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Acute Myotonometric Changes in the Masseter and Upper Trapezius Muscles After Upper Body Quarter Stretching and Coordination Exercises or Chewing

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Abstract: Pathologies in neck and masticatory muscles affect muscle tone and biomechanical and viscoelastic properties, necessitating precise assessment for treatment. This study evaluated the impact of two guided interventions—relaxing exercises targeting the neck and masticatory muscles ("Exercise") and heavy chewing using six chewing gums ("Chewing")—on the masseter and upper trapezius muscles. Twelve participants (aged 19–40 years) underwent myotonometric assessment pre- and post-intervention, measuring tone, stiffness, decrement, relaxation time, and creep. The results showed significant changes in the masseter muscle after exercise, with increased stiffness (14.46%, $p < 0.001$) and tone (7.03%, $p < 0.001$) but decreased creep (−9.71%, $p < 0.001$) and relaxation time (−11.36%, $p < 0.001$). Conversely, chewing decreased stiffness (−8.82%, $p < 0.001$) and tone (−5.53%, $p < 0.001$), while it increased creep (9.68%, $p < 0.001$) and relaxation time (9.98%, $p < 0.001$). In the trapezius muscles, tone decreased after both interventions (Exercise: −7.65%, $p < 0.001$; Chewing: −1.06%, $p = 0.003$), while relaxation increased (Exercise: 1.78%, $p < 0.001$; Chewing: 2.82%, $p < 0.001$). These findings reveal the distinct effects of exercise and chewing on muscle properties, emphasising the complexity of their therapeutic potential and the need for further investigation.

Keywords: exercise; mastication; muscle tonus; relaxation techniques; relaxation therapy; temporomandibular joint disorders; masseter muscle; trapezius muscle; bruxism; intervention studies

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1. Introduction

Temporomandibular disorders (TMDs) impact the temporomandibular joint (TMJ) and masticatory muscles, disturbing quality of life by causing pain, a reduced jaw range of motion, psychological disorders such as anxiety and depression, as well as sleep disturbances [1–3]. Bruxism, a separate condition, is a risk factor for the development and worsening of TMDs and is characterised by repetitive jaw-muscle and teeth clenching or grinding [4]. Although, epidemiological, neuromuscular, and neurophysiological studies are still indefinite about whether the muscular symptoms are the cause or the consequence of TMDs [5], a recent study suggests a muscular component in the aetiology of temporomandibular disorders (TMDs) [6]. Nevertheless, both TMDs and bruxism underscore the role of altered masticatory muscle activity; however, there is a notable scarcity of interventional research employing myotonometry for the assessment of orofacial muscles [7–10].

Masseter muscle stiffness and tone are elevated in patients with myogenous or mixed TMDs and those with self-reported bruxism [7,9,11,12]. Increased masseter stiffness has also been reported in individuals with forward head posture, particularly due to smartphone usage [13]. Tension, acting as a self-reinforcing loop within the pain cycle by linking muscular tension, emotional distress, and behavioural responses, has been notably associated with an increased prevalence of TMD symptoms [14,15]. Moreover, because of the interconnectivity of mandibular and neck activities, prolonged nociceptive input from Myofascial Trigger Points (MTrPs) in the trapezius may contribute to central sensitization, amplifying peripheral pain and disrupting stomatognathic system function [16].

Stretching and coordination exercises for the neck and orofacial muscles have already been proposed as a non-pharmacological therapeutic option to treat TMDs [1,2,17], significantly reducing pain and muscle stiffness in the targeted region [18]. Moreover, similar exercise interventions have been used in patients with obstructive sleep apnoea [3], preventing oropharyngeal injuries due to intubation [19], improving mastication, and increasing muscle stiffness in older adults [20] and after orthodontic or surgical treatments [2]. On the other hand, chewing exercises can be used as strength training for the masseter muscle and, when adopted regularly, can increase bite force and muscle stiffness in healthy populations [21,22]. Moreover, chewing exercises have been used to increase muscle stiffness as post-operative treatment following orthognathic surgeries [23] and in patients with orofacial muscular diseases [24]. It is important to recognise that various pathologies and dysfunctions can significantly affect muscle tone and biomechanical and viscoelastic muscle properties [25–27]. These conditions necessitate the precise assessment of methods to monitor and treat the changes in muscle properties effectively.

Historically, evaluations of muscle tone and stiffness have relied on manual palpation. This traditional assessment method relies heavily on expert assessment and is subject to significant bias, particularly in detecting small changes over time. The limitations of this approach have triggered the development of objective tools like myotonometric and tensiomyographic measurement devices. Myotonometry has proven valid and reliable in various conditions [28,29], and different muscle groups and subjects of different age groups [30,31]. Compared to tensiomyography, which uses uncomfortable electrical impulses to induce muscle contractions, myotonometric devices offer a painless and non-intrusive alternative. This is particularly advantageous for measuring muscle tone in sensitive areas such as the face. Evidence in the literature shows that myotonometric parameters can assess muscle proneness to injury, fatigue, and muscular performance [32–35]. These compact handheld devices are used to determine the mechanical properties of muscles such as muscle (i) stiffness, the resistance of muscle tissue to external forces, indicative of its intrinsic elasticity; (ii) tone, that is, the continuous, passive partial contraction, highlighting the readiness of muscles for action; (iii) decrement, a measure of muscle endurance against repeated contractions, serving as an indicator of fatigue resistance; (iv) creep, describing the muscle's length change under sustained load and providing insights into the viscoelastic properties of the muscle; and (v) relaxation, which assesses the time needed by the muscle to return to its resting state post-contraction [11,30].

Despite the growing number of studies collecting data from myotonometric devices, there are only a few studies applying such technology to investigate the muscles that are mostly involved in TMDs, such as the orofacial muscles [7,9,27] and the upper trapezius muscle [36–38]. A recent study found that increased muscle tone can alter masticatory performance in older adults [39]. Moreover, another study reported that malocclusion affects the biomechanical and viscoelastic properties of core stability muscles more than the masticatory ones [40]. Taş et al. [27] found increased masseter and upper trapezius stiffness and tone in subjects with myogenous and mixed TMDs.

Interventional studies using myotonometric devices, particularly on limbs, provide foundational insights into the effects of various exercises on muscle tone and stiffness. For example, there is evidence that stretching decreases stiffness in leg muscles [35,41], while eccentric exercise is known to increase the stiffness of the calf muscles [42]. Extending these insights beyond the limbs, interventional studies investigating myotonometric changes in the masseter and upper trapezius muscles after exercise periods reveal similar muscle response patterns. For example, ultrasound therapy led to a transitory lowering of the myotonometric parameter decrement [43]. Lee et al. [9] found that TMD treatment, which led to a reduced masseter and sternocleidomastoid muscle tone, also augmented jaw opening. Moon et al. found that using lumbar lordosis assistive support lowers the decrement and stiffness of the upper trapezius in subjects with a forward head posture [37]. Moreover, the stiffness of the upper portion of the trapezius muscles was decreased with the ischemic compression of the myofascial trigger points, a six-week programme with stretching, mobilisation, strengthening, stabilisation workout, eccentric exercises, and cervical stretching with craniocervical flexion exercises [36,38,44,45].

Within this context, the primary goal of this study is to investigate the changes in muscle tone and the biomechanical and viscoelastic properties of the masseter and the upper trapezius muscles, as assessed by myotonometry, following two distinct guided exercise interventions. These interventions are designed to (i) mobilise the orofacial and neck muscles and (ii) engage subjects in heavy chewing. Drawing upon existing literature using similar interventions, we hypothesised that the masseter muscle's stiffness and tone, as well as those of the orofacial and trapezius muscles, would decrease as a result of the exercise intervention. Conversely, we hypothesise an increase in stiffness and tone in response to heavy chewing activities.

2. Materials and Methods

2.1. Study Design

The present study employed a cross-over, repeated-measures design. Each participant underwent two different intervention protocols during a single visit. Initially, participants completed an adapted version of the Fonseca anamnestic index questionnaire (FAI) to assess the presence of temporomandibular disorders. During the interventions, the participants were instructed to maintain a steady sitting posture on a standard chair. They were then exposed to two distinct interventions as follows: (i) a structured series of exercises aimed at enhancing the intramuscular coordination of muscles directly or indirectly involved in mastication and maintaining head posture (Exercise), and (ii) vigorously chewing peppermint-flavoured sugar-free chewing gum for 6 min (Chewing). A 20 min washout period was incorporated between the Exercise and Chewing interventions to mitigate carry-over effects (Figure 1a). The duration of the washout period was tested in a previous pilot study. Before and after each intervention, the participants were assessed using myotonometry.

2.2. Power Analysis and Sample Size Justification

Based on a previous myotonometric study of the trapezius [44] showing a large effect size, a power calculation (G*Power, effect size = 1.0) indicated that 10 participants would provide an 80% power at $\alpha = 0.05$; therefore, we recruited 12 participants to enhance reliability and account for potential dropouts.

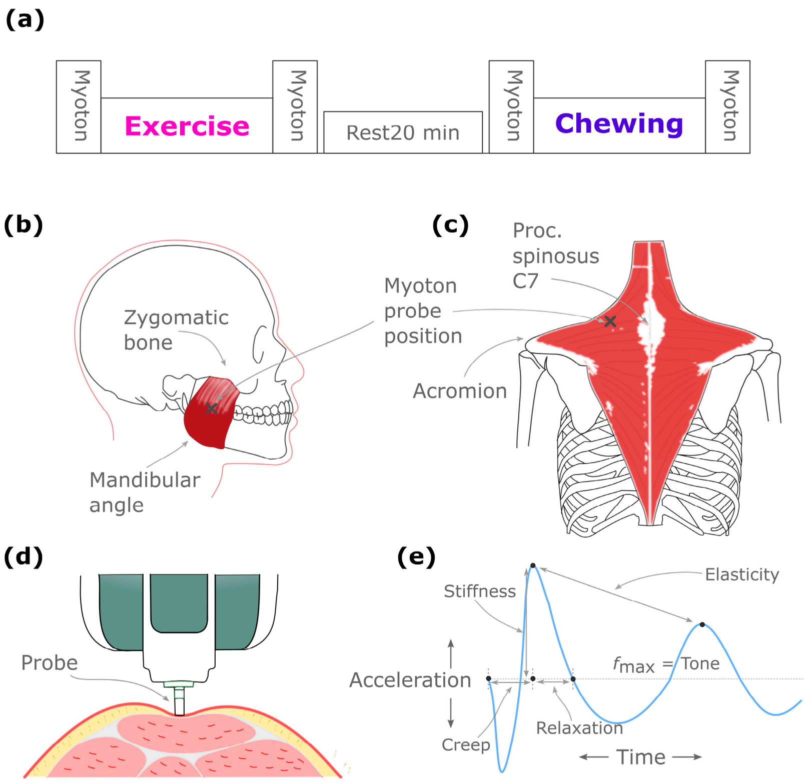

Figure 1. Study design and methodology overview. (**a**) Study design. (**b**) Position of the Myoton probe on the masseter muscle. (**c**) Position of the Myoton probe on the upper trapezius muscle. (**d**) Myoton probe. (**e**) Myoton parameters.

2.3. Participants

Twelve healthy participants (6 men, aged 19–40 years; mean age 28,5 years) volunteered. The inclusion criteria for the study were individuals of both sexes, aged 18 to 40 years, with a Body Mass Index (BMI) between 18.5 and 24.9, and a Fonseca anamnestic index (FAI) score > 15. The upper limit of 40 years was chosen to focus on a population with a relatively stable muscle function, given that muscle mass and strength typically show a more pronounced decline after the age of 40 [46]. Participants were required to have a stable occlusion (defined as at least 20 teeth) and to exhibit pain-free passive and active mouth opening, as confirmed by a dentist. Exclusion criteria were known muscular and neurological disorders, pregnancy, and previous orthodontic treatments. Participants were instructed to avoid caffeinated and alcoholic drinks on the day of the study and to refrain from intense sports activities. All measurements were performed in the morning, starting at 9 AM, in a quiet room maintained at 22 °C. This approach was adopted to reduce potential circadian rhythm influences on muscle stiffness [47] and to avoid thermal fluctuations that may affect muscle function [48]. The study was approved by the National Medical Ethics Committee of the Republic of Slovenia (Ethical Approval 0120-417/2021/3). All procedures were performed according to the Declaration of Helsinki.

2.4. Assessment Procedures

2.4.1. Fonseca Anamnestic Index Questionnaire

All participants were initially screened using the Fonseca anamnestic index (FAI), a widely used standardised diagnostic tool designed to assess the presence and severity of TMDs through patient self-report [49]. For this study, the FAI was translated into Slovenian; however, this version has not yet undergone formal validation. The FIA questionnaire consists of 10 questions that cover the following four categories of symptoms:

pain and discomfort, jaw movement, clicking/popping sounds, and functional impact. Only one answer was allowed per question, which was scored as follows: “yes—10 points”, “sometimes—5 points”, or “no—0 points”. A score of 0–15 points indicates the absence of signs and symptoms of TMDs, 20–45 points indicate mild TMDs, 50–65 points indicate moderate TMDs, and 70–100 points indicate severe TMDs [50]. All included participants attained a FAI score of 15 or less, rendering them suitable for the study. The questionnaire contained additional epidemiological inquiries about gender, age, previous orthodontic treatments, and the habituality of chewing gum, collected for future research and epidemiological analysis (not needed for the present study).

2.4.2. Clinical Assessment

A comprehensive clinical assessment was performed on each patient by a licenced dentist in a controlled clinical setting. The evaluation included a detailed medical and dental history. Also, a standardised physical intraoral and extraoral examination was conducted. The presence of parafunctional habits such as clenching or grinding was assessed based on dental wear patterns and patient self-reports.

2.4.3. Myotonometry

The Myoton-PRO device (Myoton SA, Tallinn, Estonia) measured the tone, biomechanical, and viscoelastic properties of the masseter and the upper trapezius muscles. The device, equipped with a 3 mm probe, provides a constant pre-load force and delivers a quick-release mechanical impulse (0.6N) to induce soft tissue deformation, which is recorded by the device (Figure 1d). This deformation provides information on several parameters, such as natural oscillation frequency or tone (Hz), biomechanical properties (stiffness, N/m; logarithmic decrement or decrement, indicating elasticity), and viscoelastic properties (mechanical stress relaxation time or relaxation, ms; creep, the ratio of deformation to relaxation time) (Figure 1e). The device’s interrater (0.65–0.95) and interrater (0.66–0.88) reliability has been validated [11].

Measurements were performed with the participants being seated, their shoulders and head in neutral positions, hips and knees at 90°, and feet parallel to the ground. The masseter and upper trapezius muscles were chosen for their roles in mastication and head posture, respectively. Measurement points were determined in accordance with previous studies as follows: mid-way between the C7 and the acromion angle for the upper trapezius [51] (Figure 1c) and between the zygomatic bone and mandibular angle for the masseter muscle [8] (Figure 1b). Locations were marked with a water-based pen. The probe was held perpendicular to the skin, and 15 mechanical impulses were delivered at 0.7 s intervals for 15 ms each. Participants were instructed to maintain a relaxed mandibular position. Assessments occurred before and within 60 s after each intervention, conducted by the same examiner.

2.5. Interventions

The first intervention (Exercise) comprised stretching and coordination exercises for the orofacial, neck, and shoulder girdle muscles. These exercises targeted the muscles engaged in mastication and head posture [52]. The intervention protocol consisted of 25 exercises (Table 1). Exercises 1–4 were for tongue proprioception and control, Exercise 5 activated the orofacial muscle spindles and relaxed the orofacial muscles due to desensitisation, Exercise 6 was for facial muscle relaxation, Exercise 7 was for the relaxation of the mandible, Exercises 8–9 were mobilisation exercises (hold 30 s, pause 10 s, repeat 2×), Exercises 10–12 were coordination exercises (20 s active, pause 10 s, repeat 3×), Exercises 13–16 were isometric strength exercises (hold 30 s. pause 10 s, repeat 2×), Exercises 17–18 aimed to increase the upper cervical flexion and extension, Exercises 19–24 were isometric exercises for the cervical region, and Exercise 25 involved scapular retraction. Exercises 17–25 are techniques used to increase axial extension (hold 20 s, pause 10 s, repeat 3×). The first intervention protocol lasted around 25 min. The second intervention (Chewing) involved chewing 6 commercially available sugar-free gums (22 g each) at 60 bites/minute for 6 min. The Supplementary Materials include a detailed exercise description with photos and videos https://osf.io/u7jyv/?view_only=c868938ea0984c2f989cdb62c6571126 (accessed on 28 December 2024).

Table 1. Intervention protocol exercise summary.

Exercise n	Aim	Instructions
Exercise intervention		
1	Tongue proprioception and control	Hold for 30 s. Rest for 10 s, repeat 2×
2–4		Repeat at 0.5 Hz for 30 s. Rest for 10 s repeat for 2×
5	Activate orofacial muscle spindles	Hold for 30 s. Rest for 10 s, repeat 2×
6	Facial muscle relaxation	
7	Relaxation of the mandible	
8–9	Mobilisation exercises	
10–12	Coordination exercises	Repeat at 0.5 Hz for 20 s. Rest for 10 s repeat for 3×
13–18	Isometric strength exercises	Hold for 30 s. Rest for 10 s, repeat 2×
19–24	Isometric exercises for the cervical region	Hold for 20 s. Rest for 10 s, repeat 3×
25	Scapular retraction	
Chewing intervention		
	Chewing	60 bites/min for 6 min

2.6. Data Analysis

All data analyses, data cleaning, and statistical analyses were conducted using the R programming language (version 4.2.1) in the Rstudio environment (version 2022.07.1). We fitted separate repeated measure-nested linear mixed-effects models, estimated using REML (lmerTest package 3.1-3; [53]), to examine the effects of each experimental intervention (Exercise and Chewing) and time on the following Myoton parameters: stiffness (reflecting the tissue's resistance to shape changes), relaxation (the time required for the muscle to regain its initial shape post-deformation), tone, creep (the deformation to relaxation time ratio), and decrement (logarithmic decrement indicating elasticity). The model included 'intervention' and 'time' as fixed effects and 'participants' as random effects. To test the assumptions of the mixed linear models, residuals were plotted against the fitted values to assess homoscedasticity, and Q-Q plots were used to verify the normality of the residuals. The visual inspection of residual plots revealed no obvious deviations from homoscedasticity or normality. Moreover, p-values were computed using a Wald t-distribution approximation, and Sidak-corrected post hoc tests were employed to identify differences in cases of statistically significant interactions or main effect differences. To quantify the magnitude of changes, we calculated effect sizes in terms of standardised beta for mixed effect effects and Cohen's d for post hoc measures. Standardised beta effect sizes between 0.10 and 0.29 were considered small, effects between 0.30 and 0.49 were considered medium, and effect sizes of 0.5 or greater were considered large. Coden's d effect sizes between 0.20 and 0.49 were considered small, effects between 0.50 and 0.79 were considered medium, and effect sizes of 0.8 or greater were considered large [54].

3. Results

Stiffness: For the masseter muscle, there was a significant interaction between time and intervention on stiffness (β = −88.60, t(745) = −9.03, $p < 0.001$). In practical terms, the stiffness of the masseter increased by 14.46% ($p < 0.001$) following the Exercise intervention, whereas it decreased by 8.82% ($p < 0.001$) following the Chewing intervention. By contrast, no significant interaction or main effects were detected for trapezius stiffness (all $p > 0.05$) (Figure 2).

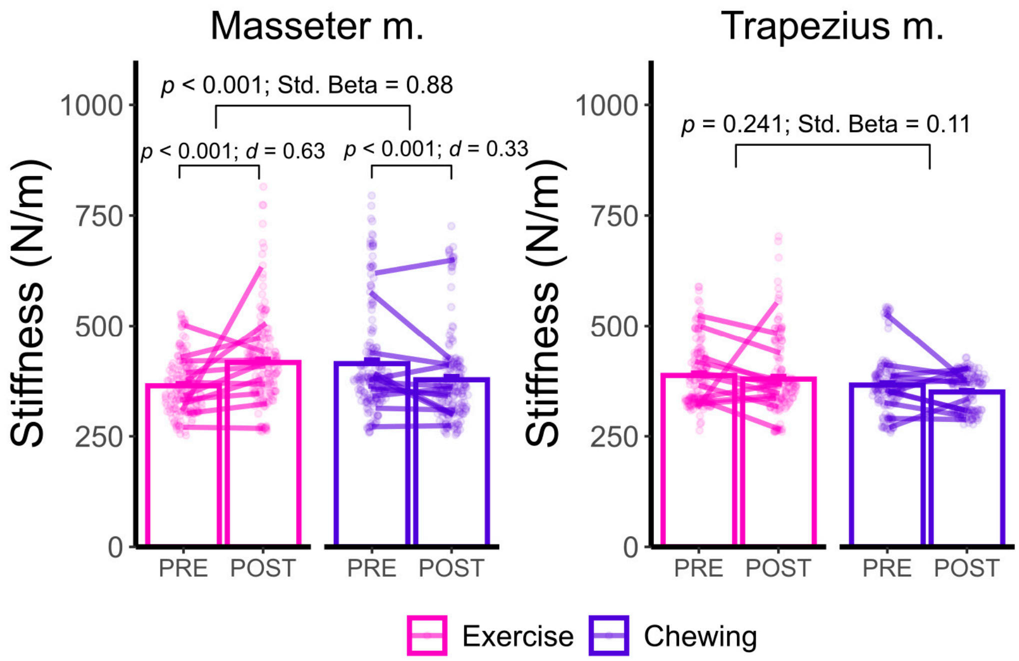

Figure 2. Tissue stiffness is defined as the peak acceleration of the Myoton probe. The mean, standard error, and individual changes in stiffness of the masseter and upper trapezius muscles. *p*: statistical significance; Std. Beta: effect size of the interaction between time and intervention; d: Cohen d.

Tone: For the masseter muscle, there was a significant interaction between time and intervention on tone (β = −2.15, t(745) = −11.08, $p < 0.001$). Post hoc comparisons indicated that tone increased by 7.03% ($p < 0.001$) for the Exercise group, whereas it declined by 5.53% ($p > 0.001$) following the Chewing intervention. In the trapezius muscle, a statistically significant interaction also emerged between time and intervention (β = 1.38, t(683) = 6.40, $p < 0.001$). Post hoc tests showed that tone decreased by 7.65% ($p < 0.001$) in the Exercise group and by 1.06% ($p = 0.003$) in the Chewing group (Figure 3).

Decrement: For the masseter muscle, there was no significant interaction between time and intervention on decrement (β = −0.0014, t(745) = −0.07, $p = 0.943$). The main effect of the intervention was significant (β = −0.03, t(745) = −2.08, $p = 0.038$), while the main effect of time did not reach any statistical significance ($p = 0.965$). In practical terms, both the Exercise and Chewing interventions showed a negligible change in decrement. By contrast, the trapezius muscle exhibited a significant interaction between time and intervention (β = 0.15, t(683) = 7.45, $p < 0.001$). In practical terms, the Exercise group demonstrated an 11.57% decrease ($p < 0.001$), whereas the Chewing group showed no statistically significant changes ($p = 0.861$) (Figure 4).

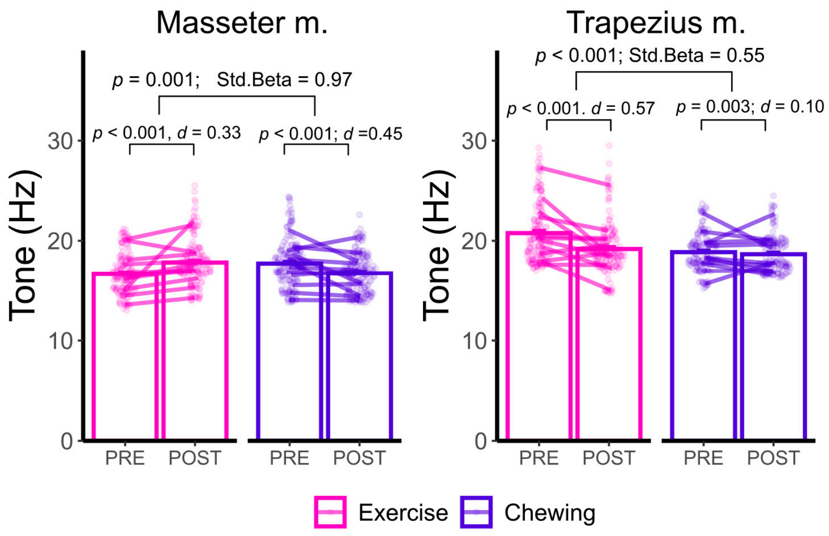

Figure 3. Tone is defined as the oscillation frequency of the Myoton probe. The mean, standard error, and individual changes in tone of the masseter and upper trapezius muscles. *p*: statistical significance; Std. Beta: effect size of the interaction between time and intervention; d: Cohen d.

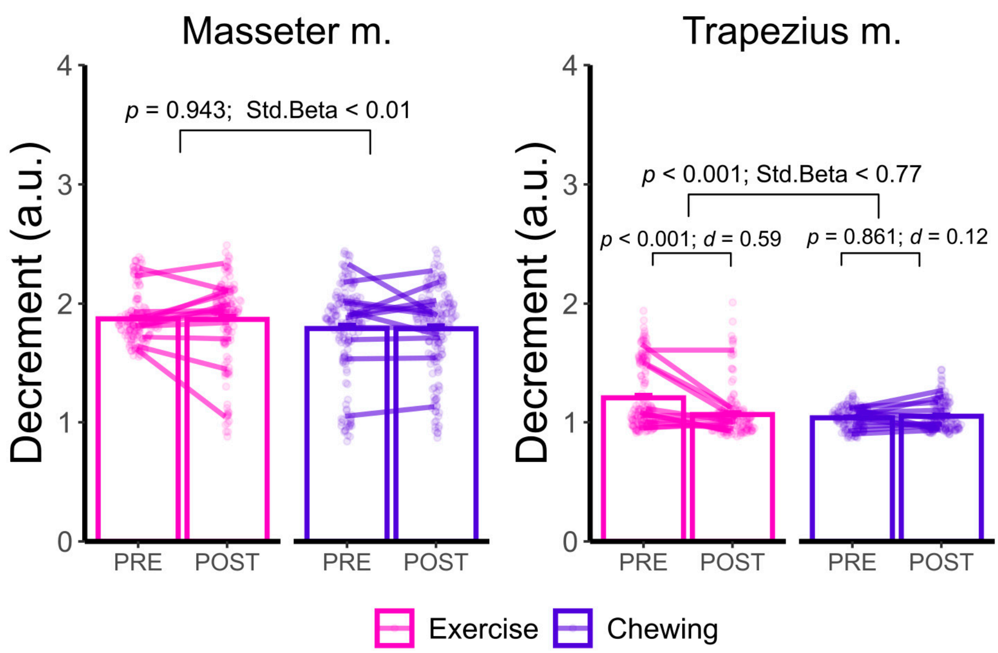

Figure 4. Decrement represents the relaxation of the muscle after the mechanical stimulus induced by the Myoton device. The mean, standard error, and individual changes in the decrement of the masseter and upper trapezius muscles. *p*: statistical significance; Std. Beta: effect size of the interaction between time and intervention; d: Cohen d.

Creep: For the masseter muscle, there was a significant interaction between time and intervention on creep ($\beta = 0.19$, $t(745) = 11.52$, $p < 0.001$). In practical terms, the Exercise group experienced a 9.71% decrease in creep ($p < 0.001$), whereas the Chewing group exhibited a 9.68% increase ($p < 0.001$). By contrast, no significant main or interaction effects were found for creep in the trapezius muscle (all $p > 0.05$) (Figure 5).

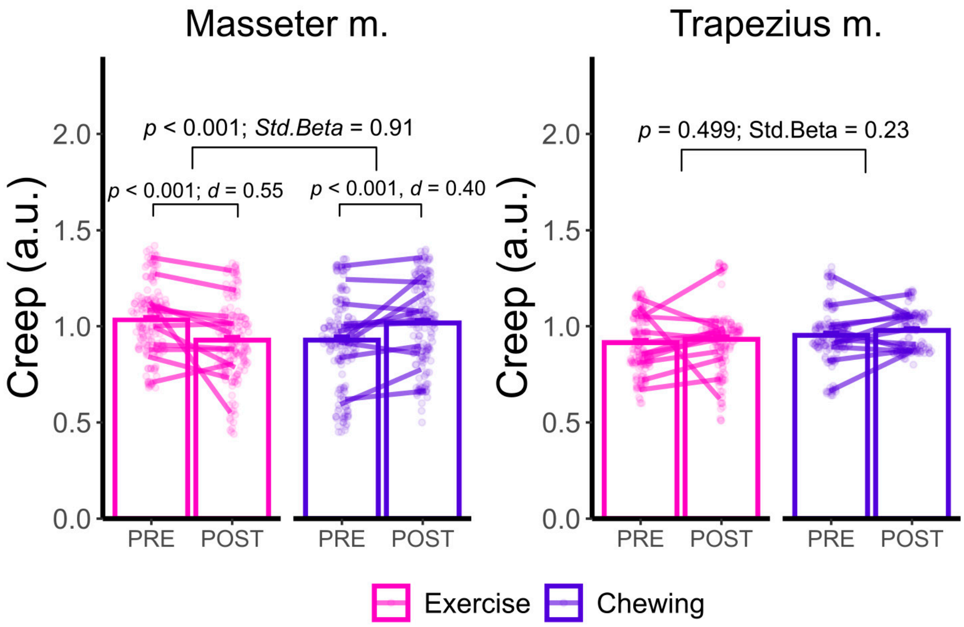

Figure 5. Creep parameter is defined as the ratio between deformation and relaxation time. The mean, standard error, and individual changes in the creep of the masseter and upper trapezius muscles. *p*: statistical significance; Std. Beta: effect size of the interaction between time and intervention; d: Cohen d.

Relaxation: For the masseter muscle, there was a significant interaction between time and intervention on relaxation (β = 3.27, t(745) = 11.38, $p < 0.001$). Post hoc tests revealed that the Exercise intervention led to an 11.36% decrease in relaxation time ($p < 0.001$), whereas the Chewing intervention produced a 9.98% increase ($p < 0.001$). Turning to the trapezius muscle, there was a significant main effect of intervention (β = 0.57, t(683) = 3.59, $p < 0.001$), but neither the main effect of time ($p = 0.090$) nor the interaction ($p = 0.441$) reached statistical significance (Figure 6).

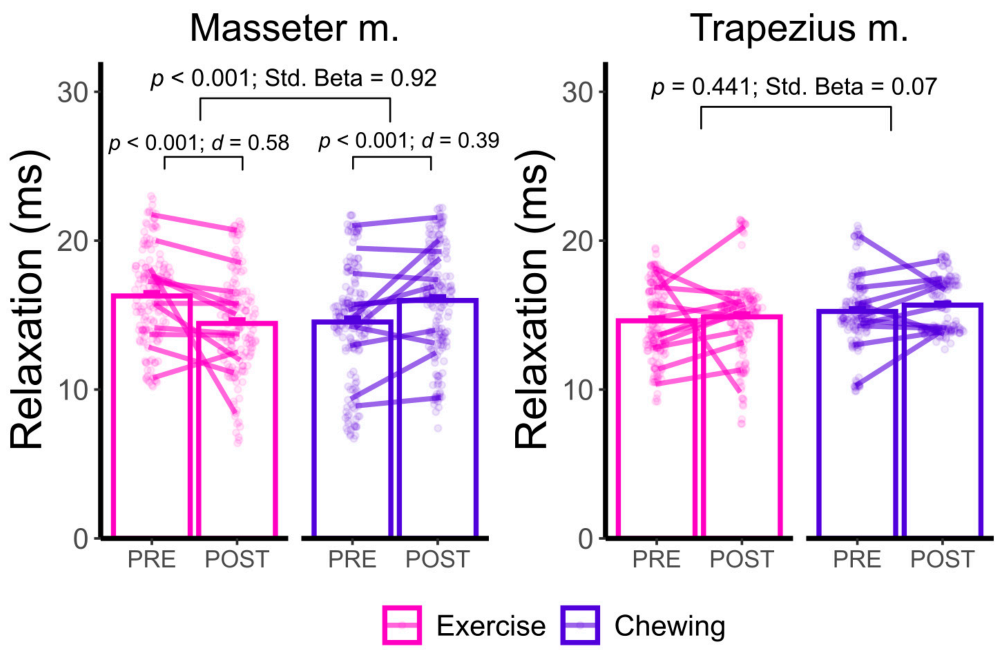

Figure 6. Relaxation is the time required for the muscle to regain its initial shape post-deformation. The mean, standard error, and individual changes in the relaxation of the masseter and upper trapezius muscles. *p*: statistical significance; Std. Beta: effect size of the interaction between time and intervention; d: Cohen d.

A table with all model terms and results can be found in the Supplementary Materials (Tables S1 and S2), while post hoc tests are summarised in Table 2.

Table 2. Descriptive statistics of myotonometric parameters. Data are expressed as the mean ± standard deviation. Δ% represents the relative changes from pre- to post-measurements. Sig. represents the statistical relevance of post hoc tests, where asterisks represent the following: *** 0.001.

		Exercise			Chewing		
Group		**PRE**	**POST**	**Δ%/Sig.**	**PRE**	**POST**	**Δ%/Sig.**
Masseter m.	Stiffness (N/m)	364.03 ± 64.05	416.67 ± 98.76	14.46% ***	414.16 ± 118.66	377.64 ± 101.74	−8.82% ***
	Relaxation (ms)	16.29 ± 3.04	14.44 ± 3.29	−11.36% ***	14.53 ± 3.79	15.98 ± 3.62	9.98% ***
	Tone (Hz)	16.65 ± 2.00	17.82 ± 2.30	7.03%	17.71 ± 2.37	16.73 ± 1.94	−5.53%
	Creep (a.u.)	1.03 ± 0.18	0.93 ± 0.20	−9.71% ***	0.93 ± 0.23	1.02 ± 0.22	9.68% ***
	Decrement (a.u.)	1.87 ± 0.21	1.87 ± 0.34	0%	1.79 ± 0.38	1.79 ± 0.35	0%
Trapezius m.	Stiffness (N/m)	387.45 ± 69.67	379.27 ± 79.32	−2.11%	365.61 ± 65.63	350.01 ± 42.50	−4.27%
	Relaxation (ms)	14.62 ± 2.50	14.88 ± 2.72	1.78%	15.24 ± 2.48	15.67 ± 1.74	2.82%
	Tone (Hz)	20.77 ± 2.95	19.18 ± 2.56	−7.65% ***	18.86 ± 1.90	18.66 ± 1.82	−1.06%
	Creep (a.u.)	0.91 ± 0.15	0.93 ± 0.16	2.20%	0.95 ± 0.15	0.98 ± 0.10	3.16%
	Decrement (a.u.)	1.21 ± 0.27	1.07 ± 0.19	−11.57% ***	1.04 ± 0.08	1.05 ± 0.12	0.96%

4. Discussion

The aim of the present study was to investigate the changes in muscle tone and the biomechanical and viscoelastic properties of the masseter and the upper trapezius muscles, as assessed by myotonometry, following two distinct guided exercise interventions. These interventions were designed to (i) mobilise the orofacial and neck muscles or (ii) engage participants in heavy chewing.

In the present study, we observed an increase in the stiffness and tone of the masseter muscle following the Exercise intervention, contrasted by a decrease in both parameters after the Chewing intervention. The observed changes contrast with previous studies [7,9,27], thus contradicting our hypotheses. We had anticipated that the Exercise intervention, which included stretching and mobility exercises, would decrease both stiffness and tone, while the Chewing intervention, which can be compared to strength training, would lead to an increase in these parameters.

However, the stiffness of the masseter muscle increased after the Exercise intervention, which was contrary to our expectations. This increase might be attributed to the exercise protocol inducing a higher blood flow, like a warm-up effect, rather than solely providing the stretching benefits typically associated with decreased muscle stiffness [33]. Similarly, the increase in tone following the Exercise intervention suggests a complex interplay of factors beyond simple mobilisation, potentially involving enhanced muscle temperature and performance improvements, as seen in other studies on muscle rigidity. Baumgart et al. [55], for example, reported an increase in the stiffness of the thigh leading to a boost in jumping performance after a 10 min cycling workout. In another study, manual therapy induced a similar increase in muscle tone in gastrocnemius muscle [56]. Conversely, the decreased stiffness and tone after the Chewing intervention might be due to a fatigue-induced decrease in muscle contraction capabilities. Although we could not monitor the biting force in this study, we can speculate that the decrease in stiffness after the Chewing intervention happened due to a loss in muscle contraction capabilities and, consequently, a reduction in biting force. If this is true, the results of the present study are in line with previous studies conducted on leg muscles, where the authors reported that the maximal muscle contraction level and stiffness were positively correlated [57]. Similarly, a fatigue-induced decrease in muscle tone, assessed using tensiomyography, was recently reported after an intervention inducing peripheral fatigue but without inducing central fatigue [58], suggesting that the type, duration, and mode of muscle contraction might have an important role in the fatigue-induced modulation of muscle tone.

The trapezius muscle, however, showed decreased tone following both interventions, potentially leading to a relaxation of neck and shoulder muscles. These results support previous findings that demonstrate the impact of various therapeutic and exercise interventions on the upper trapezius, for example, after thoracic mobilisation [59], after resistance training of the cervical and scapular region [60], and after trigger point therapy [61].

Creep represents the viscoelastic properties of skeletal muscles reflecting muscle extensibility over time [62]. In this study, we found a significant decrease in masseter muscle creep following the Exercise intervention, and an increase after the Chewing intervention, while the trapezius muscle showed no significant changes in creep. This pattern of response is in contrast with findings from a previous study on the rectus femoris muscle, where creep decreased after strengthening exercises and increased following massage [63]. Our results suggest that the creep response may be muscle-specific and influenced by each muscle's contraction history, indicating a multifaceted interplay of factors that determine a muscle's viscoelastic properties.

The parameter decrement is inversely proportional to muscle elasticity, which represents the muscle ability to revert its initial shape after a contraction or a removal of an external deformation force [62]. In our study, we observed a significant decrease in decrement following the Exercise intervention in the trapezius muscle, but not in the masseter muscle. Namely, the trapezius muscle was able of regaining its original shape quicker after the deformation induced by the myometer probe [26]. On the contrary, there were no statistically significant changes in masseter and trapezius muscles following the Chewing intervention. The results of this study are consistent with previous research, highlighting the variable responses of upper trapezius decrement to different treatments. For instance, lumbar lordosis assistive support, aimed to optimise the muscular dynamics of office workers, decreased decrement [37], which is similar to the effects ultrasound therapy [43]. In contrast, an increase in upper trapezius muscle decrement was observed in sedentary workers with a rounded shoulder posture [26], patients with cervicogenic headache [25], and those with myogenous and mixed TMDs [27].

In our study, unlike the decrement parameter, which did not show statistically significant changes in the masseter muscle after exercise, the relaxation of the masseter muscle significantly decreased following the Exercise intervention and increased after the Chewing intervention. This decrease in relaxation may suggest a reduction in the dissipation of muscle mechanical energy [64], indicating that the masseter muscle required less effort to return to its original resting position after being mechanically stimulated by the myotonometric probe. Our results align with previous findings, where relaxation in the masseter and sternocleidomastoid muscles increased in patients with malocclusion [40]. Additionally, the relaxation of the trapezius muscle increased after both Exercise and Chewing interventions. This increase implies that the upper trapezius muscle needed more time to revert to its structural baseline [62]. These observations align with the findings of Pèrez-Bellmunt et al. [61], who observed increased relaxation in the gastrocnemius muscles following ischemic compression on latent trigger points, commonly used for pain relief, inducing an improvement in range of motion and muscular relaxation. Moreover, MTrPs therapy of the trapezius muscle may prevent the development of dysfunction within the stomatognathic system, as the introduction of myofascial pain in the trapezius contributes to functional imbalances within the stomatognathic system [16]. The results of this study reveal that the type of physical activity significantly affects the muscle tone and the biomechanical and viscoelastic properties as measured by myotonometry. These findings highlight a complex interaction between the kind of exercise performed and its effects on muscle properties, demonstrating the importance of considering specific muscle groups and exercise types in such assessments.

This study is not without its limitations. The sample size was small and comprised only healthy individuals, which may not be representative of the broader population, especially those with temporomandibular disorders (TMDs), who were not included in this study. The primary aim was to investigate the effects of guided exercise interventions designed to mobilise orofacial and neck muscles or the effects of heavy chewing in a healthy sample. However, this focus meant that only acute effects were studied, leaving long-term impacts unexplored. Moreover, the study could have benefited from multiple time points during the intervention to better capture the time course of changes in myotonometric parameters through more frequent assessments. The absence of randomization and the potential for carry-over effects between interventions, along with exclusion criteria that did not account for shoulder pathology or posture abnormalities, further limit the generalizability of our findings. Another notable limitation was the absence of a control condition without any intervention, which would have provided a clearer understanding of the distinct effects of each intervention. However, previous studies have demonstrated the high inter-visit reliability of the Myoton device, suggesting that no significant changes in myotonometric parameters would be expected after a period of rest. Nonetheless, we recommend that future research include a control condition to better differentiate these effects. Moreover, the masseter and upper trapezius muscles differ significantly in their inherent characteristics, which may influence the outcomes observed in this study. The masseter, predominantly influenced by genetic factors such as variations in the ACTN3 gene, exhibits structural and functional traits linked to craniofacial morphology [65]. In contrast, the upper trapezius, with its dual mesodermal origin and susceptibility to myofascial trigger points, reflects a more complex interplay of developmental and functional influences [66]. A further limitation of this study was that the presence of myofascial trigger points (MTrPs) was not assessed. This omission represents a drawback, as MTrPs in the upper trapezius and TMDs are known to be associated with alterations in the electromyographic activity patterns of masticatory muscles. Future research should include an evaluation of MTrPs to address this limitation [67]. Additionally, the study did not analyse the results based on sex. Myotonometry also has restrictions in its ability to measure muscles covered by thick subcutaneous fat (>20 mm) or tissues not categorised as soft biological tissue. Our study involved the repeated measurements of the masseter and upper trapezius muscles in subjects with a normal body mass index (BMI between 20 and 24). Moreover, when used according to instructions, the Myoton device does not require any additional assessments of subcutaneous fat and connective tissue with ultrasound. Finally, the sequential measurement of different muscles due to equipment constraints may have introduced additional variability.

5. Conclusions

In conclusion, this study examined the effects of a guided exercise intervention and heavy chewing on the masseter and upper trapezius muscles. The results, which did not align with our hypotheses, highlight a complex relationship exists between these interventions and muscle properties. These findings emphasise the need for further research to better understand the therapeutic potential of exercise interventions for TMDs and shoulder-neck dysfunctions.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app15010344/s1, Table S1: Results of linear mixed effect models for the masseter muscle; Table S2: Results of linear mixed effect models for the trapezius muscle. Additional material includes a detailed exercise description with photos and videos https://osf.io/u7jyv/ (accessed on 28 December 2024).

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Data Availability Statement: The original data presented in the study are openly available in Open Science Framework at https://osf.io/vmb9r/ (accessed on 28 December 2024).

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