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Research Article

Electromyographic Analysis of Masticatory Efficiency in High-Performance Male Athletes: Part 2

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Abstract

High-performance sports practice creates physical and emotional demands that may affect the stomatognathic system. In this context, sports dentistry plays an important role in preventing orofacial dysfunctions and maintaining masticatory function. This cross-sectional observational study aimed to evaluate the masticatory efficiency of male high-performance athletes, comparing them with a control group. Thirty-six men between 15 and 40 years of age participated in the study, all without temporomandibular disorders and with normal occlusion, and were allocated into two groups: high-performance athletes (n = 18) and sedentary control (n = 18). Masticatory efficiency with peanuts and raisins was measured using the linear envelope integral of the electromyographic signal from the masseter and temporal muscles, Student's t-test was used for the analysis. During habitual mastication with peanuts, the athletes showed lower electromyographic activity in all muscles, with significant differences in the right masseter ($p = 0.03$), left masseter ($p < 0.01$), right temporalis ($p < 0.01$), and left temporalis ($p = 0.02$). During mastication with raisins, lower muscle activity was also observed in the athletes. No difference was found in the right masseter, but differences were identified in the left masseter ($p = 0.001$), right temporalis ($p = 0.004$), and left temporalis ($p = 0.009$). Male high-performance athletes exhibited a distinct activation pattern of the masticatory muscles, characterized by lower electromyographic activity during habitual chewing. This finding highlights the importance of evaluating the stomatognathic system to ensure adequate nutritional support and, consequently, to enhance athletic performance.

Keywords: High-Performance Athletes; Electromyography; Masticatory Efficiency; Stomatognathic System; Masticatory Muscles

Introduction

Sports dentistry functions as a specialty dedicated to the comprehensive care of the oral health of subjects who practice physical activities. Its focus includes identifying, preventing, and treating oral alterations and facial injuries that may occur in athletes, both professional and amateur. In addition to promoting oral well-being, this field contributes to athletic performance and to recovery after training sessions or competitions. It also addresses pathologies and dysfunctions of the stomatognathic system that may be directly related to sports practice [1,2].

Oral health has a direct influence on athletic performance, since conditions involving pain, inflammation, infections, and orofacial dysfunctions can compromise concentration, motor performance, and physical recovery [3]. In addition to the fabrication of mouthguards, the field includes the management of dental trauma, cavities, malocclusions, periodontal diseases, and temporomandibular joint disorders, reinforcing the need for specialized care [4].

The prevention of orofacial trauma in contact sports is one of the main clinical focuses, with customized mouthguards being effective strategies for safety during training sessions and competitions [5,6]. However, the impact of the stomatognathic system goes beyond trauma, influencing posture, balance, and motor coordination, since functional alterations can affect body stability and increase the risk of musculoskeletal injuries. Athletes undergoing intensive training may present significant functional adaptations, such as increased strength, reinforcing the importance of interdisciplinary monitoring among dentistry, physical therapy, and other health fields [7-9].

In this context, masticatory efficiency is a relevant parameter for assessing muscle performance, as it directly influences nutritional utilization, energy recovery, and biomechanical maintenance [10]. Quantitative methods, such as electromyography, allow for precise analysis of muscle activity. Thus, the measurement of masticatory efficiency aims to objectively quantify the functional capacity of the masticatory system, encompassing aspects related to muscular coordination [11].

Given this context, it becomes pertinent to investigate whether high-performance athletes present differences in masticatory efficiency compared with sedentary subjects. The aim of this study was to analyze the habitual masticatory efficiency of male high-performance athletes, comparing them with a control group. The null hypothesis assumes that there are no significant differences between the groups. This analysis may support clinical interventions, preventive strategies, and therapeutic protocols that enhance performance, health, and sports longevity.

Material and Methods

Study design and sample

This observational, cross-sectional, and comparative study was approved by the Ethics Committee of the School of Dentistry of Ribeirão Preto, University of São Paulo, and by the Laboratory of Biomechanical Movement Analysis of the Claretiano University Center of Batatais, São Paulo, Brazil (protocol code 60919222.2.0000.5419, date of approval: 3 August 2022). All subjects signed an informed consent form.

Sample size calculation was performed using G*Power software version 3.1.9.2 (Franz Faul, University of Kiel, Germany). For this estimation, a significance level of $\alpha = 0.05$, a 95% confidence interval, and a minimum statistical power of 80% were adopted, resulting in the need for at least 18 subjects in each group.

From a total of 120 subjects, and after applying the inclusion and exclusion criteria, the final sample consisted of 36 male subjects aged between 15 and 40 years. Among them, 18 were high-performance athletes (age: 37.44 ± 4.14 years; weight: 88 ± 12.09 kg; height: 1.75 ± 0.08 m; BMI: 28.46 ± 2.62 kg/m^2). The remaining 18 subjects were sedentary subjects, comprising the control group (age: 39.05 ± 5.01 years; weight: 79.78 ± 10.22 kg; height: 1.78 ± 0.06 m; BMI: 25.16 ± 3.29 kg/m^2).

The characterization of high-performance athletes participating in high-impact sports such as bodybuilding, Jiu-Jitsu, and CrossFit was based on having more than five years of uninterrupted practice in their respective discipline and training at least five times per week. However, the specific intensity of the training sessions was not evaluated, as each participant adhered to their usual training routine. Measurements were performed during the recovery period, meaning that athletes were evaluated during a phase of reduced muscular demand.

An anamnesis of all subjects was conducted by a single dentist, who evaluated facial structures, teeth, and general health status through clinical examination and a standardized clinical form, with the objective of obtaining personal data, medical and dental history, presence of systemic diseases, parafunctional habits, and temporomandibular dysfunction.

As inclusion criteria, subjects were required to present natural dentition with the presence of the four first permanent molars, normal occlusion, and absence of any pathology capable of compromising the musculature of the stomatognathic system, in addition to meeting the established age range. Exclusion criteria included the presence of ulcerations, open wounds, or cutaneous hypersensitivity; cognitive deficits; neurological or uncontrolled systemic disorders; use of full or removable prostheses; periodontal disease; continuous use of anti-inflammatory drugs, analgesics, or muscle relaxants that could interfere with neuromuscular physiology; as well as subjects undergoing orthodontic, speech therapy, or otorhinolaryngological treatment, or those who were smokers.

In this study, the efficiency of masticatory cycles was assessed using the same sample previously reported by Fioco., *et al*. [8]. The data were divided into two separate manuscripts, as presenting and discussing distinct analytical approaches within a single paper would have been excessively complex. One manuscript focused on the analysis of mandibular posture using root mean square, whereas the other addressed masticatory analysis in accordance with the international Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) standards [12], employing the linear envelope method.

Masticatory efficiency analysis

Masticatory efficiency was recorded using the MyoSystem-I P84 electromyograph (MyosystemBr1, Data Hominis Tec. Ltda., Uberlândia, MG, Brazil). Electrode placement was performed bilaterally over the masseter and temporal muscles, following the recommendations of SENIAM [12]. Before electrode fixation, the skin was cleaned with alcohol to reduce impedance, and the electrodes were applied a few minutes after this cleansing [13]. Muscle location was confirmed by palpation during maximal voluntary contraction. Recordings were performed in a quiet and calm environment, with subjects seated in a comfortable chair, in an upright posture, with their feet resting on the floor, arms supported on their legs, and the head aligned with the Frankfurt horizontal plane.

For the evaluation of habitual and non-habitual mastication, electromyographic signals were recorded during habitual chewing of 5 g of Japanese peanuts with skin (10 seconds), classified as a consistent food, and 5 g of seedless raisins (10 seconds), classified as a soft food. In addition, non-habitual chewing was assessed using Parafilm M® (10 seconds), consisting of a folded paraffin sheet (18 × 17 × 4 mm; 245 mg) positioned between the occlusal surfaces of the first and second permanent molars.

Electromyographic analysis considered the integral of the linear envelope of the masticatory cycles, used as the mathematical measure of masticatory efficiency, with results expressed in microvolts per second. The integral of the linear envelope was also calculated to assess signal amplitude. Bilateral masseter and temporal muscle signals were analyzed during habitual and non-habitual mastication, allowing the evaluation of masticatory performance when chewing foods of different consistencies, as well as during controlled activity with Parafilm M® [14]. To ensure comparability, all electromyographic signals were previously normalized based on the activity recorded during non-habitual mastication with Parafilm M® [15].

Statistical analysis

After collecting the variables, the Shapiro–Wilk normality test was applied, which indicated that the data had a normal distribution. Statistical analysis was performed using SPSS software, version 22.0 (SPSS Inc., Chicago, IL, USA), and the t-test was used to compare the groups regarding the integral of the linear envelope of the electromyographic signal of the masseter and temporal muscles during habitual mastication with peanuts and raisins. For all analyses, a significance level of $p < 0.05$ was adopted.

Results

Table 1 shows the EMG values of the masseter and temporal muscles during habitual mastication of peanuts and raisins. During peanut mastication, the athletes demonstrated lower electromyographic activity in all evaluated muscles, with significant differences in the right and left masseter, as well as in the right and left temporal muscles. During raisin mastication, lower muscle activity was also observed in the athletes. In this case, there was no difference in the right masseter, but differences were found in the left masseter, right temporal, and left temporal muscles.

Table 1: Differences in mean values and standard error of the integral of the linear envelope of the electromyographic signal of the masseter and temporal muscles during habitual mastication with peanuts and raisins in the high-performance athlete and sedentary control groups.

Chewing	Muscles	Groups		p value
		Male high-performance athletes	Sedentary control	
Peanuts	Right masseter	0.58 ± 0.06	0.98 ± 0.16	0.03
	Left masseter	0.41 ± 0.04	1.07 ± 0.16	<0.01
	Right temporal	0.34 ± 0.06	0.82 ± 0.09	<0.01
	Left temporal	0.31 ± 0.04	0.97 ± 0.18	0.02
Raisins	Right masseter	0.44 ± 0.07	0.55 ± 0.06	0.31
	Left masseter	0.26 ± 0.03	0.62 ± 0.09	0.001
	Right temporal	0.24 ± 0.06	0.76 ± 0.11	0.004
	Left temporal	0.30 ± 0.04	0.63 ± 0.11	0.009

Note: The differences of the mean significant at p value < 0.05.

Discussion

The null hypothesis assuming no significant differences in the masticatory efficiency of the masseter and temporal muscles between high-performance athletes engaged in high-impact sports such as bodybuilding, Jiu-Jitsu, and CrossFit and sedentary subjects was rejected, The results indicated that high-performance athletes differed from sedentary subjects in masticatory muscle electromyographic activity, suggesting that intense physical training may be associated with functional characteristics of the stomatognathic system.

The study showed that male athletes engaged in high-performance exercise exhibited a significant reduction in the electromyographic activity of the masseter and temporal muscles during the mastication of both hard foods (peanuts) and soft foods (raisins). The only exception was the right masseter muscle during raisin mastication, whose reduction was not statistically significant. This pattern may reflect differences in neuromuscular control strategies between athletes and sedentary subjects, as observed in previous investigations on masticatory muscle activity [16].

Proper mastication depends on repetitive movements of the masticatory muscles, alternating between isotonic and isometric contractions [17]. Among the mathematical methods used to analyze masticatory cycles, the calculation of the integral of the linear envelope of the electromyographic signal stands out, as it quantifies muscle electrical activity and indicates the intensity of activation during the formation of the masticatory cycle [14]. In the present study, this method was used to analyze the masticatory performance of high-performance athletes, allowing the identification of distinct electromyographic patterns when compared with sedentary subjects.

The alteration in the electromyographic activity of the masseter and temporal muscles in high-performance athletes may be interpreted in light of neuromuscular characteristics commonly reported in trained populations, such as differences in neural drive, motor command organization, and corticospinal excitability. However, given the cross-sectional design of the study, these mechanisms cannot be interpreted as training-induced adaptations, but rather as plausible explanations consistent with existing literature [18].

In parallel, peripheral factors such as contractile efficiency, motor unit recruitment strategies, and proprioceptive regulation have been described in athletes and may contribute to lower electromyographic amplitudes during functional tasks [19]. Moreover, postural factors and musculoskeletal interactions may influence masticatory muscle activation, reinforcing the notion that systemic characteristics of trained subjects can be associated with stomatognathic function, without implying a direct causal relationship [20].

The observed adaptations are consistent with evidence that highly trained athletes exhibit systemic changes in muscle composition, greater neuromuscular efficiency, and refined motor recruitment patterns [21]. Thus, the reduction in muscle activity during the masticatory process identified in this study can be understood as part of physiological adjustments associated with the high physical demands imposed by training. Resistance training activates repair and adaptation pathways that modulate muscular and neural function without functional impairment, especially in experienced athletes [22]. In this way, the lower myoelectric activity of the masticatory muscles represents an adjustment consistent with the motor adaptation state typical of athletes who are continuously exposed to intense and prolonged stimuli [23].

Data collection during a recovery period should be considered when interpreting the electromyographic findings. Reduced neuromuscular fatigue and restored motor control during recovery may result in lower electromyographic amplitudes, reflecting increased neuromuscular efficiency rather than diminished muscle function. Since neuromuscular activation varies according to fatigue and recovery status, the observed results likely represent a stabilized adaptive condition of trained athletes and should be interpreted within this methodological contex [24].

The electromyographic data were collected during a recovery period, which may have influenced the results. Recovery phases are associated with reduced neuromuscular fatigue and greater motor efficiency, potentially attenuating electromyographic amplitudes [25]. Thus, the lower activation observed should be interpreted cautiously, as it may reflect a stabilized adaptive condition rather than neuromuscular behavior across different training phases. Future studies should include assessments during distinct stages of sports periodization.

Another aspect to be considered is the relationship between posture, cervical control, and masticatory function. The athletes in the present study had an intense training routine, which could often be associated with stability of the cervical and thoracolumbar regions [26]. Since the stomatognathic system maintains direct integration with cervical musculature and overall postural adjustments, greater stabilization of the cranio-cervical system in athletes could favor more coordinated masticatory patterns, reducing the need for compensatory activation of the masticatory muscles.

Athletes are exposed daily to high training loads, which are commonly associated with musculoskeletal characteristics such as increased stiffness, greater fiber thickness, and efficient force transmission [27]. These modifications make contraction more efficient and allow dynamic body activities to be performed more economically, that is, with lower energy expenditure and reduced need for motor unit recruitment [23]. Thus, it can be inferred that athletes present lower electromyographic activity during habitual mastication, since more efficient muscles require less neural activation to perform masticatory movements when compared to sedentary subjects.

In the case of raisins, a soft-consistency food, mastication requires less force and therefore tends to promote lower muscle activation when compared to harder foods [28]. The findings of this study are consistent with what is described in the literature. Nevertheless, high-performance athletes continued to show lower electromyographic activity levels in the masseter and temporal muscles during habitual mastication with raisins. In any case, the overall pattern remained: athletes chew with lower neuromuscular effort, even when the food does not require intense crushing. This pattern suggests that differences in neuromuscular activation persist across food consistencies, although such differences should be interpreted as functional characteristics.

In addition to the physiological factors mentioned, it is also important to consider the nutritional context. Efficient mastication is essential for proper food breakdown, bolus formation, and the initiation of the digestive process [29]. Reduced muscle activation in athletes can be explained by better coordination and greater neuromuscular economy, without compromising mechanical efficiency, as long as force production and performance remain preserved [30].

An additional aspect that deserves consideration refers to the experimental conditions. The data collection took place during a recovery period, in which the athletes were experiencing lower muscular demands. If these electromyographic recordings had been performed after intense training sessions or competitions, muscle behavior would likely have shown changes, since systemic muscle fatigue influences motor control and may increase or decrease activity depending on the physiological state [31]. Future research should consider different stages of sports periodization to clarify this issue.

Finally, it is necessary to acknowledge that the observed adaptations represent a multifactorial response to intense training and do not necessarily reflect a direct relationship between sport modality and masticatory function. Nevertheless, the findings reinforce the importance of sports dentistry in monitoring orofacial function, as changes in activation patterns may indicate both positive adaptations and potential future risks.

Considering this adaptive complexity, it becomes relevant to analyze how different sport modalities and training levels may affect masticatory function, contributing to a better understanding of the observed effects and to the development of clinical interventions in sports dentistry.

This study has some limitations. It is a cross-sectional observational design, which does not allow establishing causal relationships between sports training and the electromyographic differences observed. The sample consisted of male athletes, limiting the generalization of the findings to female athletes, who may present distinct masticatory patterns due to hormonal, biomechanical, and motor behavior differences. Moreover, although the athletes were characterized as high-performance, there was no objective measurement of training intensity, duration, or load, which could have allowed more robust correlations between training parameters and masticatory efficiency. Finally, data collection occurred during a recovery period rather than during different phases of sports periodization, which restricts the understanding of possible fluctuations in electromyographic activity throughout the training cycle.

Conclusion

The study suggests that high-performance male athletes exhibit lower electromyographic activity in the masseter and temporal muscles during the mastication of both hard and soft foods, possibly due to greater neuromuscular efficiency. Identifying these changes in the dynamics of masticatory function is fundamental for sports dentistry, as it may guide preventive and therapeutic strategies aimed at preserving orofacial function, supporting nutritional performance, and consequently improving the athletes' overall performance. Thus, the study contributes both to advancing knowledge about masticatory physiology in athletes and to the development of more comprehensive, evidence-based clinical practices, with a direct impact on health and sports performance.

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