided into three groups: sedentary individuals (mean ± SD 15.0 ± 0.9 years; 6 individuals); professional swimmers who breathe to the left during the crawl (mean ± SD 17.0 ± 2.4 years; 6 individuals), and professional swimmers who breathe to the right during the crawl (mean ± SD 21.0 ± 2.4 years; 6 individuals).

Participants in these groups were matched based on gender, age, and body mass index. No significant difference ($p < 0.05$) was found among the groups with respect to age ($p = 0.10$) and body mass index ($p = 0.62$).

The exclusion criteria were as follows: absence of upper and lower first permanent molars, use of removable partial prosthesis or total prosthesis, bruxism when asleep and/or awake, presence of mandibular torus or orthodontic appliance, periodontal disease, dental restoration with risk of fracture, physical indisposition at the time of the examination, neurological, or psychiatric disorders, and the use of medications that could alter muscle function (analgesic, anti-inflammatory and muscle relaxant).

Electromyographic analysis

Trigno™ electromyography using wireless surface electrodes (Delsys Inc., Boston, MA, USA) was used for data collection of the EMG activity in microvolts (uV). The characteristics of the electrodes are CMRR of 92 dB, input impedance > 1,015 in parallel with 0.2 pF, the voltage gain of 10 times, noise of 1.2 uV (root-mean-square -RMS). All data collections were conducted using Delsys EMGworks® acquisition software (Delsys Inc., Boston, MA, USA).

Delsys Trigno sensor were positioned on the temporalis and masseter muscles following the standardized international protocol by the European Recommendations for Surface Electromyography of the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) [9]. Prior to the placement of the wireless electrodes, the skin surface was cleaned with alcohol to reduce electrical impedance [10]. The EMG activity was recorded using an instrument that recorded, amplified, digitized, and filtered the analogical EMG signal.

Muscle activity was analyzed using the electromyographic records of the masseter and temporalis muscles during the following mandibular movement tasks rest (4s), maximal right laterality (10s), maximal left laterality (10s), maximal protrusion (10s) and maximal voluntary isometric contraction (4s). Root mean squared (RMS) values were obtained for all conditions and normalized by maximal voluntary isometric contraction.

At the time of electromyographic activity examination, the participants sat erect in a comfortable chair, with their feet resting on the floor and their palms on the thighs. The Frankfurt horizontal plane was kept parallel to the ground [11].

Muscle thickness analysis

To measure muscle thickness in centimeters (cm), an ultrasound with a 10 MHz linear transducer (SonoSite, Inc., Bothell, WA, USA) was used. Ultrasonographic images of the masseter and temporalis muscles were obtained mandibular movement tasks: rest and dental clenching at maximum voluntary contraction.

The linear transducer was positioned transversely to the direction of the muscle fibers and coupled to the skin surface with a conductive gel. The linear transducer was positioned on the masseter muscle, taking into account the temporal fossa region, which is approximately 1.0 to 1.5 cm behind and above the lateral commissures of the eyelids on both sides. On the temporalis muscles, the linear transducer was positioned approximately 1.5 to 2.0 cm above the angle of the mandible toward the zygomatic arch [12].

The location of the masseter and temporalis muscles was confirmed by digital palpation and linear transducer movement. Three examinations were performed for each clinical condition, and the average thickness was measured, allowing a 2-min interval between each measurement the imaging.

Maximum molar bite force analysis

A model digital dynamometer (model IDDK; Kratos®, Cotia, São Paulo, Brazil), with capacity up to 980.665 N and adapted to oral conditions was used to determine the maximum molar bite force. The maximum bite force was measured in the first permanent molar area, on both sides, region where greater bite force is developed [13].

Maximum molar bite force data were collected with the participants sitting in a chair with their arms extended along the body and their hands extended over the thighs. The digital dynamometer stems were sanitized with 70% alcohol and protected with disposable latex finger cots (Wariper, São Paulo, Brazil) for biosafety reasons.

The participants were instructed to bite the dynamometer rods to ensure the reliability of the procedure. The results were obtained by averaging the three measures of each side, alternating the right and left sides, with an interval of 2- min between each bite. The greatest molar bite force (right and left) was used [13].

This study was designed to run in one type of lab configuration of the maximum molar bite force.

Method errors

Dahlberg's formula ($Se = \sqrt{\Sigma d2/2 * n}$) was used to calculate the method errors of this study. Eight individuals were evaluated during two different sessions, with an interval of 7 days. It was possible to observe a small variation in the measurements between the first and second sessions for ultrasound (4.38%), electromyography (3.74 %), and dynamometry with averages recorded for three bites, which were calculated for the right and left sides (5. 21 %) [12].

Statistical analysis

The normality test was applied, and the normal distribution of the data was observed. The normalized electromyographic activity, muscle thickness, and maximum molar bite force values were tabulated and submitted to statistical analysis using SPSS software version 22.0 for Windows (SPSS Inc., Chicago, IL, USA). Descriptive statistics including means and standard errors were assessed for each condition. The values were compared using analysis of variance (ANOVA), with a significance level of 5% and a 95% confidence interval.

Results

Table 1 shows the normalized electromyographic activity data of the right masseter, left masseter, right temporal and left temporal muscles in mandible tasks for the three groups. Professional swimmers who breathe to the right group presented lower electromyographic activity averages for left temporal, right masseter and left masseter muscles when the mandible was at mandibular rest position, with no statistically significant difference ($P \leq 0.05$) among the groups. Professional swimmers who breathe to the right and left groups showed lower electromyographic activity averages in right and left temporalis muscles with respect to maximal protrusion and higher electromyographic activity averages in right and left in relation to sedentary individuals, with no statistically significant difference ($P \leq 0.05$). With respect to maximal right laterality and maximal left laterality, the professional swimmers who breathe to the right group presented lower electromyographic activity than sedentary participants, with a significant statistical difference between the two groups in right temporal ($p = 0.04$) in maximal right laterality.

			Groups		
Mandibular tasks	**Muscles**	**CG**	**LG**	**RG**	**P value**
Rest	RM	0.04 ± 0.01	0.08 ± 0.04	0.01 ± 0.01	0.25
	LM	0.03 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.74
	RT	0.10 ± 0.02	0.04 ± 0.01	0.04 ± 0.01	0.07
	LT	0.06 ± 0.01	0.06 ± 0.01	0.05 ± 0.01	0.77
Right laterality	RM	0.03 ± 0.01	0.05 ± 0.02	0.02 ± 0.01	0.52
	LM	0.06 ± 0.01	0.06 ± 0.01	0.05 ± 0.01	0.57
	RT	0.10 ± 0.01	0.06 ± 0.01	0.05 ± 0.01	0.04
	LT	0.06 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.28
Left laterality	RM	0.04 ± 0.01	0.09 ± 0.01	0.03 ± 0.01	0.13
	LM	0.03 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.53
	RT	0.08 ± 0.01	0.04 ± 0.01	0.05 ± 0.01	0.10
	LT	0.09 ± 0.01	0.09 ± 0.01	0.08 ± 0.01	0.93
Protrusion	RM	0.07 ± 0.02	0.15 ± 0.06	0.11 ± 0.03	0.38
	LM	0.09 ± 0.01	0.13 ± 0.05	0.10 ± 0.01	0.71
	RT	0.10 ± 0.02	0.04 ± 0.01	0.05 ± 0.01	0.04
	LT	0.05 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.78

Table 1: Means, standard errors (±), and statistical significance ($P \leq 0.05$) of the normalized electromyographic data averages of the right masseter (RM), left masseter (LM), right temporalis (RT), and left temporalis (LT) muscles for the sedentary individuals (CG), professional swimmers who breathe to the left during the crawl (LG) and professional swimmers who breathe to the right during the crawl (RG) groups, in the mandibular tasks.

Table 2 shows the data on the thickness of the masseter and temporalis at mandibular rest and dental clenching at maximum voluntary contraction for the three groups. No statistically significant difference ($P \leq 0.05$) was found among the groups.

Table 3 shows the data on maximum molar bite force. The professional swimmers who breathe to the right and left groups demonstrated lower molar bite force on the left and right sides, respectively, with no significant statistical difference among the three groups ($P \leq 0.05$).

	Groups			
Muscular thickness	**CG**	**LG**	**RG**	**p Value**
Rest				
RM	0.95 ± 0.02	0.93 ± 0.04	0.91 ± 0.04	0.84
LM	0.92 ± 0.02	0.88 ± 0.04	0.92 ± 0.05	0.80
RT	0.34 ± 0.01	0.32 ± 0.01	0.31 ± 0.01	0.08
LT	0.32 ± 0.01	0.30 ± 0.01	0.95 ± 0.02	0.17
MVC				
RM	1.29 ± 0.02	1.29 ± 0.09	1.31 ± 0.05	0.95
LM	1.32 ± 0.03	1.25 ± 0.07	1.31 ± 0.04	0.60
RT	0.43 ± 0.01	0.44 ± 0.02	0.42 ± 0.02	0.81
LT	0.43 ± 0.01	0.42 ± 0.01	0.41 ± 0.01	0.88

Table 2: Means, standard errors (±), and statistical significance ($P \leq 0.05$) of muscle thickness (cm) of the right masseter (RM), left masseter (LM), right temporalis (RT), and left temporalis (LT) muscles for the sedentary individuals (CG), professional swimmers who breathe to the left during the crawl (LG) and professional swimmers who breathe to the right during the crawl (RG) groups, in rest and maximum voluntary contraction (MVC).

Discussion

This study aimed to determine the functional and morphological changes in the stomatognathic system of professional swimmers by evaluating the maximum molar bite force, electromyographic activity, and thickness of the masseter and temporalis muscles.

In swimming, breathing must be effective, smooth, and automatic, and is considered a primordial function that enables a professional swimmer to achieve better functional performance

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[14]. Crawl is considered the fastest modality among the four types of competitive swimming, and exercises almost every muscle group in the human body [15].

Studies have evaluated the performance of athletes using this modality by conducting biomechanical analysis of their strokes and breathing [16], but no studies have measured the effect of swimming, especially crawl modality, on the stomatognathic system.

We found functional changes in postural conditions of mandibular rest position, maximal protrusion, maximal right laterality, and maximal left laterality in swimmers using front crawl. Maximal voluntary isometric contraction normalized the electromyographic activity variables to obtain a better interpretation of comparison among different individuals, muscles, and collection periods, which reduced the difference among individuals [17-19]. During the rest, the electromyographic activity pattern for the professional swimmers who breathe to the right group was lower than that the sedentary individuals, with no statistically significant difference. Keeping the face on the aquatic surface is an essential factor for correct body position, offering less resistance [20,21]. The professional swimmers who breathe to the right group likely had the correct body posture, promoting improvement in the breathing function, relaxing the masticatory muscles, consequently reducing the stress.

In the maximal protrusion condition, the professional swimmers who breathe to the right and left groups showed lower and higher electromyographic activities of the temporalis and masseter muscles, respectively, than the sedentary participants. Their masticatory muscles presented a correct neuromuscular pattern, where the masseter was more active than the temporalis muscles [12,22]. Regular physical exercise induces changes in the contractile function and morphology of muscle fibers [23,24]. Individuals who periodically practice aquatic sports, such as crawl, have a better functional performance than sedentary individuals [25].

With respect to the maximal right and left laterality positions, the mandibular movement pattern was correctly developed [22] in all groups. The professional swimmers who breathe to the right group demonstrated lower normalized electromyographic activity for the muscles that are more active in these neuroanatomic movements in relation to the sedentary individuals, with a statistically significant difference in maximal right laterality for right temporal muscle.

The functional balance of the craniocervical-mandibular system may be directly related to body mobility and stability [26]. Front crawl is a sport that can influence body movements, including breathing and masticatory patterns [27]. The movement of the head during respiration in swimming can produce functional modifications to the temporomandibular joint, which can be affected by water pressure, altering neuromuscular behavior. This hypothesis could justify the electromyographic activity data for the mandibular postural conditions in this study. Future studies could evaluate the effect of water pressure on the temporomandibular joint during head rotation during swimming, with the aim of demonstrating its influence on joint function.

When partially immersed in a liquid medium in equilibrium, the body is under the influence of upward thrust and gravity [28]. This physical property promotes resistance to movement, stimulates peripheral circulation, strengthens the muscles, and increases capillary blood flow due to water pressure [29], altering hemodynamic and muscular characteristics [30].

When partially immersed in a liquid medium in equilibrium, the body is under the influence of upward thrust and gravity [28]. This physical property promotes resistance to movement, stimulates peripheral circulation, strengthens the muscles, and increases capillary blood flow due to water pressure [29], altering hemodynamic and muscular characteristics [30].

Muscle thickness using ultrasonographic images was assessed to analyze muscle adaptations in response to different strength trainings [31]. The analysis of the morphological variables in this study demonstrated no statistically significant difference in the thickness of the masseter and temporalis muscles among the groups, both at mandibular rest and dental clenching at maximum voluntary contraction.

When practicing aquatic sports, the skeletal striated muscles are strained more than normal to withstand the overload, which produces an increase in muscle force [32]. When the muscle contracts against some resistance, protein synthesis is stimulated, forming fissures in the muscular fibers [33]. After recovery from physical exercise, new proteins are produced, and muscle fibers recover, becoming more dense and hypertrophic [34]. This was not observed in the masticatory muscles of professional swimmers who breathe to the right and left groups.

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The results of this study also showed no statistically significant difference among the groups with respect to maximum molar bite force, but the contralateral side to the respiratory movement during the crawl modality was observed to exhibit lower maxillary bite force. Evaluation of the maximum bite force is a method used to diagnose structural limitations of the stomatognathic system because it provides information on the functional status of this complex system [13,35]. No studies in the literature have evaluated the maximum molar bite force of aquatic sports athletes, so we found it difficult to compare our results with those of other studies.

The reference standards for the maximum molar bite force as a function of the age of healthy participants were described in the literature [13], with adolescents aged 13 and 20 years presenting a maximum molar bite force of 338.92 ± 27.46N and 343.92 ± 25.99N for the right and left, respectively, and young adults showing a maximum molar bite force of 279.98 ± 23.93N and 296.95 ± 24.91N for the right and left, respectively. Our results did not corroborate with the findings of literature [13] where the professional swimmers who breathe to the right and left groups presented higher maximum molar bite force values (right and left).

Even though competitive swimming may promote movement repetition, which can be associated with the type of breathing and possible impairment of skeletal striated muscles, which can lead to postural changes, this study demonstrated that crawl swimming induces positive changes in the normalized electromyographic activity of the masseter and temporalis muscles.

Therefore, our results illustrated that the crawl modality of swimming, aside from improving the quality of life [36], produces favorable changes in the electromyographic activity of the masseter and temporalis muscles in professional athlete.

The present study has limitations. This study was designed to run the bite force in the laboratory, however, was unable to obtain the actual maximum molar bite force with swimming. Future studies should measure during swimming the bite force because the rest time is different from the during swimming

Conclusion

Based on the results of this study, we can suggest that crawl swimming promotes positive changes in stomatognathic system in professional swimmers, especially in the electromyographic activity of the masseter and temporalis muscles.

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