stomaedu
www.stomaeduj.com

EFFECTS OF MASTICATORY MOVEMENTS ON THE HEAD, TRUNK AND BODY SWAY DURING THE STANDING POSITION

Keiko Shima[1a*], Kiwamu Sakaguchi[1b*], Noshir R. Mehta[2c], Tomoaki Maruyama[3d], Leopoldo P. Correa[2e], Atsuro Yokoyama[1f]

[1]Division of Oral Functional Science, Graduate, Department of Oral Functional Prosthodontics, School of Dental Medicine, Hokkaido University, Sapporo, Japan
[2]Craniofacial Pain Center, Department of Diagnostic Sciences, Tufts University School of Dental Medicine, Boston, MA, USA
[3]Computer Science Course, Department of Industrial Engineering, National Institute of Technology (KOSEN), Ibaraki College, Hitachinaka, Japan
1a and 1b contributed equally to this study

[a]DDS, PhD, e-mail: shimak@den.hokudai.ac.jp
[b]DDS, PhD; Associate Professor; e-mail: sakaguti@den.hokudai.ac.jp; ORCIDiD: https://orcid.org/0000-0002-5955-3043
[c]DMD, MDS, MS, Professor Emeritus; e-mail: noshir.mehta@tufts.edu; ORCIDiD: https://orcid.org/0000-0003-0360-9535
[d]PhD, Associate Professor; e-mail: maruyama@ee.ibaraki-ct.ac.jp; ORCIDiD: https://orcid.org/0000-0002-0553-4787
[e]BDS, MS, Associate Professor; e-mail: leopoldo.correa@tufts.edu
[f]DDS, PhD, Professor; e-mail: yokoyama@den.hokudai.ac.jp; ORCIDiD: https://orcid.org/0000-0003-4763-418

ABSTRACT

https://doi.org/10.25241/stomaeduj.2022.9(3-4).art.1

Introduction Mastication involves complex tongue movements, coordination of lip, and cheek movements and is associated with head movement to facilitate the intraoral transport of food from ingesting to swallowing; it affects many functions of the whole body. However, studies to evaluate the relationship between masticatory movements and the body posture are still lacking to our knowledge. The purpose of this study was to characterize the effects of masticatory movements on the head, trunk, and body sway during the standing position.
Methodology A total of 30 healthy subjects were evaluated. The MatScanTM system was used to analyze changes in body posture (center of foot pressure: COP) and the 3-dimensional motion analysis system was used to analyze changes in the head and trunk postures while subjects remained in the standing position with the rest position, centric occlusion, and masticating chewing gum.
Results The total trajectory length of COP and head and trunk sways during masticating chewing gum were significantly shorter and smaller respectively than it was in the rest position and centric occlusion ($p<0.016$). COP area during masticating chewing gum was significantly smaller than it was in the 2 mandibular positions ($p<0.016$).
Conclusion Masticatory movements positively affect the stability of the head, trunk, and body sways and enhance the postural stability during the standing position.

KEYWORDS

Masticatory Movements; Head, Trunk, and Body Sways; Changing Body Posture; Standing Position; Postural Stability

1. INTRODUCTION

One of the purposes in dental prosthetic treatment includes the recovery of the masticatory function. Mastication involves not only simple sequential jaw-opening and jaw-closing movements but also complex tongue movements, coordination of lip, and cheek movements and is associated with head movement to facilitate the intraoral transport of food from ingesting to swallowing [1-3].
It has been reported that masticatory movements affect many functions of the whole body, including the awakening effect [4,5], promotion of cerebral function [6], reaction latency to external disturbances [7], and are closely related to health promotion [8].
There is a report in the literature that the head moves in rhythmical coordination with the mandibular movement during mastication [9]. The height of the body's center of mass is somewhere between 55% (women) and 57% (men) of the standing height [10], and the small area of the sole of the foot supports the weight of the whole body. Therefore, stability in head posture is indispensable to the control of the body posture during the standing position.
Previous studies have analyzed the relationships between the mandibular position and body posture [11,12]. Further studies have discussed relationships between mastication and the static [13,14] and dynamic [7] balance of body posture, leg muscle activity [15], neck muscle activity [16], head position [17], and upper half of body [18].

Peer-Reviewed Article
Citation: Shima K, Sakaguchi K, Mehta NR, Maruyama T, Correa LP, Yokoyama A. Effects of masticatory movements on the head, trunk and body sway during the standing position. *Stoma Edu J.* 2022;9(3-4):81-87.
Received: October 06, 2022; **Revised:** October 29, 2022; **Accepted:** November 05, 2022; **Published:** November 15, 2022.
***Corresponding author:** Kiwamu Sakaguchi, Division of Oral Functional Science, Department of Oral Functional Prosthodontics, Graduate School of Dental Medicine, Hokkaido University, Sapporo, Japan.
Tel.: +81-11-706-4270; **Fax:** +81-11-706-4903; **e-mail:** sakaguti@den.hokudai.ac.jp

However, studies to evaluate the relationship between masticatory movements and the body posture are still lacking to our knowledge. The purpose of this study was to characterize the effect of masticatory movements on head, trunk, and body sways during the standing position.

2. METHODOLOGY

2.1 Study population and ethics

30 healthy students (15 males and 15 females) with an average age of 28.6 years (range 22-32 years) were recruited among the students and staff members of the Graduate School of Dental Medicine Hokkaido University. The sample size was calculated using the software program G*Power 3.1.9.2 (Heinrich-Heine-Universität Düsseldorf). When the sample size was calculated by setting $\alpha = 0.05$, $\beta = 0.8$, and effect size = 0.8, 26 participants were needed. All subjects met the following inclusionary criteria: (1) no history of head and neck or back problems, (2) no history of signs and symptoms of temporomandibular disorders or orofacial pain, (3) no history of orthopedic or otolaryngologic problems affecting body balance, (4) absence of prosthesis (i.e., crowns, bridges, implants or removable prosthetics) and class I dental occlusion, and (5) the pattern during mastication assessed by a linear or concave opening path from centric occlusion toward the working side and a subsequent convex closing path in the vicinity of centric occlusion [19].

The movement of the mandibular incisal point during chewing gum on habitual chewing side was recorded by the optical jaw motion tracking device (FUJITA Medical Instruments Co, Japan) and was analyzed using the overlapping of each cycle and average path [19] (Fig. 1).

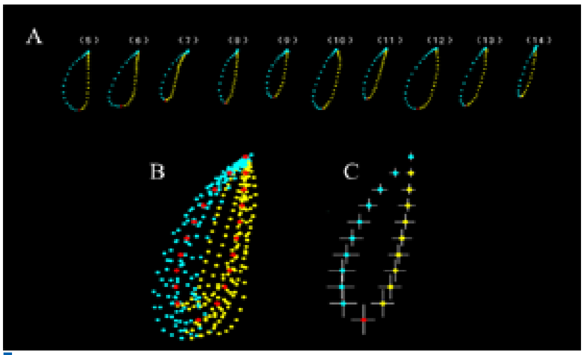

Figure 1. An example of overlapping of cycle and average path during chewing on the right side. Using the centric occlusion of each cycle as the standard, coordinates for each cycle were determined by vertically dividing the opening and closing paths into 10 equally spaced sections in the frontal view. From these coordinates, the average path and SD (standard deviation) were calculated. The method used to calculate the average path is as follows: (A) 5-14 cycles on the habitual side chewing were recorded, and the coordinates for each cycle were determined by vertical division into 10 equally spaced sections. (B) Overlapping of each cycle and average path. (C) Average path and SDs of each level.

This study was approved by the ethical committee of the Graduate School of Dental Medicine Hokkaido University (2019-No.2). The study methodology was explained, and written consent was obtained from all participants prior to their inclusion in the study.

2.2 Analysis of simultaneous measurements of head, trunk, and body sways (Fig. 2)

The MatScanTM system (Tekscan Inc., Boston, MA, Nitta Corp., Osaka, Japan) was used to analyze body sway [11,12,20]. This instrument provided a dynamic evaluation of body posture. This system could measure weight distribution and changes in the position of the center of foot pressure (COP) on a footplate during a standard measuring period. The COP is the center of vertical force acting on the support surface. It indicates gravity shifts in the anteroposterior and lateral directions.

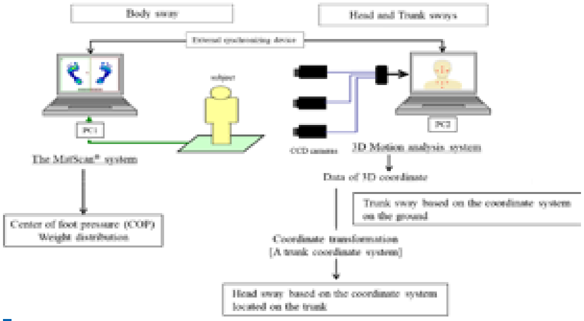

Figure 2. Analysis of simultaneous measurements of the head, trunk and body sways. Data sampling was performed simultaneously at a sampling rate of 60 Hz using a self-made external synchronization device. For the head and trunk sway measurements, a three-dimensional motion analysis system (Library Co., Ltd., Tokyo, Japan) was used to analyze the motion of the target points set on the head and trunk respectively. In the head sway analysis, the coordinates were transformed to a coordinate system, a trunk coordinate system, based on the trunk to eliminate the trunk sway. The center of foot pressure (COP) and weight distribution were measured using a footplate, the MatScanTM system (Tekscan Inc., Boston, MA, Nitta Corp., Osaka, Japan). CCD: Charge coupled device.

The three-dimensional motion analysis system (Library Co., Ltd, Tokyo, Japan) was used to analyze head and trunk sways. This instrument enabled the measurement of the three-dimensional movements of target points on the surface of the facial skin and body surface simultaneously. The movements of the target points were recorded by three charge coupled device (CCD) cameras, and the three-dimensional coordinates were calculated by using an analyzing software (Library Co., Ltd, Tokyo, Japan). The target points on the face and trunk skin were marked by attaching 4 points respectively (Fig. 3).

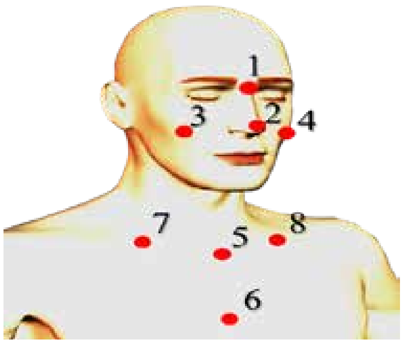

Figure 3. Target points set on the head and trunk. Four target points were set on the head (No. 1-4) and trunk (No. 5-8) respectively for the motion analysis. No. 1: nasion, No. 2: top of the nose, No. 3 and 4: right and left zygomatic bones, No. 5: jugular notch, No. 6: xiphoid process, No. 7 and 8: right and left clavicle middle point. Round reflecting markers (10 mm in diameter) were used as target points to be recognized by using their luminance values, and double-sided tape was used for setting these markers on the head and trunk.luminance values.

The center of the 4 target points was calculated in each sampling frame. Then the mean coordinate of all the centers of the 4 target points on the face was defined as the virtual central coordinate of the head (MCB-h). In the same way, the mean coordinate of all the centers of the 4 target points on the trunk was defined as the virtual central coordinate of the trunk (MCB-t). The head sway was analyzed based on the coordinate system located on the trunk (A trunk coordinate system). The trunk sway was analyzed based on the coordinate system on the ground.

For all tests, the subjects were asked to remove their shoes and socks, to stand with their feet apart to the width of their shoulders in a natural stance on the force platform of the MatScanTM system. To assist in obtaining the natural standing posture, the subjects were asked to look directly into a reflected image of their eyes, two meters away with arms hanging free at their sides and to remain in this position during the measurements. Simultaneous measurement of the head, trunk, and body sways was conducted under the following three conditions: (1) The subjects maintained the rest position (teeth slightly apart and masticatory muscles in a relaxed non-contractile condition). (2) The subjects maintained the centric occlusion without clenching. (3) The subjects chew softened chewing gum on their habitual chewing side and were requested not to swallow it for the time tested. These three conditions were randomly conducted in each subject, based on the table of random numbers. Testing under each condition was recorded for 20 seconds. The recording was started after the subject stood on the MatScanTM sensor and the investigator confirmed that their head and body positions were stable. Each trial was recorded three times with a one-minute rest period.

2.3 Parameters

The total trajectory length of the COP and COP areas (Rectangular area, Outer peripheral area, Root mean square area) were used to evaluate the stability of the body posture [11,12]. Each trial of the MatScanTM system was recorded in 1200 frames for 20 seconds. The 2-dimensional coordinates of the COP were acquired for every frame. First, the effective distance of the COP between one frame and the next frame was calculated based on the pitch of the sensor sheet in each trial. The total trajectory length of the COP for each trial was then calculated by summing up all the effective distances of the COP between 1200 consecutive frames. The COP areas were the rectangular area, the outer peripheral area, and the root mean square area of the total trajectory of 1200 COPs respectively.

The lateral and anteroposterior weight distribution were used to evaluate the balance of body posture [11,12]. A four-quadrant weight distribution value was measured in percentages (%) for every frame in each trial (Fig. 4). First, the lateral weight distribution and the anteroposterior weight distribution values for each frame were calculated. Next, the mean value of the sum of all lateral weight distribution values in each trial was calculated (LWD). The same calculation was carried out for the anteroposterior weight distribution value (AWD). The calculation for the LWD and AWD was as follow: LWD (%) = 50 - (the right-anterior value + the right-posterior value), and AWD (%) = 50 - (the right-posterior value + the left-posterior value).

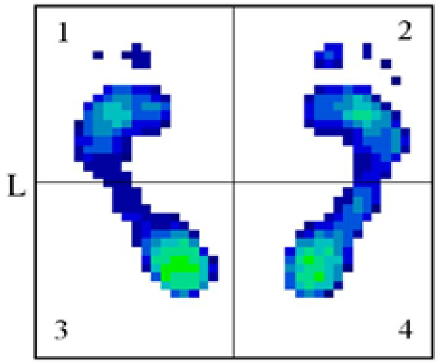

Figure 4. A four-quadrant weight distribution. Pressure at the soles of both feet was measured in equalized four-quadrant sections: (1) left anterior, (2) right anterior, (3) left posterior, and (4) right posterior. L: left side, R: right side.

The head and trunk sway values were used to evaluate the stability of the head and trunk position respectively. Each trial of the three-dimensional motion analysis system was recorded in 1200 frames for 20 seconds. The 3-dimensional coordinate of the center of the 4 target points of the head was acquired for every frame. The head sway value was defined as the mean distance between MCB-h and each center of the 4 target points. The trunk sway value was obtained in the same manner as the head sway value.

Each trial was repeated three times and the average value of the three trials was used as the representative value for each subject.

2.4 Statistical analysis

The total trajectory length of the COP, the COP areas (Rectangle area, Outer peripheral area, Root mean square area), the lateral and anteroposterior weight distribution and the head and trunk sway values were compared to evaluate whether the masticatory movements affected the head, trunk, and body sways. All comparisons were performed using Friedman's two-way analysis of variance ($p<0.05$) and the Wilcoxon t-test with Bonferroni correction (0.05/3 = 0.016) were used. SPSS version 21 (SPSS Japan Inc., Tokyo, Japan) was used for statistical analysis.

3. RESULTS

The results of the comparisons (median values) in total trajectory length of COP among the rest position, centric occlusion, and masticating chewing gum are shown in Fig. 5. The total trajectory length of COP in the centric occlusion was significantly shorter than it was in the rest position. The total trajectory length of COP during masticating chewing gum was significantly shorter than it was in the rest position and in centric occlusion.

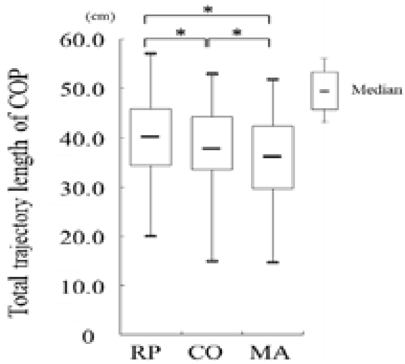

Figure 5. Comparison of total trajectory length of COP among rest position (RP), centric occlusion (CO), and mastication of gum (MA). Differences among RP, CO, and MA were tested with the Friedman's two-way analysis of variance (P < 0.05), and multiple comparisons was assessed by the Bonferroni adjustment (0.05/3 = 0.016) after Wilcoxon t-test. *: P<0.016, and n = 30. Medians (IQR) of RP, CO, and MA were as follows: RP 40.2(34.4 - 45.9), CO 37.7(33.5 - 44.3), MA 36.2(29.6 - 42.4).

The median COP areas (Rectangle area, Outer peripheral area, Root mean square area) are shown in Fig. 6. The median COP areas in the centric occlusion were significantly smaller than it was in the rest position. The median COP areas during masticating chewing gum were significantly smaller than they were in the rest position and centric occlusion.

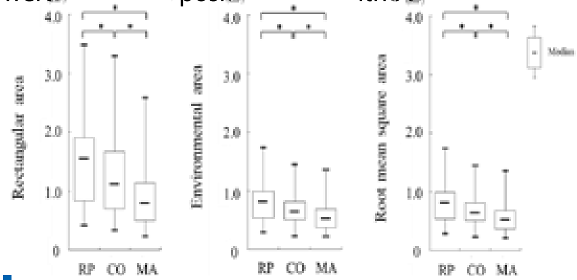

Figure 6. Comparison of COP areas (rectangle area, outer peripheral area, and root mean square area) among RP, CO, and MA. *:P<0.016, and n=30. Medians (IQR) of RP, CO, and MA for rectangle area were as follows: RP 1.6(0.8-1.9), CO 1.1(0.7-1.7), MA 0.8(0.5-1.1). Medians (IQR) of RP, CO, and MA for outer peripheral area were as follows: RP 0.8(0.5-1.0), CO 0.6(0.5-0.8), MA 0.5(0.4 - 0.7). Medians (IQR) of RP, CO, and MA for root mean square area were as follows: RP 0.8(0.5 - 1.0), CO 0.6(0.5 - 0.8), MA 0.5(0.4 - 0.7).

The results of the comparisons (median values) in the lateral and anteroposterior weight distributions among the rest position, centric occlusion, and masticating chewing gum are shown in Fig. 7. There were no significant differences in the distribution of foot pressure among the rest position, centric occlusion, and masticating chewing gum.

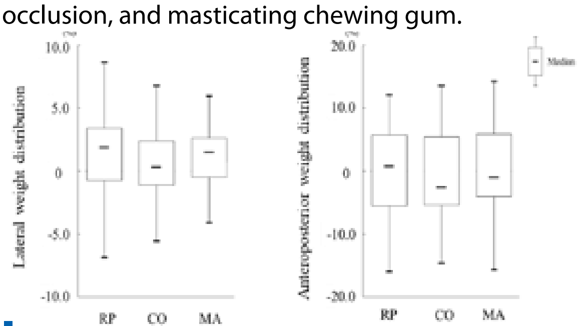

Figure 7. Comparison of lateral and anteroposterior weight distributions among RP, CO, and MA. All comparisons were not significant (P>0.016), and n=30. Medians (IQR) of RP, CO, and MA for lateral weight distribution were as follows: RP 1.9(-0.8-3.4), CO 0.3(-1.1-2.4), MA 1.5(-0.5-2.6). Medians (IQR) of RP, CO, and MA for anteroposterior weight distribution were as follows: RP 0.7(-5.5 - 5.7), CO -2.6(-5.4 - 5.4), MA -1.1(-4.0 - 5.9).

The results of the comparisons (median values) in the head and trunk sway values among the rest position, centric occlusion, and masticating chewing gum are shown in Fig. 8. The head and trunk sway values in the centric occlusion were significantly smaller than they were in the rest position. The head and trunk sway values during masticating chewing gum were significantly smaller than they were in the rest position and centric occlusion.

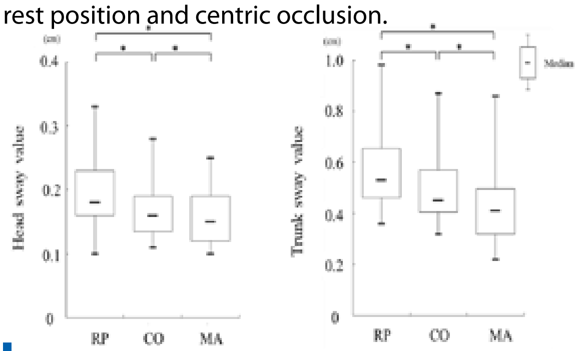

Figure 8. Comparison of head and trunk sway values among RP, CO, and MA. *: P < 0.016, and n = 30. Medians (IQR) of RP, CO, and MA for head sway value were as follows: RP 0.18(0.16 - 0.23), CO 0.16(0.14 - 0.19), MA 0.15(0.12 - 0.19). Medians (IQR) of RP, CO, and MA for trunk sway value were as follows: RP 0.53(0.46 - 0.66), CO 0.45(0.41 - 0.57), MA 0.41(0.32 - 0.50).

4. DISCUSSION

The results for the total trajectory length of COP (Fig. 5), COP areas (Rectangle area, Outer peripheral area, and Root mean square area) (Fig. 6), head and trunk sway values (Fig. 8) suggested that the body posture was significantly more stable when the subjects bit down in centric occlusion than when they maintained their mandibles in the rest position. Stability in the head position is indispensable to the control of the body posture. The anterior and posterior cervical muscles are concerned with the stability and movement of the head [21-24]. The loss of posterior occlusal support deprives the stomatognathic system of valuable proprioceptive information, and likely alters muscle contraction patterns. These changes are reported to effect the cervical muscles through the trigeminal nerve [16].

The cervical nerves C1 to C4 are primarily involved in controlling head posture [25] and the proprioceptive inputs from the muscles and articulations of the neck are important in the maintenance of postural balance [26]. Stimulation of the vestibular system by changing the head position has a descending influence on the triceps surae muscle and the soleus muscle, both antigravity muscles [27].

Based on these previous reports, the stability of the head is maintained through the action of the cervical area. The present result found that the body posture was significantly more stable in the centric occlusion than in the rest position, and suggests that bilateral occlusal contacts in the centric occlusion caused a change bilaterally in the peripheral inputs from each organ in the stomatognathic system and resulted in improving both the stability of the neck, the head, and the trunk positions. Consequently, body posture was more stable when the subjects bit down in the centric occlusion compared to when they maintained in a muscular rest position.

The results for the total trajectory length of COP (Fig. 5), COP areas (Rectangle area, Outer peripheral area, and Root mean square area) (Fig. 6), head and trunk sway values (Fig. 8) suggested that the body posture was significantly more stable when the subjects masticated chewing gum than when they bit down in centric occlusion or they maintained their mandibles in a muscular rest position.

Yagi et al. [26] reported that the leg muscles, which directly regulate the movement of the ankle joint, and the dorsal neck muscles, which change the static equilibrium through the central nervous system, are important for maintaining the standing posture. Takahashi et al. [15] indicated that the H reflexes in both the pretibial and soleus muscles undergo a nonreciprocal facilitation during mastication. Takada et al. [28] found the increase in amplitude of the pretibial and soleus H reflex showed a positive correlation with the strength of teeth clenching. Lundgren and Laurell [29] confirmed on average 37% of the total maximal bite force in habitual occlusion was utilized during chewing. Moreover, Watanabe et al. [30] suggested that the pattern of masticatory movement path with a linear or concave opening path and a convex closing path (Pattern I) had the stability of the path and rhythm and a superior masticatory function compared to the pattern of the masticatory movement path with a similar open path to that in Pattern I and a concave closing path.

The present results found that the body posture was significantly more stable when the subjects masticated chewing gum than when they bit down in centric occlusion or maintained their mandible in the rest position (Figs. 5, 6 and 8). Based on the previous reports [15,26,28-30], one can infer that when the subjects masticated chewing gum, the occlusal force might have been larger compared to it in centric occlusion, and the pattern of the masticatory movement path had the stability of the path and rhythm and a superior masticatory function. Moreover, the present results showed the possibility that the peripheral inputs from each organ in the stomatognathic system during mastication may have strongly affected the muscles, pretibial and soleus muscle, and the upper central nervous system, which regulate the craniocervical muscles, as the positive feedback control to maintain and stabilize the standing posture. Namely, a positive impact to the posture control system during mastication may have extended to both the upper and lower extremities. Consequently, the mastication movement may have affected the postural control by enhancing the postural stability standing position.

Stable human standing is usually considered to depend on an integrated reflex response to vestibular, visual, and somatosensory input [31]. When the center of gravity changes its position in space, the neuromuscular system must compensate so that the center of gravity remains in a balanced position [21]. The present results found that there were no significant differences in the distribution of the foot pressure among the rest position, centric occlusion, and masticating chewing gum anteroposteriorly and laterally (Fig. 7). These results suggest that changes in mandibular position and masticating chewing gum did not affect the postural balance anteroposteriorly and laterally.

4.1 Limitations

This study has some limitations. The simultaneous measurements of head, trunk, and body sways were carried out to evaluate a relationship between the stomatognathic function and body posture in the present study. However, analyses were not done on the motion analysis of the lower legs and muscle activities in the head, neck, trunk, and lower legs. The future direction of study should be to include the motion analysis of the lower legs and the analysis of electrical activities of craniocervical and whole body muscles to elucidate the relationship between mastication and body posture in detail. Moreover, it also needs further analysis on the subjects with the other patterns of masticatory movement path other than Pattern I (the pattern of masticatory movement path with a linear or concave opening path and a convex closing path) [30].

Kushiro et al. [13] investigated the effect of masticating chewing gum on the postural stability during upright standing, using only the force plate for postural assessment, and they suggested that mastication of chewing gum affects the postural control by enhancing the postural stability during upright standing. Goto et al. [14] also conducted a similar study and reported that the chewing gum indirectly affected postural control by influencing the vestibular function to stabilize posture during upright standing. Our results in the present study, which were obtained by adding the motion analysis to the force plate analysis, corroborate these previous studies, and suggest that the jaw sensory motor system can modulate postural control mechanisms. Gum chewing activity can enhance postural stability during upright standing in healthy young adults. Detailed investigations on the mechanism underlying these effects should be performed in future studies. Our findings could be taken into consideration in treatment and rehabilitation planning for some patients with postural instability due to balance disorders.

5. CONCLUSION

Masticatory movements affect the head, trunk, and body sways and enhance the postural stability during standing position.

CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

FUNDING

This study was supported by JSPS KAKENHI Grant Numbers JP15K11188 and JP19K10219.

AUTHOR CONTRIBUTIONS

KS: data gathering and analysis, literature collection and writing some parts of manuscript. **KS:** concept and design, protocol, data gathering and analysis, their interpretation and drafting the manuscript, manuscript revision and submission. **NRM:** concept and design, data interpretation, critical revision of the manuscript for important intellectual content. **TM:** technical support of the measurement system. **LPC:** concept and design, critically revised the manuscript. **AY:** administrative, technical, and material support; study supervision. All authors read and approved the final manuscript.

Original Articles

REFERENCES

1. Hori K, Ono T, Nokubi T. Coordination of tongue pressure and jaw movement in mastication. *J Dent Res.* 2006;85(2):187-191. doi: 10.1177/154405910608500214. PMID: 16434740.
Full text links CrossRef PubMed Google Scholar Scopus WoS
2. Sakaguchi K, Maeda N, Yokoyama A. Examination of lower facial skin movements during left- and right-side chewing. *J Prosthodont Res.* 2011;55(1):32-39. doi: 10.1016/j.jpor.2010.08.002. PMID: 20947466.
Full text links CrossRef PubMed Google Scholar Scopus WoS
3. Taniguchi H, Matsuo K, Okazaki H, et al. Fluoroscopic evaluation of tongue and jaw movements during mastication in healthy humans. *Dysphagia.* 2013;28(3):419-427. doi: 10.1007/s00455-013-9453-1. PMID: 23446812.
Full text links CrossRef PubMed Google Scholar Scopus WoS
4. Momose T, Nishikawa J, Watanabe T, et al. Effect of mastication on regional cerebral blood flow in human examined by positron-emission tomography with 15O-labelled water and magnetic resonance imaging. *Arch oral Biol.* 1997;42(1):57-61. doi: 10.1016/s0003-9969(96)00081-7. PMID: 9134116.
Full text links CrossRef PubMed Google Scholar Scopus
5. Ono Y, Yamamoto T, Kubo K, Onozuka M. Occlusion and brain function: mastication as a prevention of cognitive dysfunction. *J Oral Rehabil.* 2010;37(8):624-640. doi: 10.1111/j.1365-2842.2010.02079.x. PMID: 20236235.
Full text links CrossRef PubMed Google Scholar Scopus WoS
6. Hirano Y, Obata T, Kashikura K, et al. Effects of chewing in working memory processing. *Neurosci Lett.* 2008;436(2):189-192. doi: 10.1016/j.neulet.2008.03.033. PMID: 18403120.
Full text links CrossRef PubMed Google Scholar Scopus WoS
7. Kaji K, Katoh M, Isozaki K, et al. The effect of mastication on reaction latency to unanticipated external disturbances in the standing position. *J Med Dent Sci.* 2012;59(4):83-88. PMID: 23897116.
PubMed Google Scholar Scopus
8. Miura H. Miura K. Mizugai H, et al. Chewing ability and quality of life among the elderly residing in a rural community in Japan. *J Oral Rehabil.* 2000;27(8):731-734. doi: 10.1046/j.1365-2842.2000.00590.x. PMID: 10931271.
Full text links CrossRef PubMed Google Scholar Scopus WoS
9. Häggman-Henrikson B, Eriksson PO. Head movements during chewing: relation to size and texture of bolus. *J Dent Res.* 2004;83(11):864-868. doi: 10.1177/154405910408301108. PMID: 15505237.
Full text links CrossRef PubMed Google Scholar Scopus WoS
10. Virmavirta M. Isolehto J. Determining the location of the body's center of mass for different groups of physically active people. *J Biomech.* 2014;47(8):1909-1913. doi: 10.1016/j.jbiomech.2014.04.001. PMID: 24742487.
Google Scholar Scopus WoS
11. Sakaguchi K, Mehta NR, Abdallah EF, et al. Examination of the relationship between mandibular position and body posture. *Cranio®.* 2007;25(4):237-249. doi: 10.1179/crn.2007.037. PMID: 17983123.
Full text links CrossRef PubMed Google Scholar Scopus WoS
12. Maeda N, Sakaguchi K, Mehta NR, et al. Effects of experimental leg length discrepancies on body posture and dental occlusion. *Cranio®.* 2011;29(3):194-203. doi: 10.1179/crn.2011.028. PMID: 22586828.
Full text links CrossRef PubMed Google Scholar Scopus WoS
13. Kushiro K, Goto F. Effect of masticating chewing gum on postural stability during upright standing. *Neurosci Lett.* 2011;487(2):196-198. doi: 10.1016/j.neulet.2010.10.021. PMID: 20959136.
Full text links CrossRef PubMed Google Scholar Scopus WoS
14. Goto F, Kushiro K, Tsutsumi T. Effect of chewing gum on static posturography in patients with balance disorders. *Acta Otolaryngol.* 2011;131(11):1187-1192. doi: 10.3109/00016489.2011.607846. PMID: 21892900.
Full text links CrossRef PubMed Google Scholar Scopus WoS
15. Takahashi T, Ueno T, Taniguchi H, et al. Modulation of H reflex of pretibial and soleus muscles during mastication in humans. *Muscle Nerve.* 2001; 24(9):1142-1148. doi: 10.1002/mus.1125. PMID: 11494266.
Full text links CrossRef PubMed Google Scholar Scopus WoS
16. Häggman-Henrikson B, Nordh E, Eriksson PO. Increased sternocleidomastoid, but not trapezius, muscle activity in response to increased chewing load. *Eur J Oral Sci.* 2013;121(5):443-449. doi: 10.1111/eos.12066. PMID: 24028592.
CrossRef Google Scholar
17. Shinya A, Sato T, Hisanaga R, et al. Time course analysis of influence of food hardness on head posture and pitching of head during masticatory movement. *Bull Tokyo Dent Coll.* 2013;54(2):73-80. doi: 10.2209/tdcpublication.54.73. PMID: 903577.
Full text links CrossRef PubMed Google Scholar Scopus
18. Inada E, Saitoh I, Nakakura-Ohshima K, et al. Association between mouth opening and upper body movement with intake of different-size food pieces during eating. *Arch Oral Biol.* 2012;57(3):307-313. doi: 10.1016/j.archoralbio.2011.08.023. PMID: 21975117.
Full text links CrossRef PubMed Google Scholar Scopus WoS
19. Kobayashi Y, Shiga H, Arakawa I, et al. Masticatory path pattern during mastication of chewing gum with regard to gender difference. *J Prosthodont Res.* 2009;53(1):11-14. doi: 10.1016/j.jpor.2008.08.002. PMID: 19318065.
Full text links CrossRef PubMed Google Scholar Scopus WoS
20. Zammit GV, Menz HB, Munteanu SE. Reliability of the TekScan MatScan (R) system for the measurement of plantar forces and pressures during barefoot level walking in healthy adults. *J Foot Ankle Res.* 2010;3:11-19. doi: 10.1186/1757-1146-3-11. PMID: 20565812.
Full text links CrossRef PubMed Google Scholar WoS
21. Bracco P, Deregibus A, Piscetta R, Ferrario G. Observations on the correlation between posture and jaw position: a pilot study. *Cranio®.* 1998;16(4):252-258. doi: 10.1080/08869634.1998.11746065. PMID: 10029753.
Full text links CrossRef PubMed Google Scholar Scopus WoS
22. Nicolakis P, Nicolakis M, Piehslinger E, et al. Relationship between craniomandibular disorders and poor posture. *Cranio®.* 2000;18(2):106-112. doi: 10.1080/08869634.2000.11746121. PMID: 11202820.
Full text links CrossRef PubMed Google Scholar Scopus WoS
23. Milani RS, De Perière DD, Lapeyre L, Pourreyron L. Relationship between dental occlusion and posture. *Cranio®.* 2000;18(2):127-134. doi: 10.1080/08869634.2000.11746124. PMID: 11202823.
Full text links CrossRef PubMed Google Scholar Scopus WoS
24. Bracco P, Deregibus A, Piscetta R. Effects of different jaw relations on postural stability in human subjects. *Neurosci Lett.* 2004;356(3):228-230. doi: 10.1016/j.neulet.2003.11.055. PMID: 15036636.
Full text links CrossRef PubMed Google Scholar Scopus
25. Bogduk N. The clinical anatomy of the cervical dorsal rami. *Spine.* 1982;7(4):319-330. doi: 10.1097/00007632-198207000-00001. PMID: 71350
CrossRef PubMed Google Scholar
26. Yagi Y, Yajima H, Sakuma A, Aihara Y. Influence of vibration to the neck, trunk and lower extremity muscles on equilibrium in normal subjects and patients with unilateral labyrinthine dysfunction. *Acta Otolarygol.* 2000;120(2):182-186. doi: 10.1080/000164800750000874. PMID: 11603768.
Full text links CrossRef PubMed Google Scholar Scopus
27. Kawanokuchi J, Fu Q, Cui J, et al. Influence of vestibulo-sympathetic reflex on muscle sympathetic outflow during head-down tilt. *Environ Med.* 2001;45(2):66-68. PMID: 12353535.
PubMed Google Scholar
28. Takada Y, Miyahara T, Tanaka T, et al. Modulation of H reflex of pretibial muscles and reciprocal Ia inhibition of soleus muscle during voluntary teeth clenching in humans. *J Neurophysiol.* 2000;83(4):2063-2070. doi: 10.1152/jn.2000.83.4.2063. PMID: 10758116.
Full text links CrossRef PubMed Google Scholar Scopus WoS
29. Lundgren D, Laurell L. Occlusal force pattern during chewing and biting in dentitions restored with fixed bridges of cross-arch extension. I. Bilateral end abutments. *J Oral Rehabil.* 1986;13(1):57-71. doi: 10.1111/j.1365-2842.1986.tb01556.x. PMID: 3511198.
Full text links CrossRef PubMed Google Scholar Scopus
30. Watanabe A, Shiga H, Kobayashi Y. Occlusal contacting condition and masticatory function of 2 types of pattern that differ in the closing path of the mandibular incisal point during chewing. *J Prosthodont Res.* 2011;55(4):243-247. doi: 10.1016/j.jpor.2011.03.004. PMID: 21531190.
Full text links CrossRef PubMed Google Scholar Scopus WoS
31. Fitzpatrick R, Rogers DK, McCloskey DI. Stable human standing with lower-limb muscle afferents providing the only sensory input. *J Physiol.* 1994;480(2):395-403. doi: 10.1113/jphysiol.1994.sp020369. PMID: 7869254.
Full text links CrossRef PubMed Google Scholar Scopus WoS

Kiwamu SAKAGUCHI
DDS, PhD, Associate Professor
Division of Oral Functional, Department of Oral Functional Prosthodontics
Graduate School of Dental Medicine
Hokkaido University
Kita-ku, Sapporo, Japan

CV

Kiwamu Sakaguchi is an Associate Professor at the Department of Oral Functional Prosthodontics, Division of Oral Functional Science, Graduate School of Dental Medicine, Hokkaido University, Japan. He received his DDS at the Hokkaido University in 1995 and his PhD from the same university in 1999. He joined the Craniofacial Pain Center at Tufts University where he engaged in research from 2003 till 2004.

Questions

1. What other movements are involved in mastication besides the simple sequential jaw-opening and jaw-closing movements?

❑a. Complex tongue movements;
❑b. Coordination of lip, and cheek movements;
❑c. Head movement to facilitate the intraoral transport of food from ingesting to swallowing;
❑d. All.

2. Which of the following is not an inclusionary criteria for this study?

❑a. No history of head and neck or back problems;
❑b. No history of signs and symptoms of temporomandibular disorders or orofacial pain;
❑c. No history of orthopedic or otolaryngologic problems affecting body balance;
❑d. Malocclusion.

3. Which statistical tests were used to assess comparisons of the data in this study?

❑a. Friedman's two-way analysis of variance;
❑b. Wilcoxon t-test with Bonferroni correction;
❑c. Both;
❑d. None.

4. Which of the following is a conclusion of this study?

❑a. Masticatory movements affect head, trunk, and body sways and enhance the postural stability during standing position;
❑b Masticatory movements affect head, trunk, and body sways and deteriorate the postural stability during standing position;
❑c. Jaw clenching affect head, trunk, and body sways and enhance the postural stability during standing position;
❑d. Bruxism affect head, trunk, and body sways and enhance the postural stability during standing position.