Journal of Oral Biology and Craniofacial Research 10 (2020) 23–27

Contents lists available at ScienceDirect

Journal of Oral Biology and Craniofacial Research

journal homepage: www.elsevier.com/locate/jobcr

Original Article

Electromyography of the masticatory muscles during chewing in different head and neck postures - A pilot study

Inae Gadotti*, Kimani Hicks, Eric Koscs, Bryanna Lynn, Jansen Estrazulas, Fernanda Civitella

Department of Physical Therapy, Florida International University, Miami, USA

ARTICLE INFO

Keywords:
Masticatory muscles
Electromyography
Chewing
Posture

ABSTRACT

Objectives: The objectives of this pilot study were to analyze the electromyography (EMG) activity of masseter and anterior temporalis muscles during chewing in 2 different posture conditions: natural head posture (NHP) and maximum yet comfortable forward head posture (FHP) in healthy individuals; and to compare EMG activity between subjects based on their NHP during chewing.

Methods: Fifteen subjects participated. Sagittal head posture in sitting position was clinically assessed using a plumb line. Participants were classified as having FHP or upright head posture (UP). Surface EMG was used to evaluate superficial masseter and anterior temporalis bilaterally during chewing in NHP and FHP. Three trials with five chewing cycles were recorded. EMG data were normalized using a maximum voluntary contraction. An independent *t*-test was used to calculate differences between sides. If no differences were found, both sides were analyzed together. To analyze differences between the 2 conditions, a paired *t*-test was used. Independent *t*-test was used to calculate difference between subjects with UP and FHP.

Results: A significant increase in muscle activity was found for masseter muscle in the FHP condition. No differences were found in muscle activity in natural head position by posture classification. A trend of increased activity was observed for masseter and temporalis muscles during chewing in FHP.

Conclusion: Head and neck posture was found to influence masticatory muscle activity during the function of chewing. The results of this study may help clinicians to better understand the association between head and neck posture alterations with masticatory muscles related disorders.

1. Introduction

The resting position of the mandible is influenced not only by the masticatory muscles but by the coordination of the posterior and anterior cervical muscles.[1] The mandibular movement works in synchrony with head movements as well as masticatory and cervical muscles activation.[2] The relationship between the craniocervical region and the dynamics of the temporomandibular joint (TMJ) was supported in previous studies.[3–5] Head position has been considered to be associated with dental occlusion alterations and orofacial pain such as temporomandibular disorders (TMD).[6–8] Therefore, the balance of the craniocervico-mandibular system is important to maintain a neutral resting position and function of the mandible.[9]

Forward head posture can alter the resting position of the mandible and may affect dental occlusal contact and masticatory muscle activity.[10–12] Alterations to head position was found to affect the stability of the mandible and thus the direction of occlusal force.[13] FHP causes the passive stretching of the soft tissues of the head and mandible.[5,10,14,15] which displace the mandible backward and upward. With this altered position, the physiological freeway space (vertical dimension) between maxilla and mandible decreases during the rest position. As a result, the dental contacts is located further posteriorly.[10,16] On the other hand, a study showed that alteration of head posture not always directly influence dental occlusion during masticatory simulation.[17]

Some studies have observed that EMG activity of the masticatory muscles changes according to the head position.[10,12,16,18] Forward head posture was found to be associated with a greater muscular activity in the temporal and masseter muscles. The level of muscle activation is altered due to changes in muscle-length tension relationship with the change in the mandibular position.[5] According to Ohmure et al.,[12] when the condyle is positioned posteriorly, an additional force might be added to a posterior region of the TMJ during chewing.

Further studies are needed to investigate the influence of head and neck posture on muscle activity of the masticatory muscles during the function of chewing as most studies evaluate subjects during resting

* Corresponding author. Department of Physical Therapy, Florida International University, 11200 SW. 8th St., AHC3-427, Miami, 33199, USA.
E-mail address: igadotti@fiu.edu (I. Gadotti).

https://doi.org/10.1016/j.jobcr.2020.02.002
Received 17 May 2019; Received in revised form 7 January 2020; Accepted 3 February 2020
Available online 05 February 2020

mandibular position or during maximum clenching. In addition, many studies investigating the influence of head posture on the masticatory muscle activity focus on the effect of head flexion and extension but not on the effect of forward head posture on the masticatory muscle activity. Therefore, the objectives of this study were 1) to analyze the surface EMG activity of bilateral superficial masseter and anterior temporalis muscles during chewing in 2 different posture conditions: in a natural head posture (NHP) and in a maximum yet comfortable forward head posture (FHP) in healthy individuals; and 2) to compare the EMG activity between subjects based on their natural head position (upright-UP versus FHP classifications) during chewing. We hypothesized that the masticatory muscle activity during chewing in the FHP condition and in natural FHP will be altered when compared to chewing in NHP and in upright posture respectively.

2. Methods

This observational pilot study was approved by the Institutional Review Board from Florida International University (IRB-17-0155).

2.1. Subjects

Fifteen adults (7 males, 8 females; 26 ± 2.9 years of age), with no history of neck or temporomandibular joint pain, temporomandibular disorders, head and/or neck trauma, or under current orthodontic treatment participated in this study. The subjects were informed about the study, and if they agreed to participate, a consent form was signed. The privacy rights of the subjects was observed.

2.2. Natural head and neck postural assessment

Natural head posture (NHP) was evaluated in a sitting position. Posture was standardized by asking subjects to seat comfortably with their back resting on the back of a chair, with both feet on the ground and hands placed on top of their legs (Frankfurt plane).[19] The position of the head was also standardized using the self-balance position[20] asking the subjects to perform a large amplitude of cervical flexion and extension, and gradually decreasing to rest in the most comfortably balanced position (ie, looking parallel to the ground and keeping the gaze horizontal). A plumb line was used as a vertical reference to visually evaluate the alignment of tragus of the ear in relation to the midline of shoulder and/or trunk (Fig. 1). If shoulder was positioned forward, trunk was used for the alignment with tragus. Posture was classified as upright posture (UP) or forward head posture (FHP). The UP posture was based on the alignment between tragus and shoulder and or trunk.[21]

Fig. 1. Evaluation of head and neck posture in seating position.

Fig. 2. Surface EMG electrodes placement.

2.3. Masticatory muscles activity

Surface electromyography (sEMG) from Motion Lab Systems MA300-XII (Motion Lab Systems, Inc. Baton Rouge, LA) was used to capture muscle activity of superficial masseter and anterior temporalis bilaterally. Prior to electrode placement, the skin was prepared by slightly scrubbing the skin, followed by cleaning with an alcohol wipe. If necessary, subjects were asked to shave facial hair. **S**urface electrodes were placed on the muscle belly parallel to the muscle fibers. Electrodes were placed 2 cm apart in each muscle and the ground electrode was placed on the forehead (Fig. 2). The following verbal command was used to locate the muscles: “Bite and relax”, followed by marking the correct place with a hypoallergenic pen and then placing the electrodes.

To standardize the EMG potentials of the muscles analyzed, two strips of Parafilm (PM992; Bernis; Neenah, Wisconsin) were folded into five parts (3 mm in thickness) and positioned on the first and second mandibular molars bilaterally.[19] The maximum voluntary contraction (MVC) of clenching the teeth was recorded for a period of 3 s and repeated 2 more times. The verbal command was as follows: “Bite down on both sides maximally and hold it for 3 s”. The average of the three trials of MVC were used for further analysis.

2.4. Chewing task

Subjects were asked to chew in 2 different conditions: natural head posture (NHP) and in forward head posture (FHP). Each subject chewed along with a metronome of 70 beats per minute (bpm) to establish a consistent rhythm. Frankfurt plane for standardization of NHP was used for data collection. Three trials with five chewing cycles each were recorded. A rest period of 30 s was used between trials. After chewing in the NHP, the subject were asked to position in a comfortable maximum forward head posture while keeping their back placed on the chair (Fig. 3). In order to standardize this position, the following verbal command was used “Chew with your head forward maximally but comfortably” Three trials with five chewing cycles each were recorded in this position as well.

2.5. Analysis

EMG data were normalized using maximum voluntary contraction (MVC). To analyze MVC for each participant, the mid 2-s window was chosen for each trial. Within the 2-s frame, the mean of the amplitude for each muscle (right masseter, left masseter, right anterior temporalis, left anterior temporalis) was calculated. For the chewing task, the 2nd, 3rd, and 4th chewing cycles in each trial were used to find the mean

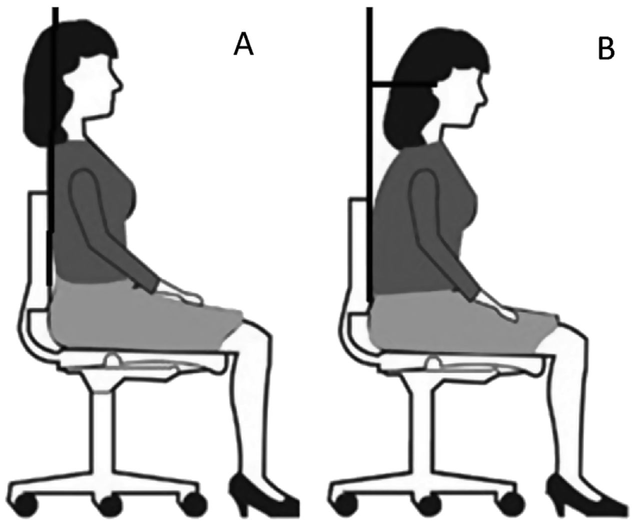

Fig. 3. Natural head posture (A) and comfortable maximum forward head posture (B) during the chewing task.

amplitude. Then all 3 trials were averaged to find the overall mean amplitude for each muscle. The mean amplitude of each muscle was calculated as a percentage of the MVC. An independent *t*-test was used to calculate differences between right and left sides. If no differences were found, both sides were analyzed together. In order to analyze differences between the 2 conditions (NHP and maximum FHP), a paired *t*-test was used. Independent *t*-test was used to calculate difference between subjects with upright posture (UP) and with natural FHP based on the postural analysis. Statistical analysis was performed using SPSS. A significance level of 0.05 was used.

3. Results

3.1. Natural head posture versus maximum forward head posture conditions

For the 15 subjects included, no significant differences in muscle activity between right and left sides were found ($p \geq 0.101$). Therefore, both sides were analyzed together. A significant difference ($p = 0.02$) was found for masseter muscle activity between NHP and maximum FHP conditions during chewing (Fig. 4). No difference was found for temporalis muscle ($p = 0.09$).

3.2. Upright versus forward head posture classifications

According to the postural evaluation in sitting position, 11subjects were classified as having upright posture (UP) and 4 subjects were classified with forward head posture (FHP). According to the analysis, no differences were found in muscle activity ($p > 0.09$) during chewing in natural head position by posture classification (upright posture and forward head posture) (Fig. 5).

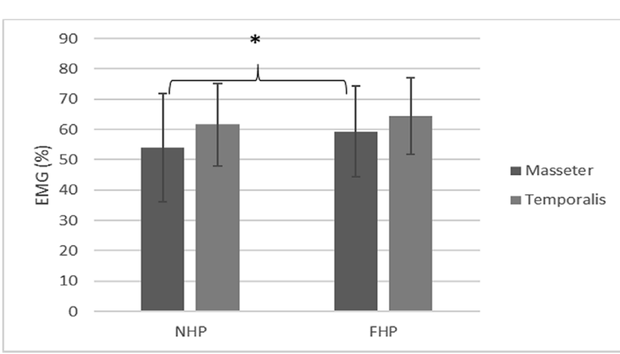

Fig. 4. EMG percentage (mean and SD) for masseter and temporalis muscles during natural head posture (NHP) and maximum forward head posture (FHP) conditions.

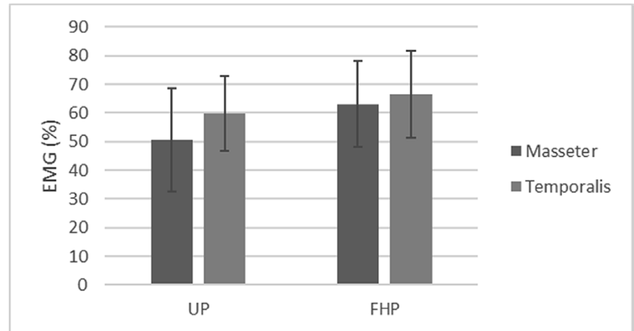

Fig. 5. EMG percentage (mean and SD) for masseter and temporalis muscles based on posture classification (Upright-UP vs. forward head posture-FHP).

4. Discussion

This study analyzed the surface EMG activity of bilateral superficial masseter and anterior temporalis muscles during chewing in a natural head posture (NHP) compared to a maximum yet comfortable forward head posture (FHP) in 15 healthy subjects. Therefore, subjects served as their own control (single-subject design). The EMG activity was also compared between subjects (group design) based on their natural head position (upright-UP versus FHP classifications). According to the results, a significant increase of muscle activity was found for the masseter muscle during chewing when subjects were asked to perform a maximum FHP compared to chewing during a NHP. A trend of increase in activity of the anterior temporalis muscle was also observed but no statistical difference was found. When analyzing muscle activity during chewing in natural head position by posture classification (upright posture versus forward head posture), no significant changes was found; however, a trend of increased activity was observed for both masseter and temporalis muscles during chewing for subjects classified with FHP.

The influence of head positioning on the masticatory region was supported in previous studies. The TMJ condylar position was found to be significantly more posterior in a deliberate forward head posture compared to condylar position in a natural head posture.[12] The same study found a significant increase of masseter and digastric muscles activation during the deliberate forward head posture. Visscher et al.[3] found that the lower incisor movement path during jaw closing was shifted posteriorly in forward head posture. In another study,[18] an increase of masseter muscle activity when the head extended at 10 and 20° was found. The results of the former study is comparable to the present study considering that the head and upper cervical (C1–C3) is extended in forward head posture. The same study[18] found no significant association with different head postures for temporalis muscle which is in agreement with the results of this study when no significant differences in temporalis muscle activity was found during chewing with the head in FHP or when comparing subjects with or without FHP. According to Ballenberger and colleagues,[5] EMG activity of anterior temporalis muscle seems to be less affected by different postures of the cervical spine.

In a larger-scale, the correlation between cervical spine and masticatory region can be explained by neuroanatomical and functional connections.[22] There is a convergence between the upper three cervical nerves with the trigeminal nerve which innervates the masticatory region. In addition, there is a synergic relationship (co-contraction) between the cervical spine and masticatory muscles during functional activities including chewing, talking and yawning.[22] This correlation can explain the coexistence of cervical spine disorders and orofacial pain.[23–26] The current study contributes to support the literature on the correlation between the cervical spine and masticatory region.

It was interesting to observe that anterior temporalis muscle presented with more activity (higher EMG amplitude) compared to masseter muscles for both conditions (NHP and maximum FHP) and posture classifications (UP and FHP) during chewing. This pattern of having temporalis more active than masseter in healthy individuals was also observed in a previous study.[12] A normal function of the masticatory muscles is characterized by masseter demonstrating greater EMG activity than temporal muscles. Masseter muscle is described as a power muscle during the mouth closing while temporal as a control muscle of the mandible position.[10,27] The normal EMG pattern during chewing was not observed in the subjects included in this study. A possible explanation is that the chewing task was not evaluated during a natural functional manner. The EMG was recorded during a non-habitual bilateral isotonic mastication using the Parafilm® material between the premolars and molars teeth. The Parafilm® was shown to be the most effective material for electromyographic studies on chewing tasks[19] and it has been used in several studies[10,28,29] No muscle activity was recorded during resting position so to analyze EMG signals during nonfunctional activity.

Most studies evaluating the influence of head and neck posture on masticatory muscles activity asked subjects to perform an extension and/or flexion of the head. In addition, muscle activity is usually evaluated with the mandible in resting position[12] or during maximum clenching. The present study contributes to the knowledge regarding the association between cervical and masticatory regions evaluating the influence of forward head posture during the function of chewing.

4.1. Study limitations

Fifteen subjects were included in this study. When subjects were divided by posture classification, only 4 presented with FHP. The small sample size decreases the power of the study and consequently impairs the ability to generalize our results to the large population. Future studies should increase the number of subjects in order to increase the power of the study. In this study, even with a small sample size, differences were found for masseter muscles. In addition, the study provides preliminary information for future studies.

A visual assessment of head and neck posture was used. This method is considered subjective when compared to photogrammetry to measure posture, for example. However, even though photogrammetry is being widely used in research to quantify posture, the visual assessment is still a common approach among clinicians. Nevertheless, the use of photogrammetry was found to be more sensitive to measure head posture than visual assessments[30] so the use of photogrammetry to measure posture should be considered in future studies.

The two conditions tested in this study (first objective), were not randomized among subjects. All subjects first chew in a natural head position and then in a maximum comfortable forward head posture. The randomization of the order of the conditions may avoid possible order effects. However, when subjects were compared by group (by posture classifications) where order effects are not an issue, similar results were found (tendency of an increase of muscle activity in forward head posture).

5. Conclusion

Head and neck posture was found to influence masticatory muscle activity during the function of chewing. The results of this pilot study may help clinicians to better understand the association between head and neck posture alterations with masticatory muscles related conditions. Future studies should include more subjects with and without forward head posture, and consider a habitual chewing task to evaluate the activity of the masticatory muscles.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors report no conflicts of interest.

References

1. Biasotto-Gonzalez D, Sousa D, Politti F, et al. Assessment of occlusal contact in pre and post global posture re-education treatment - a pilot study. *Terapia Manual.* 2012;10(15):528–532.
2. Shimazaki K, Matsubara N, Hisano M, Soma K. Functional relationships between the masseter and sternocleidomastoid muscle activities during gum chewing. *Angle Orthod.* 2006;76(3):452–458.
3. Visscher CM, Huddleston Slater JJ, Lobbezoo F, Naeije M. Kinematics of the human mandible for different head postures. *J Oral Rehabil.* 2000;27(4):299–305.
4. La Touche R, Paris-Alemany A, von Piekartz H, Mannheimer JS, Fernandez-Carnero J, Rocabado M. The influence of cranio-cervical posture on maximal mouth opening and pressure pain threshold in patients with myofascial temporomandibular pain disorders. *Clin J Pain.* 2011;27(1):48–55.
5. Ballenberger N, von Piekartz H, Paris-Alemany A, La Touche R, Angulo-Diaz-Parreno S. Influence of different upper cervical positions on electromyography activity of the masticatory muscles. *J Manip Physiol Ther.* 2012;35(4):308–318.
6. Armijo-Olivo S, Rappoport K, Fuentes J, et al. Head and cervical posture in patients with temporomandibular disorders. *J Orofac Pain.* 2011;25(3):199–209.
7. Cortese S, Mondello A, Galarza R, Biondi A. Postural alterations as a risk factor for temporomandibular disorders. *Acta Odontol Latinoam.* 2017;30(2):57–61.
8. Haralur S, Al-Gadhaan S, Al-Qahtani A, Mossa A, Al-Shehri W, Addas M. Influence of functional head postures on the dynamic functional occlusal parameters. *Ann Med Health Sci Res.* 2014;4(4):562–566.
9. Ayub E, Glasheen-Wray M, Kraus S. Head posture: a case study of the effects of the rest position of the mandible. *J Orthop Sports Phys Ther.* 1984;5:178–183.
10. Gadotti IC, Berzin F, Biasotto-Gonzalez D. Preliminary rapport on head posture and muscle activity in subjects with class I and II. *J Oral Rehabil.* 2005/11;32(11):794–799.
11. Visscher CM, De Boer W, Lobbezoo F, Habets LLMH, Naeije M. Is there a relationship between head posture and craniomandibular pain? *J Oral Rehabil.* 2002/11;29(11):1030–1036.
12. Ohmure H, Miyawaki S, Nagata J, Ikeda K, Yamasaki K, Al-Kalaly A. Influence of forward head posture on condylar position. *J Oral Rehabil.* 2008;35(11):795–800.
13. Nakamura K, Minami I, Wada J, Ikawa Y, Wakabayashi N. Head position affects the direction of occlusal force during tapping movement. *J Oral Rehabil.* 2018;45(5):363–370.
14. Solow B, Sonnesen L. Head posture and malocclusions. *Eur J Orthod.* 1998/12;20(6):685–693.
15. Sonnesen L, Bakke M, Solow B. Temporomandibular disorders in relation to craniofacial dimensions, head posture and bite force in children selected for orthodontic treatment. *Eur J Orthod.* 2001/4;23(2):179–192.
16. Goldstein DF, Kraus SL, Williams WB, Glasheen-Wray M. Influence of cervical posture on mandibular movement. *J Prosthet Dent.* 1984;52(3):421–426.
17. Motoyoshi M, Shimazaki T, Sugai T, Namura S. Biomechanical influences of head posture on occlusion: an experimental study using finite element analysis. *Eur J Orthod.* 2002;24(4):319–326.
18. Forsberg CM, Hellsing E, Linder-Aronson S, Sheikholeslam A. EMG activity in neck and masticatory muscles in relation to extension and flexion of the head. *Eur J Orthod.* 1985;7(3):177–184.
19. Ap Biasotto-Gonzalez D, Berzin F, da Costa JM, de Gonzalez TO. Electromyographic study of stomatognathic system muscles during chewing of different materials. *Electromyogr Clin Neurophysiol.* 2010;50(2):121–127.
20. Solow B, Tallgren A. Natural head position in standing subjects. *Acta Odontol Scand.* 1971/11;29(5):591–607.
21. Kendall FP, McCreary EK. *Muscles: Testing and Function.* fourth ed. Williams & Wilkins; 1993.
22. Kraus S. Temporomandibular disorders, head and orofacial pain: cervical spine considerations. *Dent Clin.* 2007;51(1):161–193.
23. Silveira A, Gadotti IC, Armijo-Olivo S, Biasotto-Gonzalez DA, Magee D. Jaw dysfunction is associated with neck disability and muscle tenderness in subjects with and without chronic temporomandibular disorders. *BioMed Res Int.* 2015;2015:512792.
24. Silveira A, Armijo-Olivo S, Gadotti IC, Magee D. Masticatory and cervical muscle tenderness and pain sensitivity in a remote area in subjects with a temporomandibular disorder and neck disability. *J Oral Facial Pain Headache.* 2014;28(2):138–146.
25. Armijo-Olivo S, Pitance L, Singh V, Neto F, Thie N, Michelotti A. Effectiveness of manual therapy and therapeutic exercise for temporomandibular disorders: systematic review and meta-analysis. *Phys Ther.* 2016;96(1):9–25.
26. Armijo-Olivo S, Silvestre R, Fuentes J, et al. Electromyographic activity of the cervical flexor muscles in patients with temporomandibular disorders while performing the craniocervical flexion test: a cross-sectional study. *Phys Ther.* 2011;91(8):1184–1197.

27. Ferrario VF, Sforza C, Miani Jr A, D'Addona A, Barbini E. Electromyographic activity of human masticatory muscles in normal young people. statistical evaluation of reference values for clinical applications. *J Oral Rehabil.* 1993;20(3):271–280.
28. Politti F, Casellato C, Kalytczak MM, Garcia MB, Biasotto-Gonzalez DA. Characteristics of EMG frequency bands in temporomandibullar disorders patients. *J Electromyogr Kinesiol.* 2016;31:119–125.
29. El Hage Y, Politti F, de Sousa DF, et al. Effect of mandibular mobilization on electromyographic signals in muscles of mastication and static balance in individuals with temporomandibular disorder: study protocol for a randomized controlled trial. *Trials.* 2013;14 316-6215-14-316.
30. Gadotti I, Biasotto-Gonzalez D. Sensitivity of clinical assessment of head posture in sagittal plane – a preliminary study. *J Eval Clin Pract.* 2010;16:141–144.