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Original article

The comparison of tone and viscoelastic properties of superior orbicularis oris muscle in multiple sclerosis patients to healthy individuals

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ABSTRACT

Background: The orbicularis oris muscle is an important muscle for oral perception in mouth and swallowing rehabilitation. The muscle can be affected in patients with multiple sclerosis for many reasons. It is important to understand the quantitative changes in this muscle to determine the many problems associated with the craniofacial region in multiple sclerosis. Therefore, this study aimed to compare the mechanical properties of the orbicularis oris muscle between MS patients and healthy individuals.
Methods: A total of 55 individuals (28 with multiple sclerosis and 27 healthy) who met the inclusion criteria were evaluated. The tone and viscoelastic properties (elasticity and stiffness) of the superior orbicularis oris muscle of both groups were evaluated bilaterally in the supine position with the MyotonPro® (Myoton AS, Estonia) device. The reference point of the muscle is accepted as the right and left paramedial philtrum dimple.
Results: It was observed that there was no difference in terms of stiffness values of the right and left orbicularis oris muscles of both groups ($p>0.05$). The tone and the elasticity of the muscle on both sides were higher in the HI group than MS group ($p<0.05$).
Conclusion: We think that the orbicularis oris muscle has a central location in the facial region, and that this muscle may be the key muscle for the symptoms arising from many neurological mechanisms. The decrease in muscle tone and elasticity may be the beginning of the changes in MS patients. We believe that the data from this muscle will be useful for comparative studies.

1. Introduction

Multiple sclerosis (MS) is an inflammatory and neurodegenerative demyelinating disease affecting the central nervous system. As the disease progresses, many sensory and motor function problems, problems arising from demyelination can be seen in the orofacial region. These problems may be in the form of tremors, muscle weakness, hemifacial spasms, and involuntary movements in the orofacial and craniofacial regions (Covello et al., 2020; Compston and Coles, 2008). Hemifacial spasm manifests as a sustained or intermittent unilateral facial contraction that sometimes begins at the orbicularis oris muscle and spreads downward to the rest of the muscles of facial expression. Sensory neuropathies can cause trigeminal neuralgia, irreversible paresthesias, pain, numbness, and stiffness in intra-oral and extra-oral muscles. At the same time, painful tonic spasms, facial myokymia, and hemifacial spasms are observed in the facial muscles of MS patients (Collazo and Tobin, 2018). Facial myokymia is characterized by wave-like, vermicular fine movement, involuntary and undulating that spreads across the face. Lesions of the cerebral peduncle, medulla, internal capsule, or spinal cord also cause spasms. These spasms originate from the hyperactivity of the central nervous system and begin on the face and spread throughout the body (Covello et al., 2020).

There are deep and superficial fibers of the extra-oral, multilayered orbicularis oris muscle located in the facial region. It is located in a region that acts as a connection point for the facial muscles. There are deep and superficial fibers of the extra-oral, multilayered orbicularis oris muscle located in the facial region. It is located in a region that acts as a connection point for the facial muscles. It is connected to the dermis of

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the upper and lower lip by a thin superficial muscular-aponeurotic junction. In addition to the isolated movements of the muscle, it is seen that it also acts together with other facial muscles. Its deep fibers perform general sphincteric activities such as closing the mouth and storing food. Superficial fibers contribute to activities during speech and facial expressions. The orbicularis oris muscle also plays a role in vital functions such as swallowing, chewing, and sucking (Park and Dong Hwan, 2017; De Caxias et al., 2018; Ramazanoglu et al., 2022). Studies related to this muscle have increased in recent years for different populations but do not include MS. As we searched the literature, we realized that the orbicularis oris muscle might have a key role derived from facial myokymia and hemifacial spasm in MS. Facial myokymia and hemifacial spasms usually originate from the orbicularis oculi to all of the face. Spasms begin in the left periorbital region, spread to the left perioral region, and than the intensity of spasms and subsequently spread to the right periorbital and perioral regions and continue during both when awake and asleep (Collazo and Tobin, 2018). There were continuous high-frequency, low-amplitude facial twitching, consistent with continuous facial myokymia. Therefore, hemifacial spasm is characterized by upward distortion of the side of the patients' mouth (activation of zygomaticus major) and a pseudoptosis (activation of orbicularis oculi) (Parr et al., 2022). Thus, patients have asymmetry on their face. In the light of all this information, continuous spasms and asymmetry could cause a change in muscles' characteristics in the periorbital and perioral regions. It is known that lesions in MS cause characteristics of muscles of the facial region (Maden et al., 2022). There was no study investigating the tone and viscoelastic properties of the orbicularis oris muscle of MS patients.

In the investigation of tone and viscoelastic properties, there are studies conducted with MyotonPro®, a device that provides easy measurement and gives results that are in accordance with EMG studies. Thanks to this device, the stiffness, tone, and elasticity properties of the muscles can be determined (Alfonsi et al., 2013; Santos et al., 2019). The MyotonPro® device is one of the few tools available for the evaluation of tone and viscoelastic properties in orofacial muscles. This previously calibrated device, with its non-invasive hand-held feature, creates a mechanical stimulus that induces the damped natural oscillations of the tissues of the 3 mm diameter probe placed perpendicular to the muscle, and the oscillations that occur are recorded with an accelerometer (Gervasi et al., 2017). MyotonPro® is a valid and reliable method for determining muscle tone, stiffness, and elasticity and also has high test-retest reliability and repeatability (Leonard et al., 2001; Agyapong-Badu et al., 2013). In the studies, it was seen that the evaluations related to the orbicularis oris muscle were generally by electromyographic and ultrasonographic methods (Sinha et al., 2018; Umay et al., 2019; Ożóg et al., 2019). Recent studies include MyotonPro in MS is getting important and popular. Because the disease's main signs are sensory and motor manifests derived from the central nervous system in MS. It includes the change of muscle tone, muscular incoordination, tremors, muscle weakness, numbness, etc. However, studies are limited to investigating craniofacial and orofacial muscles in MS.

The studies comparing multiple sclerosis patients with healthy individuals were examined. We could not find any study evaluating the orbicularis oris muscle, which plays a key role in the facial region. We think that our study will provide reference data about the orbicularis oris muscle in MS patients regarding the MyotonPro® device, which is a non-invasive alternative evaluation method.

2. Material and method

2.1. Ethical approval

Ethical approval was obtained from the ethical committee of Gaziantep University (ethics committee decision No: 2022/147). The individuals were informed about the purpose and content of the study. Informed consent has been obtained from all individuals included in this study.

2.2. Participants and study design

This cross-sectional and non-interventional study was conducted on MS patients ($n = 33$) and matched healthy controls ($n = 30$).

2.3. Inclusion and exclusion criteria

The inclusion criteria for MS group were (a) being diagnosed with revised-2017 Mc Donald's criteria, (b) consistent medical status, (c) no drug alters in the last month. The inclusion criteria for all individuals were (a) the ages of 18–45, (b) volunteering to participate in this research, (c) not having any obstacle to cognitive and verbal communication, (d) who's chewing side preference is right. The exclusion criteria for all individuals were (a) having psychological, another neurological disorders, facial paralysis (b) having trauma and fracture related to facial region, (c) with a body mass index of 30 kg/m, (d) women in the menstrual cycle, (e) pregnant, (f) had botulinum toxin history from face and application of face fillers in last 1 year (g) those who use muscle relaxant drugs, (h) who have speech disorder. The flowchart diagram is given in Fig. 1.

2.4. Measurement tool and procedure

Demographic information (gender, age, body mass index) was recorded. The Expanded Disability Status Scale (EDSS) was used to determine the disability status of patients with MS. The subjects' preferred chewing side was determined by asking the subjects whether their preferred chewing side was right, left, or mixed (Bicaj et al., 2015). The viscoelastic properties and muscle tone of the superior orbicularis oris muscle were evaluated bilaterally in a supine position with the MyotonPro® (Myoton AS, Estonia) device, which is a portable hand-held myotonometer, as shown in Fig. 2. The reference point is accepted as the right and left paramedial philtrum dimple (Ramazanoglu et al., 2022; Zhang et al., 2015). The device provides data about the tone, stiffness, and elasticity of any muscle. The probe of the device is placed vertically on the muscle. It creates constant pre-excitations (0.18 N) and generates short-term (15 ms), low-force (0.4 N) mechanical stimulation. These mechanical stimulations induce natural oscillations in the related tissue. The device records these oscillations with an accelerometer. Oscillation frequency (Hz) refers to the tone of a muscle while resting, stiffness (N/m) is a biomechanical feature of the muscle that characterizes its resistance to a contraction or an external force. The elasticity is measured as a logarithmic decrement (log) of the natural oscillations in the tissue. Logarithmic decrement describes the tissue's ability to restore its shape after being deformed. The smaller the decrement value means the higher the elasticity (Gervasi et al., 2017).

2.5. Statistical analysis

G-power package version 3.1.9 (Heinrich Heine University, Germany) was used for power analysis. The previous studies are examined to find statistically significant difference between the groups in terms of superior orbicularis oris mechanical properties with a big effect size (Cohen $d = 0.75$). The minimum required sample size for each group was estimated as 27 ($a = 0.05$, $1\text{-}b = 0.80$) (6). SPSS 23.0 version (IBM; Armonk, NY, USA) version program was used to analyze the data. Descriptive statistics were summarized as mean±standard deviation. The Independent Sample t-test was used to compare the normally distributed data. The value of $p<0.05$ was considered as significant.

3. Results

The mean age of all individuals was 37.7 ± 9.1 years, and the

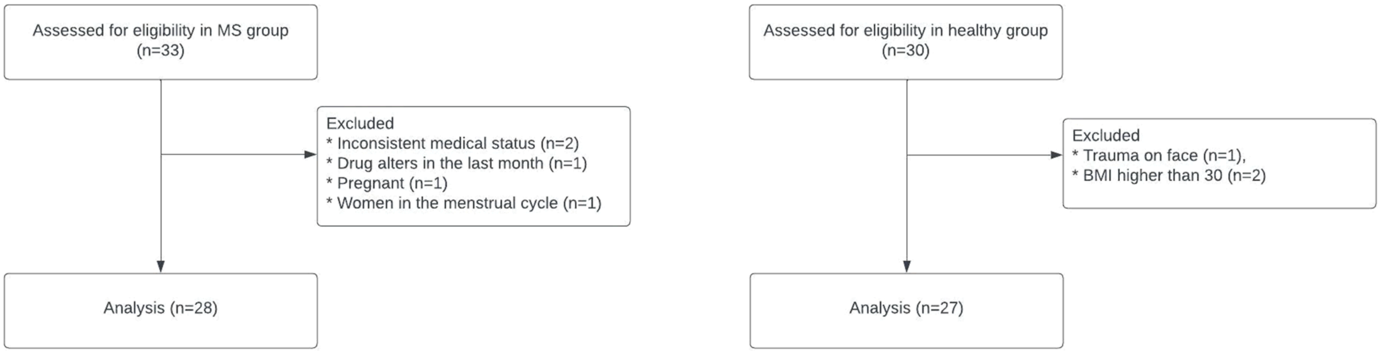

Fig. 1. Flow-chart diagram.

Fig. 2. Evaluation of the mechanical properties of the superior orbicularis oris muscle.

demographic characteristics of the participants were similar as shown in Table 1 (p>0.05). The number of female patients (71%) was higher in both groups (MS: 20 female, 8 male; HI: 19 female, 8 male). The average EDSS score for patients was 2.14±1.83 (median=2.25). MS duration of all patients was nearly 8.14±4.74 years. The type of MS for all patients was Relapsing-Remitting MS.

As shown in Table 2, there was no statistically significant difference in the stiffness values of the right and left orbicularis oris muscles of the MS and HI groups (p>0.05). The tone and the elasticity of the muscle in the right and the left side were higher (a logarithmic decrement for the elasticity parameter) in the HI group than the MS group (p<0.05).

4. Discussion

The major findings of our study, in which we compared the tone and viscoelastic properties of the superior orbicularis oris muscle with the MyotonPro® device in patients with multiple sclerosis to healthy individuals, were that there was higher stated muscle tone and elasticity in healthy individuals. This study is unique in reporting the tone and viscoelastic properties of the superior orbicularis oris muscle in patients with multiple sclerosis when compared to healthy individuals.

The orbicularis oris muscle acts as an important muscle for lip closure, swallowing, mastication, and sucking (Hee-Su et al., 2018; de Caxias et al., 2018). Considering all of its functions, this muscle that creates oral perception in the mouth has been investigated in different populations (Hee-Su et al., 2018; de Caxias et al., 2018; Mikami et al., 2019). As aging orofacial sensitivity tends to decrease and the important muscle activity changes during functions (de Caxias et al., 2018). In stroke patients, it is shown that orbicularis oris training is important for safe swallowing because it is responsible for lip closure. And the muscles can be effect from the mechanism of neurological disorders. Some neurological diseases can cause facial paralysis, which results in improper closure of the lips (Hee-Su et al., 2018). They can affect sensitivity, and muscle tone of the oral cavity at rest, contributing to an inability by patients to manage oral secretions (Mikami et al., 2019). Furthermore, it has been stated that this muscle is one of the perioral structures where facial spasms and myokymia are observed in multiple

Table 1
Demographic characteristics of the participants.

	MS (n = 28)	HI (n = 27)	t	P
Age (years)	36.71±8.59	38.85±8.59	0.862	0.393
Height (m)	165.96±6.22	164.85±6.22	0.662	0.511
Weight (kg)	73.01±14.30	76.51±15.04	0.673	0.507
Body mass index (kg/m^2)	25.38±4.79	26.33±16.46	0.507	0.435

Data are expressed as the mean±standard deviation, *p<0.05 is statistically significant, Independent Sample t-test, **MS:** Multiple sclerosis, **HI:** Healthy individuals.

Table 2
Right and left orbicularis oris muscle tone and viscoelastic properties of the participants.

Variable	MS (n = 28)	HI (n = 27)	t	P
ROT [Hz]	20.19±3.24	22.79±4.55	2.421	0.019*
LOT [Hz]	19.89±3.33	22.77±4.56	2.648	0.011*
ROS (N/m)	514.76±135.49	585.37±155.85	1.757	0.085
LOS (N/m)	527.11±115.95	581.44±156.21	1.267	0.211
ROE [log]	1.73±0.2	1.50±0.1	3.044	0.004*
LOE [log]	1.76±0.1	1.60±0.1	3.527	0.001*

Data are expressed as the mean±standard deviation, *p<0.05 is statistically significant, Independent Sample t-test, **MS:** Multiple sclerosis, **HI:** Healthy individuals, **ROT:** Right orbicularis oris tone, **LOT:** Left orbicularis oris tone, **ROS:** Right orbicularis oris stiffness, **LOS:** Left orbicularis oris stiffness, **ROE:** Right orbicularis oris elasticity, **LOE:** Left orbicularis oris elasticity.

sclerosis. It is reported that there may be weakness and other musculoskeletal problems related to the orbicularis oris muscle due to sclerotic plaque formations affecting the nervus facialis (Farazi et al., 2019; Inghilleri et al., 2016; Tibar et al., 2016; Uzawa et al., 2011). In the light of the data obtained from our study, it is thought that the changes in the tone and viscoelastic properties of the orbicularis oris muscle are caused by these neurologic mechanisms of action.

It is known that changes in tone in multiple sclerosis are variable. As the disease progresses, a reduction in muscular tone is one of the very common seen severe problems. Although an increase in muscle tone is common especially in the lower extremities, the lower tone might be observed in the head, neck, and upper extremities. The increase in the tone of the upper extremities is rarely reported (Dana et al., 2019; Etoom et al., 2018). In the literature, a clarified information has not been found in terms of tone changes in the facial muscles. We determined that the muscle tone of the orbicularis oris muscle in the MS group was lower than the healthy group data. The decrease in the tone of the orbicularis oris muscle may be the starting point of the low tone in the upper extremity in the literature. Studies showing that hemifacial spasms and myokymia start in the facial region and spread to other parts of the body support this idea (Covello et al., 2020; Collazo and Tobin, 2018; Parr et al., 2022).

In some studies, researchers stated that the stiffness, tone and elasticity are dependent on the muscle structure like muscle length and cross-sectional area, and also the intrinsic structure of the muscle (Baumgart, 2000;, Maïsetti et al., 2012). In our study, the measurements of the cross-sectional area of the orbicularis oris muscle in individuals were not investigated. However, in the absence of a serious atrophic condition, we think that it may be normal for the stiffness parameter to be similar in patients and healthy individuals. In our study, stiffness values were found to be similar in the MS group and the HI group. There are also studies where differences in stiffness were determined in dynamic measurements of the muscles and in the measurements of the muscles at different angles (Huang et al., 2018; Kubo et al., 2015). Measurement of the evaluated parameters of the muscle in the non-dynamic position of the muscle may also be the reason why the stiffness was similar in both groups. In addition, we think that this may be due to the low severity of disability according to EDSS in the MS patients who participated in the study.

Elasticity defines the ability of the structure to regain its original form, which changes with the force applied to the muscle. It expresses the ability of a muscle to return to its original state, not the ability of a muscle to elongation (Delioğlu, 2015). It has been shown that the decrease in elasticity may cause early muscular fatigue (Chuang et al., 2012; Alaca and Kablan, 2021). The lower elasticity values of the orbicularis oris muscle in MS patients are compatible with fatigue symptoms frequently seen in the disease. We also believe that the elastic deformation of the muscle can be explained by the mechanism of the disease. Besides, as it was stated in the previous studies performed by the MyotonPro® device and where the different muscles' strength and contraction abilities decreased in various situations, we found that the muscle elasticity was lower in the MS group than in the healthy group. It is already known that muscle weakness is one of the common physical symptoms of multiple sclerosis (Lee et al., 2021; Morgan et al., 2020; Trybulski et al., 2022).

In light of the results of this study, the tone and elasticity of the orbicularis oris in the MS group are lower than in the healthy group, but not stiffness. Tone and viscoelasticity changes in MS may start from the orbicularis oris muscle and spread to the body. In addition, we think that it is not possible to generalize about the stiffness, tone, and elasticity of the muscles in the evaluations with Myoton. We believe that each muscle has its own inner structure and that the conditions being evaluated are unique. Also, our study will benefit clinicians in terms of comparison data before and after treatment in swallowing and speech rehabilitation or any other problems with this muscle in MS patients. Long-term follow-up studies are needed to understand the changes in the orbicularis oris muscle during MS progression.

This study has a number of limitations. Firstly, the device gave warnings during the measurement of this muscle, and it was hard to required to get the correct signal. We thought that this might be due to the anatomical structure of the oral cavity. The close proximity of the vestibulum oris, teeth, and maxilla may cause confusion during the measurements by the received oscillations reflected from these different structures. Secondly, our patient population had low EDSS scores. This may be the main reason for the non-significant differences between the groups. Thirdly, our sample included only the relapse-remitting type, which is the most common type in the clinic. The fact that the sample of the study consisted of only one type of MS patient can be considered as a limitation. Fourthly, the lack of dynamic measurements is also a limitation in order to better understand the muscle's tone and viscoelastic properties. Additionally, we did not evaluate the emotional status, depression, and anxiety levels of the individuals. These parameters might affect the viscoelastic properties of muscles. We think that the homogenized measurements in terms of emotional status will be more clear. Nevertheless, we believe that the findings of our study provide insight into the viscoelastic properties and tone of the superior orbicularis oris muscle in MS patients and matched healthy controls.

5. Conclusion

In this study, we compared the tone, stiffness, and elasticity of the superior orbicularis oris muscle between MS patients and healthy individuals who met our inclusion criteria. We think that the orbicularis oris muscle has a central location in the facial region, and that this muscle may be the key muscle for the symptoms arising from many neurological mechanisms. The decrease in muscle tone and elasticity may be the beginning of the changes in MS patients. We believe that the data from this muscle will be useful for comparative studies. However, we should also state our experience that the data related to the viscoelastic properties of muscles is very variable and cannot be generalized in disease conditions or even in healthy individuals. The results never seem consistent for any muscle. Each situation of the muscle is evaluated in its current conditions. Briefly, myotonometric measurements of the muscle give results in terms of current conditions, muscle position, inclusion criteria, and the inner structure of the muscle.

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Declaration of Competing Interest

None.

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References

Alaca, N., Kablan, N., 2021. Acute Effects of Cold Pack for Different Periods on the Biomechanical Properties of the Rectus Femoris Muscle. Altern. Ther. Health Med. 27, 92–99.

Agyapong-Badu, S., Aird, L., Bailey, L., Mooney, K., Mullix, J., Warner, M., Stokes, M., 2013. Interrater reliability of muscle tone, stiffness and elasticity measurements of rectus femoris and biceps brachii in healthy young and older males. Work. Pap. Health Sci. 4, 1–11.

Alfonsi, E., Bergamaschi, R., Cosentino, G., Ponzio, M., Montomoli, C., Restivo, D., Bertino, G., 2013. Electrophysiological patterns of oropharyngeal swallowing in multiple sclerosis. Clin. Neurophysiol. 124, 1638–1645. https://doi.org/10.1016/j.clinph.2013.03.003.

Baumgart, E., 2000. Stiffness–an unknown world of mechanical science? Injury 31, 14–23. https://doi.org/10.1016/S0020-1383(00)80040-6.

Bicaj, T., Pustina, T., Ahmedi, E., Dula, L., Lila, Z., Tmava-Dragusha, A., Ajeti, N., 2015. The relation between the preferred chewing side and occlusal force measured by T-Scan III System. Open J. Stomatol. 5, 95. https://doi.org/10.4236/ojst.2015.54014.

Chuang, L.L., Wu, C.Y., Lin, K.C., 2012. Reliability, validity, and responsiveness of myotonometric measurement of muscle tone, elasticity, and stiffness in patients with stroke. Arch. Phys. Med. Rehabil. 93 (3), 532–540. https://doi.org/10.1016/j.apmr.2011.09.014.

Collazo, I.V.M., Tobin, W.O., 2018. Facial myokymia and hemifacial spasm in multiple sclerosis: a descriptive study on clinical features and treatment outcomes. Neurologist 23, 1–6. http://doi.org/10.1097/NRL.0000000000000163.

Compston, A., Coles, A., 2008. Multiple sclerosis. Lancet 372, 1502–1517. https://doi.org/10.1016/s0140-6736(08)61620-7.

Covello, F., Ruoppolo, G., Carissimo, C., Zumbo, G., Ferrara, C., Polimeni, A., Vozza, I., 2020. Multiple sclerosis: impact on oral hygiene, dysphagia, and quality of life. Int. J. Environ. Res. Public Health 17, 3979. https://doi.org/10.3390/ijerph17113979.

Dana, A., Rafiee, S., Gholami, A., 2019. Motor reaction time and accuracy in patients with multiple sclerosis: effects of an active computerized training program. Neurol. Sci. 40, 1849–1854. https://doi.org/10.1007/s10072-019-03892-6.

Delioğlu, K. 2015. Obstetrik Brakiyal Pleksus Paralizisi Olan Cocuklarda Kaslarin Viskoelastik Özellikleri ile Motor Fonksiyonları Arasındaki Iliskinin Araştırılması.

De Caxias, F.P., Dos Santos, D.M., Goiato, M.C., Bitencourt, S.B., da Silva, E.V., Laurindo-Junior, M.C., Turcio, K.H, 2018. Effects of mouth rehabilitation with removable complete dentures on stimulus perception and the electromyographic activity of the orbicularis oris muscle. J. Prosthet. Dent. 119, 749–754. https://doi.org/10.1016/j.prosdent.2017.07.017.

Etoom, M., Khraiwesh, Y., Lena, F., Hawamdeh, M., Hawamdeh, Z., Centonze, D., Foti, C., 2018. Effectiveness of physiotherapy interventions on spasticity in people with multiple sclerosis: a systematic review and meta-analysis. Am. J. Phys. Med. Rehabil. 97, 793–807. https://doi.org/10.1097/PHM.0000000000000970.

Farazi, M., Ilkhani, Z., Jaferi, S., Haghighi, M., 2019. Rehabilitation Strategies of Dysphagia in a Patient with Multiple Sclerosis: a Case Study. Zahedan. J. Res. Med. Sci. 21, 1–4. https://doi.org/10.5812/zjrms.85773.

Gervasi, M., Sisti, D., Amatori, S., Andreazza, M., Benelli, P., Sestili, P., Calavalle, A.R., 2017. Muscular viscoelastic characteristics of athletes participating in the European Master Indoor Athletics Championship. Eur. J. Appl. Physiol. 117, 1739–1746. https://doi.org/10.1007/s00421-017-3668-z.

Hee-Su, P., Jae-Young, P., Young-Hwa, K., Su, C.H., Jeong, K.H., 2018. Effect of orbicularis oris muscle training on muscle strength and lip closure function in patients with stroke and swallowing disorder. J. Phys. Ther. Sci. 30, 1355–1356. https://doi.org/10.1589/jpts.30.1355.

Huang, J., Qin, K., Tang, C., Zhu, Y., Klein, C.S., Zhang, Z., Liu, C., 2018. Assessment of passive stiffness of medial and lateral heads of gastrocnemius muscle, Achilles tendon, and plantar fascia at different ankle and knee positions using the MyotonPRO. Med. Sci. Monit. 24, 7570. https://doi.org/10.12659/MSM.909550.

Inghilleri, M., Onesti, E., Frasca, V., 2016. Hemifacial spasm in late-onset multiple sclerosis: a case report and literature review. Med. Res. Arch. 4, 1–11.

Kubo, K., Miyazaki, D., Yamada, K., Yata, H., Shimoju, S., Tsunoda, N., 2015. Passive and active muscle stiffness in plantar flexors of long distance runners. J. Biomech. 48 (10), 1937–1943. https://doi.org/10.1016/j.jbiomech.2015.04.012Get.

Lee, Y., Kim, M., Lee, H., 2021. The measurement of stiffness for major muscles with shear wave elastography and myoton: a quantitative analysis study. Diagnostics 11 (3), 524. https://doi.org/10.3390/diagnostics11030524.

Leonard, C.T., Stephens, J.U., Stroppel, S.L., 2001. Assessing the spastic condition of individuals with upper motoneuron involvement: validity of the myotonometer. Arch. Phys. Med. Rehabil. 82, 1416–1420. https://doi.org/10.1053/apmr.2001.26070.

Maden, T., Usgu, G., Tuncer, A., 2022. Myotonometric comparison of sternocleidomastoideus and masseter muscles in multiple sclerosis patients with swallowing problem and healthy individuals. Mult. Scler. Relat. Disord. 57, 103387 https://doi.org/10.1016/j.msard.2021.103387.

Maïsetti, O., Hug, F., Bouillard, K., Nordez, A., 2012. Characterization of passive elastic properties of the human medial gastrocnemius muscle belly using supersonic shear imaging. J. Biomech. 45, 978–984. https://doi.org/10.1016/j.jbiomech.2012.01.009.

Mikami, D.L.Y., Furia, C.L.B., Welker, A.F., 2019. Addition of Kinesio Taping of the orbicularis oris muscles to speech therapy rapidly improves drooling in children with neurological disorders. Dev. Neurorehabil. 22, 13–18. https://doi.org/10.1080/17518423.2017.1368729.

Morgan, G.E., Martin, R., Welch, H., Morris, K., 2020. Quantitative Weight Bearing and non-weight Bearing Measures of Stiffness in the Achilles Tendon and Gastrocnemius Muscle. Muscles Ligaments Tendons J. 10 (1) https://doi.org/10.32098/mltj.01.2020.14.

Ożóg, P., Natański, D., Zukow, W., 2019. Principles of management in the case of dysphagia in the course of amyotrophic lateral sclerosis. J. Educ. Health Sport 9 (7), 786–798. https://doi.org/10.5281/zenodo. 3358845.

Park, J.S., Dong Hwan, O., 2017. Effect of expiratory muscle strength training on swallowing-related muscle strength in community dwelling elderly individuals: a randomized controlled trial. Gerodontology 34, 121–128.

Parr, A.M.C., Bashford, J., Silber, E., 2022. Facial myokymia as the presenting feature of multiple sclerosis. Pract. Neurol. https://doi.org/10.1136/practneurol-2021-003268.

Ramazanoglu, E., Turhan, B., Usgu, S., 2022. Age Related Changes of Superior Orbicularis Oris Muscle in Terms of Tone and Viscoelastic Properties. J. Craniofac. Surg. 33, 236–239. https://doi.org/10.1097/SCS.0000000000007992.

Santos, V.A.D., Vieira, A.C.D.C., Silva, H.J.D., 2019. Electrical activity of the masseter and supra hyoid muscles during swallowing of patients with multiple sclerosis. Codas 31. https://doi.org/10.1590/2317-1782/20192018207.

Sinha, G., Sharma, M.L., Ram, C.S., 2018. An electromyographic evaluation of orbicularis oris and masseter muscle in pretreatment and posttreatment patients of oral submucous fibrosis: a prospective study. J. Indian Acad. Oral Med. Radiol. 30, 210. https://doi.org/10.4103/jiaomr.jiaomr_109_18.

Tibar, H., Benhaddou, E.A., Regragui, W., Benomar, A., Yahyaoui, M., Birouk, N., Jiddane, M., 2016. Myokymia revealing multiple sclerosis. Parkinsonism Relat. Disord. 22, 131–132. https://doi.org/10.1016/j.parkreldis.2015.10.315.

Trybulski, R., Wojdała, G., Alexe, D.I., Komarek, Z., Aschenbrenner, P., Wilk, M., Krzysztofik, M., 2022. Acute Effects of Different Intensities during Bench Press Exercise on the Mechanical Properties of Triceps Brachii Long Head. Appl. Sci. 12, 3197. https://doi.org/10.3390/app12063197.

Umay, E., Ozturk, E., Gurcay, E., Delibas, O., Celikel, F., 2019. Swallowing in Parkinson's disease: how is it affected? Clin. Neurol. Neurosurg. 177, 37–41. https://doi.org/10.1016/j.clineuro.2018.12.015.

Uzawa, A., Mori, M., Ito, S., Kuwabara, S., 2011. Isolated abducens and facial nerve palsies due to a facial collicular plaque in multiple sclerosis. J. Neurol. Neurosurg. Psychiatry 82, 85–86. https://doi.org/10.1136/jnnp.2010.206870.

Zhang, W.H., Chen, Y.Y., Liu, J.J., Liao, X.H., Du, Y.C., Gao, Y., 2015. Application of ultrasound imaging of upper lip orbicularis oris muscle. Int. J. Clin. Exp. Med. 8 (3), 3391.