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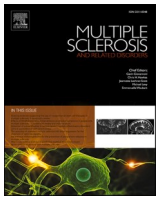

Original article

Myotonometric comparison of sternocleidomastoideus and masseter muscles in multiple sclerosis patients with swallowing problem and healthy individuals

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ABSTRACT

Background: Dysphagia occurring in the oral and pharyngeal phases of swallowing in MS patients may be caused by changes in muscles' viscoelasticity. The aim of this study was to compare the muscles' (sternocloideomastoideus and masseter) viscoelasticity properties by myotonometer between MS patients and healthy individuals.
Methods: This study design was a cross-sectional, non-interventional study. Ten healthy individuals were allocated to the control group, eleven MS patients without swallowing problems were allocated to the without swallowing group, ten MS patients with swallowing problems were allocated to the swallowing group. Disability was evaluated using the Expanded Disability Status Scale (EDSS), swallowing problem was assessed with Dysphagia in Multiple Sclerosis (DYMUS) scale, and to measure the viscoelastic parameters (tone, stiffness, elasticity) of sternocloideomastoideus (SCM) and masseter muscles bilaterally, MyotonPro® was used. The comparison between the groups was performed using the Kruskal-Wallis H test.
Results: It was observed that there was no difference in terms of viscoelastic properties of the masseter muscle in groups ($p > 0.05$). There was no difference between the groups in terms of the elasticity of the SCM muscle ($p > 0.05$). However, the tonus and stiffness of the SCM on the left side of the MS patients were higher than in other groups ($p = 0.050$, $p = 0.005$).
Conclusion: The increment level of tone and stiffness of SCM muscle is related to swallowing problems in patients with MS. Due to swallowing problems in MS, the orofacial and neck region's muscles' viscoelastic properties may change in time and may be affected by phases of swallowing problems.

1. Introduction

Multiple sclerosis (MS) is an inflammatory and neurodegenerative, progressive, long-lasting demyelinating disease that affects the central nervous system (Compston and Coles, 2008). The numerous sensory and motor manifests occur in the orofacial region due to demyelination of the nerves of the head and neck region in MS patients (Zhang and Meng, 2015). The main signs in the head and neck region are facial paralysis, cranial neuralgias, visual complication, temporomandibular disorders, dysphagia, and dysarthria (Covello et al., 2020). As demyelination of the motor nerves, it may present in the orofacial and craniofacial region as tremor, muscle weakness, hemifacial spasms, involuntary facial muscle contraction (Covello et al., 2020; Danesh-Sani et al., 2013). Moreover, sensory neuropathy may occur with the affected trigeminal nerve and cause irreversible paresthesia (Covello et al., 2020). Thus, extraoral or intraoral numbness, pain, tingling may present. These manifests, which may be attributed to the underlying myofascial and neck pain, may explain the high prevalence of temporomandibular joint (TMJ) problems in MS (Kovac et al., 2005). Also, the painful tonic spasm of the facial muscles is specific to MS. The lesions in the cerebral peduncle, medulla, internal capsule or spinal cord lead to spasms. The spasm derives from hyperactivity of the central nervous system may start from the face, spread to an adjacent part of the body (Covello et al., 2020). Considering all of these lesions-related symptoms, the viscoelastic properties of the orofacial and craniofacial muscles may change.

The above symptoms, increased spasticity, tremor, fatigue, muscular incoordination, affect the physiology of swallowing (Danesh-Sani et al., 2013). Swallowing is a complex sensory-motor function that is controlled from the brain stem, sensory information is obtained from the cerebral cortex, and many muscle groups are actively involved.

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Swallowing consists of three phases: oral, pharyngeal, and esophageal (Johansson et al., 2020). The prevalence of dysphagia has been reported to vary between 30 and 40% depending on the type of MS (Aghaz et al., 2018; Guan et al., 2015). Dysphagia occurring in the oral and pharyngeal phases of swallowing in MS patients is often thought to be caused by a decrease in orofacial muscle strength, endurance, and cranial nerves' involvement for tongue movements and swallowing function (Klugman and Ross, 2002). The orofacial muscles, floor of the mouth, hyoidal and neck flexor muscles play an essential role in swallowing function (Sayaca et al., 2020). Although masseter, which is one of the masticatory muscles, plays a role in closing the mouth and jaw, it is known that the head and neck flexors muscles improve the larynx anterior and upward movement and increase the opening of the upper esophageal sphincter (Easterling, 2017). There are EMG studies in literature by associating the activity levels of these muscles in MS patients, but viscoelastic examinations of the muscles were not performed (Alfonsi et al., 2013; Pernambuco et al., 2011; Santos et al., 2019; Woo, 2013).

Clinical assessment of the orofacial muscle tone increased in recent years (Chu et al., 2010; Clark and Solomon, 2010; Dietsch et al., 2014; Veldi et al., 2002). The myotonometer device gives a mechanical stimulation on the skin to evaluate muscle tone and measures the muscle tissue's oscillatory responses against this stimulus (Chuang et al., 2012). The device, which has been used in many different clinical studies, can be used in chronic diseases that affect the orofacial muscles. However, evaluation of the tone of the muscles (SCM and Masseter) is very limited in the literature. The association between dysarthria, sleep apnea, Parkinson and oral muscle tone levels has been reported by some studies (Chu et al., 2010; Dietsch et al., 2014; Veldi et al., 2002), but there is no study to assess comparison between oral muscle tone levels on MS patients with swallowing problems.

In light of this knowledge, MS patients include many symptoms that may affect swallowing function, and it is important to understand the swallowing problems in MS to determine how viscoelastic properties vary according to healthy people. Therefore, this study aimed to compare the muscles' (SCM and Masseter) viscoelasticity properties by myotonometer between MS patients and healthy individuals.

2. Material and methods

2.1. Study design

The study design was a cross-sectional, non-interventional study.

2.2. Participants

Thirty-one individuals participated in this study. These individuals were enrolled according to inclusion criteria. The inclusion criteria were: (1) being diagnosed with revised-2017 Mc Donald's criteria (McNicholas et al., 2018), (2) patients between the ages of 18–45, (3) volunteering to participate in the research, (4) and not having any obstacle to cognitive and verbal communication. The exclusion criteria were: (1) having psychological, orthopedic, and other neurological disorders, (2) pregnancy, (3) having had an attack in the last 3 months, (4) and application of botulinum toxin in the last 6 months. Ten healthy of thirty-one individuals were allocated to the control group (CG), eleven MS patients without swallowing problems were allocated to the without swallowing problem group (WSG), and ten MS patients with swallowing problems were allocated swallowing group (SG). The individuals in groups matched in terms of age and gender.

The study was approved by Hasan Kalyoncu University; Noninvasive Research Ethics Committee on 01/10/19 (Number: 2019/105). All individuals were informed about the purpose and stages of this study and freely signed informed consent forms. The study was conducted in Ozel Kalyon Medicine Center, between November 2019 and December 2019.

2.3. Assessments

2.3.1. General characteristics

Demographic information (gender, age, body mass index) and information of MS disease (duration, type, disability status, etc.) were recorded.

2.3.2. Expanded disability status scale (EDSS)

EDSS was used to determine the disability status in patients with MS. The scale evaluates eight functional systems, including pyramidal, cerebellar, brainstem, sensory, bowel, bladder, visual, cerebral, and ambulation. The EDSS score ranges from 0 (no disability) to 5 or 6 (more severe disability) up to10 (death due to MS) and is ranked with an increase of 0.5 points. As the score increases, the severity of the disability increases (Kurtzke, 1983). The patient's EDSS scoring was performed by a neurologist.

2.3.3. Dysphagia in Multiple Sclerosis (DYMUS)

DYMUS was a valid and reliable scale for evaluating oropharyngeal dysphagia in MS patients (Bergamaschi et al., 2008). DYMUS consisted of two subscales: dysphagia for solid food, dysphagia for the liquids. The questions in the scale are coded as "no = 0″ and "yes = 1″. Scoring is made consisting of 10 questions with a scale score between 0 and 10. Answer "yes" to at least one of the items in the DYMUS indicates that the patient has dysphagia, 3 or more points as severe swallowing problem (Bergamaschi et al., 2008). MS patients who have 3 or more points according to the DYMUS scale allocated to the swallowing problem group (SP). The Turkish version of DYMUS was used to determine swallowing problems (Tenekeci et al., 2018). The all of MS patients were assessed by DYMUS.

2.3.4. Myotonometric measurements

The probe of the MyotonPRO generated mechanical impulses via an electromagnetic mechanism after precompression of the subcutaneous tissues. The impulses cause oscillations of the skin and underlying muscle or fascia (Chang et al., 2020). MyotonPro® is a valid and reliable device (Myoton AS, Tallinn, Estonia) for measuring muscles' viscoelastic parameters (Agyapong-Badu et al., 2013; Dietsch et al., 2014) such as tonus, stiffness, and elasticity of the muscles. The device was set to give 5 mechanical impulses through the end of the small lever. The tissue's response to each impulse was recorded using an acceleration graph, providing oscillation frequency, decrement, and stiffness parameters. The oscillation frequency (Hz) determined the tone at rest: the higher the oscillation frequency, the greater the tone. Stiffness (N/m) was defined as the resistance of the tissue to the force that attempted to deform it. The logarithmic decrement damping of the oscillations quantified the elasticity, the elasticity being inversely proportional to the decrement of the oscillations. Elasticity refers to the ability of the muscle to return to its original shape after a force that causes deformation in the muscle (Klugman et al., 2002).

Three measurements were bilaterally taken for each muscle. For each muscle, the average values of tone, stiffness, and elasticity were retained as the main MyotonPRO outcomes. Patients were rested for 5 min before the measurement was made. Bilateral myotonometric measurements were made from the masseter and sternocleidomastoid (SCM) muscles while the patient was in the supine position. The masseter test site was selected by identifying the center of the most prominent palpable bulge during contraction (Fig. 1a) (Dietsch et al., 2014). SCM muscle was assessed from the midpoint between the muscle's origo and insertion (Fig. 1b) (Kocur et al., 2017).

2.4. Statistically analyses

Statistical Package for the Social Sciences version 22.0 software was used for statistical analysis. For the descriptive analyses, the frequency in percent (%) and mean ± standard deviation (X ± SD) of necessary

Fig. 1. Myotonometric measurements. (a) Masseter, (b) sternocleidomastoid.

variables were calculated. Normality of distribution was tested with the Shapiro-Wilk test and histogram. Non-parametric statistical methods were used in this study because the data showed non-normal distribution. Kruskal-Wallis H test was used to investigate the homogeneity between the groups for age, BMI. Chi-square test were used to investigate the homogeneity between the groups for gender, dominant side. The comparison between the groups was performed using the Kruskal–Wallis H test. The Mann–Whitney U test was performed to test the significance of pairwise differences using Bonferroni correction to adjust for post-hoc analysis. An overall%5 type-I error level was used to infer statistical significance.

At the end of the study, the minimum sample size was required to detect a significant difference using the left SCM stiffness variable should be at least 8 in each group (24 in total), considering type I error (alfa) of 0.05, power (1-beta) of 0.9, and effect size of 0.79.

Table 1
Characteristics of the participants.

Subjects per group	CG$n = 10$	WSG$n = 11$	SG$n = 10$	X^2	P
Gender				0.164	0.921[a]
- males, n	2	3	2		
- females, n	8	8	8		
Age (years)					
(mean ± SD)	39.60 ± 3.65	35.45 ± 8.69	41.00 ± 7.21	2.721	0.257[b]
(min-max)	(34–45)	(23–46)	(32–48)		
BMI (kg/m^2)					
(mean ± SD)	23.48 ± 1.89	23.75 ± 3.32	27.34 ± 6.43	3.009	0.222[b]
Dominant side					
Right, n	7	11	10	3.960	0.138[a]
Left, n	3	-	-		
MS duration (years) (mean ± SD)	–	5.72 ± 4.45	10.33 ± 4.89		
EDSS score	–	1.45 ± 1.43	3.88 ± 1.19		
(mean ± SD)			3.5		
(median)		1.0			
Type of MS	–				
RRMS, n		10	7		
PPMS, n		1	2		
DYMUS	0	0	5.11 ± 2.47		
(mean ± SD)			(4.0)		
(median)					

*$p < 0.05$; CG: Control Group; WSG: MS patients without swallowing problem group; SG: MS patients with swallowing problem group; RRMS: Relapsing Remitting Multiple Sclerosis; PPMS: Primer Progressive Multiple Sclerosis; EDSS: Expanded disability status scale; DYMUS: Dysphagia in multiple sclerosis

[a] Chi-square test

[b] Kruskal Wallis test.

3. Results

The demographic characteristics of the participants are shown in Table 1. The number of female patients was higher in the groups. The groups were homogeneous in terms of age, body mass index, dominant side ($p > 0.05$).

Table 2 shows the comparison of the viscoelastic properties of masseter and SCM muscles in groups. It was observed that there was no difference in terms of viscoelastic properties of the masseter muscle between groups ($p > 0.05$). The groups were similar in the elasticity of SCM ($p > 0.05$). However, a significant difference was found between the groups in terms of left side SCM tone and stiffness ($p = 0.050$, $p = 0.005$). The tone and stiffness of the left side SCM muscle were higher in the SG group. The differences between the control group and MS patients with the swallowing problem group were found in left side SCM tone and stiffness ($p = 0.046$, $p = 0.026$). In addition, the difference between the with and without swallowing problem patients' groups was only in the stiffness of the SCM muscle ($p = 0.007$).

Table 3 shows the distribution of symptoms of swallowing difficulty for solid and liquid foods in MS patients with swallowing problems. It was found that individuals were most uncomfortable with swallowing solid foods, the need to swallow several times, and the feeling of food remaining in the throat.

4. Discussion

The aim of this study was to compare changes in the viscoelastic properties of the SCM and masseter muscles using a myotonometer in

Table 2
Comparison of myotonometric measurements between groups.

Myotonometric measurements	Side	CG Mean ± SD ($n = 10$)	WSG Mean ± SD ($n = 11$)	SG Mean ± SD ($n = 10$)	X^2	p
Masseters						
Tone (Hz)	Right	15.06 06 ± 1.26	16.26 ± 2.93	15.55 ± 2.69	0.468	0.791
	Left	14.56 ± 1.97	14.81 ± 1.71	13.61 ± 2.09	2.040	0.361
Stiffness ($N.m^{-1}$)	Right	329.11 ± 33.86	334.27 ± 64.91	329.71 ± 55.76	0.007	0.996
	Left	311.11 ± 67.67	296.55 ± 39.06	299.29 ± 47.85	0.001	1.000
Elasticity	Right	2.09 ± 0.14	1.86 ± 0.25	1.98 ± 0.38	3.508	0.173
	Left	2.06 ± 0.16	1.88 ± 0.23	1.99 ± 0.17	2.757	0.252
Sternocleidomastoid						
Tone (Hz)	Right	13.35 ± 0.45	13.86 ± 1.10	12.70 ± 4.69	1.039	0.595
	Left	13.23 ± 1.00[#]	13.88 ± 1.72	14.70 ± 1.17[#]	5.998	0.050*
Stiffness ($N.m^{-1}$)	Right	212.44 ± 12.64	216.64 ± 32.93	230.71 ± 40.07	1.840	0.399
	Left	203.56 ± 15.87[#]	200.27 ± 25.49**	235.71 ± 18.10[#],**	10.427	0.005*
Elasticity	Right	1.50 ± 0.22	1.33 ± 0.14	1.57 ± 0.27	4.304	0.116
	Left	1.59 ± 0.08	1.43 ± 0.29	1.60 ± 0.18	4.714	0.095

CG: Control Group; WSG: MS patients without swallowing problem group; SG: MS patients with swallowing problem group. *Statistically significant differences between groups with Kruskal-Wallis test $p < 0.05$.

[#] Statistically significant differences between SG-CG with Mann-Whitney U Test $p < 0.05$, post-hoc.

** Statistically significant intergroup differences between WSG-SG with Mann-Whitney U Test $p < 0.05$, post-hoc.

Table 3
The distribution of symptoms on swallowing difficulty for solid and liquid foods.

Solid Swallowing Problems	SG ($n = 10$)
Difficulty in swallowing solid food	8
Globus sensation in your throat during swallowing	5
Retention of food in the throat	6
Cough during eating solid food	1
Need to repeatedly swallow solid food	7
Cut food in small pieces before swallowing	6
Weight loss	3
Liquids Swallowing Problems	**SG ($n = 10$)**
Difficulty in swallowing liquids	3
Cough during drinking liquids	2
Need to repeatedly swallow liquids	5

SG: MS patients with swallowing problem group.

MS patients and healthy individuals. In our study, it was determined that viscoelastic properties of SCM muscle might change in MS patients with swallowing problems, not masseter muscle.

The SCM muscle, which is the neck flexor muscle, plays an essential role in swallowing function, especially in the pharyngeal phase (Alfonsi et al., 2013). Head flexion posture is used to support swallowing by compensating for the decrease in tongue base retraction, decrease in contact with tongue base and pharyngeal wall, prolongation of the oral phase, and delay of the pharyngeal phase and aspiration during swallowing. In chin-down posture, with head flexion, the chin is pulled down to provide tongue base retraction, and the distance between the tongue base and pharynx decreases (Hori et al., 2011). These compensatory mechanisms occur with the head and neck's postural control and may cause changes in the contractions of the swallowing-related muscles in that area (Woo, 2013). Deep neck flexors play an active role in the control and maintenance of the cervical posture. In the weakness of these muscles, the stabilisation effect will decrease, causing deviations in the movements of the mandible, temporomandibular joints, and cervical segments. This decrement in control causes excessive mandible and head movements (Jull et al., 2008). In these conditions, the SCM muscle, which is a superficial neck flexor muscle, is activated faster and more movement (Hudswell et al., 2005). Increment activity of anterior neck flexor muscles increased craniocervical angle and an anterior tilt of the head (Woo, 2013). Orofacial and neck muscles' viscoelastic properties are affected by the head's anterior tilt position. In a study examining the SCM muscle's viscoelastic properties with a myotonometer, it was shown that the stiffness in the muscle increased with the anterior tilt of the head (Kocur et al., 2019). In our study, we think that the increase in the stiffness of the left SCM muscle of MS patients with swallowing problems could be due to the decrease in postural control, MS symptoms, and the head's forward tilt position. Sensory manifests derived from head-neck lesions could cause a motor response in the region; postural control of the head and neck gradually deteriorate in MS patients with swallowing problems. Besides, the increase in tone on one side can be explained by the spread of symptoms from unilateral to both sides due to the progressively degenerative nature of MS (Patel et al., 2020).

Masseter, another muscle we have assessed, is one of the main masticatory muscles, plays a crucial role in the oral phase of swallowing by assisting the suprahyoid muscles in stabilizing the mandible. It is performed safely with the suprahyoid muscles' contraction, the rise of the hyoid bone, and the larynx ventral movement (Pernambuco et al., 2011). The dynamics of oropharyngeal swallowing consist of simultaneous and sequential muscular activities. In the oral phase, chewing coincides initially with the bolus into the mouth and the onset of tongue movements. In cases where these activities are insufficient, superficial neck muscles such as SCM become more active (Kocur et al., 2019). For this reason, we think that the active role of SCM in the compensation of swallowing problems may cause changes in viscoelastic properties to be seen in the SCM, not the Masseter muscle. The viscoelastic changes seen in the SCM muscle were not seen in the Masseter muscle, as our patients could perform compensatory swallowing activity using head and neck movements. Santos et al. (2019) compared the activities of the masseter and suprahyoid muscles during swallowing and resting on healthy individuals and MS patients. In MS patients, increment the masseter muscle activity was found at resting compared to healthy individuals at the same age. The increment in the activity on the masseter muscle was explained by this adaptation mechanism. Due to the progressive nature of MS disease, compensation and adaptation mechanisms in the muscles may develop in the future. These compensation mechanisms cause changes in the muscles' activity, and over time, the muscles' structural properties may change. However, the low EDSS scores, which measure the disability levels included in our study, may indicate that structural changes have not yet occurred.

Dysphagia can appear in mildly impaired MS patients according to EDSS score (EDSS 2–3), and occurrence rates being increased in moderate to severe impaired (EDSS 8–9) MS patients (Alali et al., 2018a, 2018b; Calcagno et al., 2002). Printza et al. (2019) have found a positive correlation between EDSS score and dysphagia. When the EDSS scores are examined in our study, we see that the patients are in the early period of MS. For this reason, it was found that structural changes in the muscles were not at a level that would increase the swallowing problem seriously. However, we think that it is critical to add swallowing clinical assessments at each stage of MS.

In clinical studies conducted on patients with MS dysmotility, decreased tongue retraction, delay and elongation in the pharyngeal phase, dysfunction of the upper esophageal sphincter, deficit in laryngeal closure, and decreased laryngeal and pharyngeal sensation are amongst the findings (Alfonsi et al., 2013; Prosiegel et al., 2004; Wiesner et al., 2002). The most frequent symptom reported by MS patients with swallowing problems is food sticking in the throat, choking, coughing, and throat cleaning during or after drinking or eating liquid or solid foods (De Pauw et al., 2002). Alali et al. (2018a) used self-report scales and found that the main complaint in swallowing problems was coughing after eating and drinking. Coughing is an indicator of a problem in the laryngeal, tracheal penetration, and pharyngeal phase of swallowing. Problems in the pharyngeal phase of swallowing are one of the frequent swallowing abnormalities in MS patients (Poorjavad et al., 2010). Based on the SG patients' statements in this study, the most common symptom was difficulty swallowing solid foods (Table 3). We found that individuals were most uncomfortable with swallowing solid foods, the need to swallow several times, and the feeling of food remaining in the throat. In the study, SG patients were mildly impaired, but the duration of the MS was 10 years. Dysphagia was found to be associated with disease duration in this study, and its prevalence increased as the disease duration increased.

Studies examining the myotonometric comparison between the muscles in the craniofacial and neck region MS patients with swallowing problems will bring a new perspective to the literature. Longitudinal studies in which patients with MS are followed from the early to the severe stages will help to understand the long-term viscoelastic changes. In order to understand the effect of the viscoelastic properties of the muscles in the orofacial and neck area, further studies are needed to examine the head and neck muscles of MS patients with different levels of swallowing involvement.

The most important limitation of the study is not using instrumental tools like the videofluoroscopy, the fiberoptic evaluation of swallowing, which are gold standards for assessing early symptoms of dysphagia and underlying cause, was not used in the detection and classification of swallowing problems. There are disadvantages to using instrumental tools. For fiberoptic evaluation does not permit assessment of the oral phase of swallowing, and observation of the pharyngeal phase is limited; in videofluoroscopy, the risks of X-ray exposure limit the possibility of prolonged or frequently repeated assessments (Alfonsi et al., 2013; Alali et al., 2018a). In the study, we used the patient-reported questionnaire DYMUS to evaluate swallowing problems. The purpose of using

validated patient-reported questionaries is a non-invasive assessment tool and easy to administer on individuals. The evaluation viscoelastic properties of only two muscles on the affected structures is amongst the limitations of our study since there are only two muscles that have been shown to be appropriate for myotonometric assessment in the head-neck region and to be associated with swallowing functions.

5. Conclusions

The study was designed to compare the muscles' (SCM and Masseter) viscoelasticity properties by myotonometer between MS patients and healthy individuals. The tone and stiffness of the left side SCM muscle were higher in the SG group, according to the study. MS patients with swallowing problems state that the most common symptom was difficulty in swallowing solid foods. Although MS disease does not affect the viscoelastic properties of the masseter muscle bilaterally, unilateral SCM muscle tone and stiffness might increase in MS patients with swallowing problems. MS patients with swallowing problems could increase the stiffness of the unilateral SCM muscle with the swallowing strategies (compensation) they have developed. Clinicians may pay attention to asymmetric postural deviations, especially in the cervical region, when evaluating swallowing. It could be useful to investigate the effects of treatments on muscles' viscoelastic properties in MS patients with swallowing problems in further studies.

Declaration of Competing Interest

None.

Acknowledgment

None.

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