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Correlations of head and trunk sways, and sitting and foot pressure distributions during chewing in the sitting position

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Abstract

Purpose: The head plays an important role in the postural control. Chewing co-activates jaw and neck muscles leading to coordinated jaw and head-neck movements. Therefore, examination of the relationships among head and trunk sways, and sitting and foot pressure distributions during chewing is helpful in the attempt to understand an interrelationship between chewing and posture control system in the sitting position. This purpose of this study was to examine what kind of correlation exists among head and trunk sways, and sitting and foot pressure distributions during chewing in the sitting position. **Methods:** A total of 32 healthy young male subjects were evaluated. The CONFORMat^{TM} and MatScan^{TM} system were used to analyze changes in sitting pressure distribution (center of sitting pressure: COSP) and changes in foot pressure distribution (center of foot pressure: COFP) respectively, and the three-dimensional motion analysis system was used to analyze changes in head and trunk positions while subjects remained sitting position with rest position, centric occlusion, and chewing. Data were analyzed using Spearman's rank correlation coefficients. **Results:** There was a significant positive correlation between head and trunk sways in all three studied test conditions (correlation 0.76 to 0.92, $P < 0.01$). During chewing, significant positive correlations were also found between head sway and the displacement of COFP (correlations 0.64 and 0.65, $P < 0.05$) and between trunk sway and the displacement of COSP (correlations 0.66 and 0.75, $P < 0.05$). **Conclusions:** This study confirmed that there were significant positive correlations between head and trunk sways, between head sway and foot pressure distribution, and between trunk sway and siting pressure distribution during chewing in the sitting position.

Keywords: chewing; correlation; head and trunk sways; sitting and foot pressure distributions; sitting position

1. Introduction

Mastication is a sensory-motor activity aimed at the preparation of food for swallowing, and rhythmically repeated and coordinated movements of the jaw, tongue and perioral soft tissues of the lips and cheeks. Smooth masticatory movements are generated through the cooperative activities of these organs [1-3].

It has been reported that mastication can physiologically improve the cerebral blood flow [4], and improve cognition, mood, and relieve stress by relieving anxiety [5,6]. Studies have also been discussed relationships between mastication and leg muscle activity [7], neck muscle activity [8], head posture [9], upper body movement [10].

Researchers have also investigated the relationship between mastication and body posture [11-13], and suggest the possibility that mastication affects the postural control by enhancing the postural stability. All these reports examined the relationship between mastication and standing posture. Chewing is usually performed sitting down. If mastication affects standing posture, it is reasonable to believe that mastication can affect the postural control system during sitting posture as well.

A recent study [14] has reported that masticatory movements affect sitting pressure distribution and head movements during sitting position. However, studies to investigate the relationship between mastication and sitting posture are still lacking and the mechanism by which mastication affects sitting posture could not be yet fully understood to our knowledge.

Chewing co-activates jaw and neck muscles leading to coordinated jaw and head-neck movements [15]. Head position plays an important role in the control body posture and the maintenance of postural balance [16,17]. There have been no reports to our knowledge that verified the relationships among head and trunk sways, and sitting and foot pressure distributions during chewing in the sitting position. Examination of the interrelationships among head and trunk sways, and sitting and foot pressure distributions during chewing, which is accompanied by the coordinated movements of the head that play an important role in the postural control, is meaningful and helpful in the attempt to understand the relationship and mechanism between chewing and posture control system in the sitting position.

Thus, the purpose of this study was to test the hypothesis in healthy subjects that there are correlations among head and trunk sways, and sitting and foot pressure distributions during chewing in the sitting position. Toward this goal, the head and trunk sways, and sitting and foot pressure distributions during chewing, which are interlocking dynamic movements of the living body, were simultaneously recorded using motion analyzing and two pressure distribution measurement systems and analyzed.

2. Materials and methods

2.1. Study population and ethics

In total, 32 healthy males with an average age of 26.7 years (range, 21-32 years) were included 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 inclusion criteria: (1) healthy condition, (2) no history of head and neck or back problems, (3) no history of orthopedic or otolaryngologic problems affecting body balance, (4) no history of signs or symptoms of temporomandibular (TMD) or orofacial pain, (5) absence of prosthesis (i.e., crowns, bridges, implants, or removable prosthetics) and Class I dental occlusion, and (6) no loose or broken teeth, filling, or crowns that could be further damaged during the course of this study. Exclusionary criteria included: (1) history of head and neck and/or back problems, (2) history of TMD and orofacial pain signs and symptoms, (3) history of orthopedic and/or otolaryngologic problems affecting body balance, (4) presence of five or more permanent dental restorations (i.e., crowns, bridges, implants and/or removable prosthetics), and (5) presence of loose or broken teeth, fillings or crowns which could be further damaged during the course of the study.

This study was approved by the ethical committee of the Graduate School of Dental Medicine Hokkaido University (2019-No.2) and was conducted in accordance with the ethical principles of the Declaration of Helsinki. 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 and trunk sways, and sitting and foot pressure distributions (Figure 1)

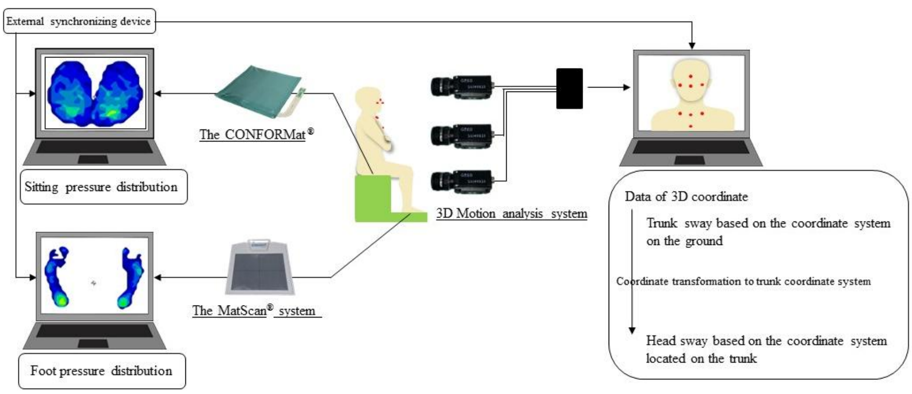

Figure 1. Analysis of simultaneous measurements of head and trunk sways, and sitting and foot pressure distributions. Data sampling was performed simultaneously at a sampling rate of 50 Hz using a self-made external synchronization device. For head and trunk sway measurements, a three-dimensional motion analysis system was used to analyze the motion of target points set on the head and trunk respectively. In

the head sway analysis, the coordinates were transformed to a coordinate system, trunk coordinate system, based on the trunk to eliminate the trunk sway. Sitting pressure distribution was measured using a pressure mapping device, CONFORMat^{TM} , and foot pressure distribution was measured using a footplate, the MatScan^{TM} system.

The CONFORMat^{TM} (Tekscan Inc., South Boston, MA, USA, Nitta Corp., Osaka, Japan) [14,18,19] was used to analyze the pressure distribution on the sitting surface. This pressure mapping device measures sitting pressure distribution and changes in the position of the center of sitting pressure (COSP) on the sitting surface during a standard measuring period, and consists of 1,024 pressure sensors that are connected in a flexible way to minimize the hammocking effect. The pressure-mapping device was calibrated according to the manufacturer's guidelines. The COSP is the center of vertical force acting on the sitting surface, and indicates the center shifts of sitting pressure distribution in the anteroposterior and lateral directions.

The MatScan^{TM} system (Tekscan Inc., South Boston, MA, USA, Nitta Corp., Osaka, Japan) [13,14,20-22] was used to analyze foot pressure distribution. This instrument provided a dynamic evaluation of foot pressure distribution. This system measures foot pressure distribution and changes in the position of the center of foot pressure (COFP) on the footplate during a standard measuring period. The COFP is the center of vertical force acting on the support surface, and indicates the center shifts of foot pressure distribution in the anteroposterior and lateral directions.

The three-dimensional motion analysis system (Library Co., Ltd., Tokyo, Japan) was used to analyze head and trunk sways [13,14]. This instrument enabled measurement of three-dimensional movements of target points on the surface of the facial skin and body surface simultaneously. The movements of target points were recorded by three charge coupled device (CCD) cameras, and the three-dimensional coordinates were calculated by using analyzing software (Library Co., Ltd, Tokyo, Japan). Target points on the skin of the face and the trunk were marked by attaching 4 points respectively [13,14] (Figure 2). The center of 4 target points was calculated in each sampling frame. Then the mean coordinate of all the center of 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 center of 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 [13,14].

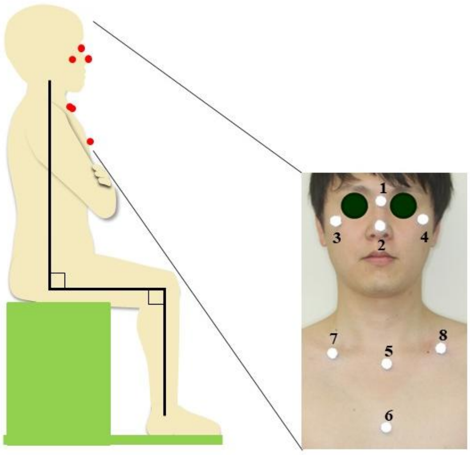

Figure 2. Target points set on the head and trunk and measuring posture. Four target points were set on the head (No. 1-4) and trunk (No. 5-8) respectively for the motion analysis. No. 1 Nasion, No. 2 Top of the nose, No. 3 and 4 Right and left zygomatic bones, No. 5 Jugular notch, No. 6 Xiphoid process, 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 setting these markers on the head and trunk was used double-sided tape. The measurement posture was the sitting posture on a height adjustable chair with hip and knee joints at 90° flexion position, and with both soles of the feet fully grounded. Both upper limbs were lightly crossed at the anterior chest.

For all tests, subjects were asked to remove their shoes and socks, to seat with hip and knee joints at 90° flexion position on the height adjustable chair, and to cross their arms at the anterior chest to minimize the effect of their arms on the posture [14] (Figure 2). The pressure mapping mat of the CONFORMat^{TM} under the buttocks and the force platform of the MatScan^{TM} system under both feet was set respectively. To assist in obtaining the natural sitting posture, the subjects were asked to look directly into a reflected image of their eyes two meters away, and to remain in this position during the measurements. Simultaneous measurements of head and trunk sways and sitting and foot pressure distributions 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 and with light contact between upper and lower teeth, (3) The subjects chew gummy jelly on their habitual chewing side [23] 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 subjects was seated in the chair, ready for the simultaneous measurements of head and trunk sways, and sitting and foot pressure distributions, and the investigator confirmed that their head and body positions were stable. The 20-second recording of gummy jelly chewing was similarly initiated after the subjects began chewing and the investigator visually confirmed the stability of their head and body positions. Each trial was recorded three times with a one-minute rest period. The sampling rate for simultaneous measurements was 50 Hz. All recordings were performed by a single investigator to account for measurement bias. Figure 3 shows an example of the trajectory data set during rest position, centric occlusion, and chewing gummy jelly respectively of head and trunk sways and the displacements of COSP and COFP obtained from one subject [14].

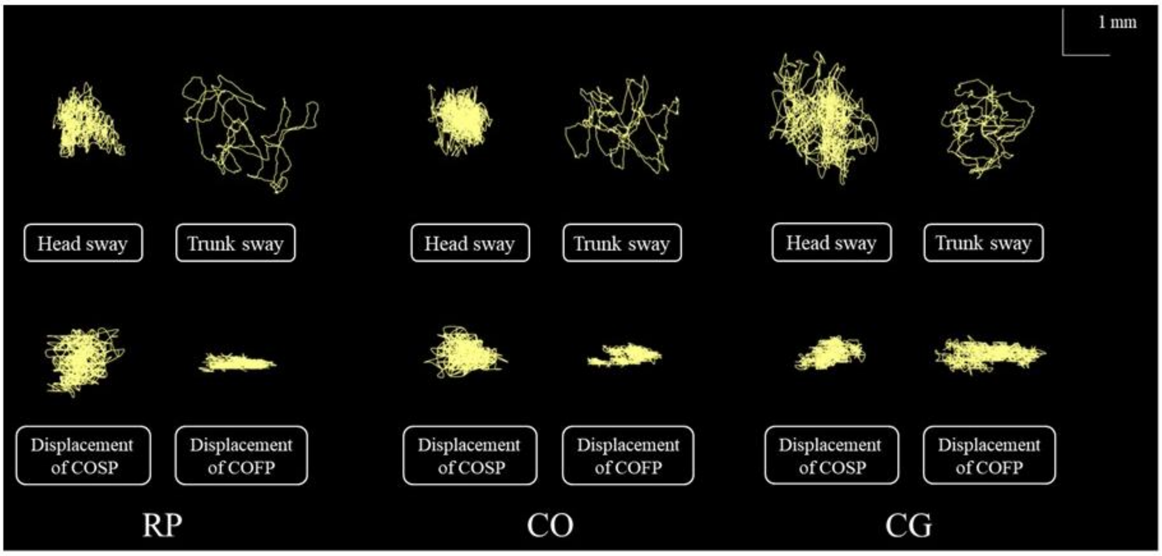

Figure 3. An example of the trajectory data set during rest position (RP), centric occlusion (CO), and chewing gummy jelly (CG) respectively of head and trunk sways and the displacements of COSP and COFP obtained from one subject. For head sway, the trajectories in the horizontal plane of the center of 4 target points set on the skin of the face were shown. Similarly for trunk sway, the trajectories in the horizontal plane of the center of 4 target points set on the skin of the trunk were shown. Head and trunk sways tended to show the centripetal type, and the displacements of COSP and COFP tended to show the right-left type. The head sway was large and the displacement of COSP was small and stable during CG. COSP, the center of sitting pressure. COFP, the center of foot pressure.

2.3. Parameters

The total trajectory length of COSP/COFP (TTL-COSP, TTL-COFP) and the COSP/COFP area (COSP-A, COFP-A): For each trial of the CONFORMat^{TM} was recorded in 1,000 frames for 20 seconds. The two-dimensional coordinates of COSP were acquired for every frame. First, the effective distance of COSP between one frame and the next frame was calculated based on the pitch of the sensor sheet in each trial. TTL-COSP (mm) for each trial was then calculated by summing all of the effective distances of COSP between 1,000 consecutive frames [14] (Figure 4). The above calculation was carried out for the TTL-COFP for the MatScan™ system data (Figure 5) [13,14,20,21]. COSP-A is the rectangular area of the total trajectory of 1,000 COSPs [14]. The same calculation was carried out for the COFP-A [13,14,20,21]. The calculation for the COSP-A/COFP-A was as follows:

COSP-A/COFP-A (mm^2) = maximum anteroposterior amplitude width of COSP/COFP modification (mm) X maximum lateral amplitude width of COSP/COFP modification (mm).

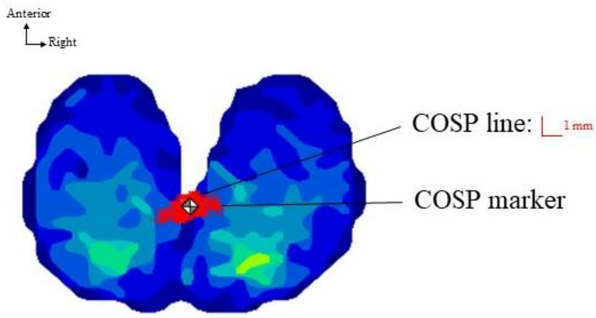

Figure 4. Schematic illustration of the TTL-COSP (mm). Output from the CONFORMat™ with color-graded seated interface pressure, the center of sitting pressure (COSP) marker, and COSP line (red line), which was the trajectory traveled by the COSP within a 20 s recording. The vertical and horizontal scales of the COSP line were 1 mm respectively. The TTL-COSP was the total distance traveled by the COSP within one recording.

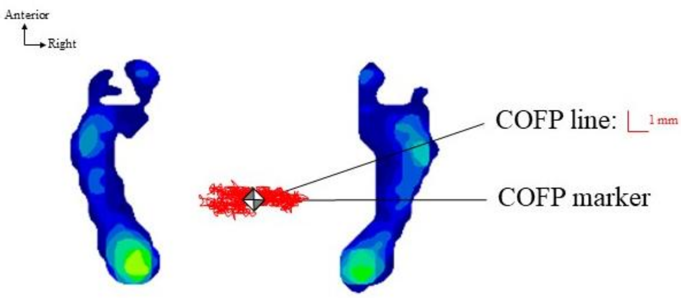

Figure 5. Schematic illustration of the TTL- COFP (mm). Output from the MatScan™ system with color-graded footed interface pressure, center of foot pressure (COFP) marker, and COFP line (red line), which was the trajectory traveled by the COFP within a 20 s recording. The vertical and horizontal scales of the COFP line were the same as those of COSP line. The TTL-COFP was the total distance traveled by the COFP within one recording.

For each trial of three-dimensional motion analysis system was recorded in 1,000 frames for 20 seconds. The three-dimensional coordinate of the center of 4 target points of the head was acquired for every frame. Head sway value (HSV) was defined as the mean distance between MCB-h and each center of 4 target points [13,14]. The trunk sway value (TSV) was obtained in the same manner as the head sway value [13,14].

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

Spearman's rank correlation coefficient was used to examine the correlation between all parameters to evaluate the interrelationships among head, trunk, and body sways. A *P*-value < 0.05 was regarded as statistically significant. All statistical analyses were performed in SPSS version 21 (SPSS Japan Inc., Tokyo, Japan).

3. Results

Medians and interquartile range (IQR) for each parameter and all Spearman's rank correlation coefficients between all parameters during rest position are found in Table 1. There was a significant positive high correlation between HSV and TSV with a Spearman correlation coefficient 0.92.

Table 1. Medians and interquartile range (IQR) for each parameter and Spearman's rank correlation coefficients between all parameters while subjects remained sitting position with rest position. Medians (IQR) is shown on the left-hand side and Spearman's rank correlation coefficients on the right-hand side. ** Correlation is significant at the 0.01 level (2-tailed). HSV, Head sway value. TSV, Trunk sway value. TTL-COSP, Total trajectory length of the COSP. COSP-A, COSP area. TTL-COFP, Total trajectory length of the COFP. COFP-A, COFP area.

Median (IQR)	Parameters	HSV	TSV	TTL-COSP	COSP-A	TTL-COFP
0.9 (0.7-1.0)	HSV, cm					
1.4 (1.0-2.2)	TSV, cm	0.92**				
188.6 (138.0-198.8)	TTL-COSP, cm	0.30	0.20			
2.9 (2.5-3.3)	COSP-A, cm^2	0.02	0.30	0.13		
165.7 (144.7-199.0)	TTL-COFP, cm^2	0.09	0.08	0.01	0.09	
5.9 (4.0-9.1)	COFP-A, cm^2	0.41	0.38	0.03	0.28	0.44

Medians (IQR) for each parameter and all Spearman's rank correlation coefficients between all parameters during centric occlusion are shown in Table 2. As during rest position, a significant positive high correlation was observed between HSV and TSV (correlation 0.88).

Table 2. Medians and interquartile range (IQR) for each parameter and Spearman's rank correlation coefficients between all parameters while subjects remained sitting position with centric occlusion. Medians (IQR) is shown on the left-hand side and Spearman's rank correlation coefficients on the right-hand side. ** Correlation is significant at the 0.01 level (2-tailed). HSV, Head sway value. TSV, Trunk sway value. TTL-COSP, Total trajectory length of the COSP. COSP-A, COSP area. TTL-COFP, Total trajectory length of the COFP. COFP-A, COFP area.

Median (IQR)	Parameters	HSV	TSV	TTL-COSP	COSP-A	TTL-COFP
0.7 (0.6-0.9)	HSV, cm					
1.3 (1.0-1.7)	TSV, cm	0.88**				
169.8 (129.2-175.4)	TTL-COSP, cm	0.36	0.41			
2.6 (2.1-3.7)	COSP-A, cm^2	0.33	0.20	0.02		
145.0 (133.0-183.7)	TTL-COFP, cm^2	0.48	0.28	0.26	0.35	
4.1 (3.4-6.0)	COFP-A, cm^2	0.13	0.16	0.30	0.38	0.38

Medians (IQR) for each parameter and all Spearman's rank correlation coefficients between all parameters during chewing gummy jelly are shown in Table 3. In addition to a significant positive correlation between HSV and TSV (correlation 0.76), significant positive correlations were found between HSV and TTL-COFP (correlation 0.64) and between HSV and COFP-A (correlation 0.65), and moreover, between TSV and TTL-COSP (correlation 0.66) and between TSV and COSP-A (correlation 0.75).

Table 3. Medians and interquartile range (IQR) for each parameter and Spearman's rank correlation coefficients between all parameters while subjects remained sitting position with chewing gummy jelly. Medians (IQR) is shown on the left-hand side and Spearman's rank correlation coefficients on the right-hand side. ** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). HSV, Head sway value. TSV, Trunk sway value. TTL-COSP, Total trajectory length of the COSP. COSP-A, COSP area. TTL-COFP, Total trajectory length of the COFP. COFP-A, COFP area.

Median (IQR)	Parameters	HSV	TSV	TTL-COSP	COSP-A	TTL-COFP
1.5 (1.2-1.8)	HSV, cm					
1.8 (1.6-2.0)	TSV, cm	0.76**				
109.1 (105.3-123.2)	TTL-COSP, cm	0.54	0.66*			
1.0 (0.9-1.4)	COSP-A, cm^2	0.53	0.75*	0.54		
184.9 (164.3-236.2)	TTL-COFP, cm^2	0.64*	0.60	0.44	0.04	
8.1 (5.7-16.7)	COFP-A, cm^2	0.65*	0.58	0.05	0.03	0.65

4. Discussion

In the present study, the head and trunk sways, and sitting and foot pressure distributions while subjects remained sitting position with rest position, centric occlusion, and chewing gummy jelly were simultaneously recorded and examined in healthy subjects to verify whether there were correlations among head and trunk sways, and sitting and foot pressure distributions during chewing in the sitting position.

Results for Spearman's rank correlation coefficients between HSV and TSV during rest position, centric occlusion and chewing gummy jelly (Tables 1, 2 and 3) indicated that there was a significant positive correlation between head and trunk sways in all three studied test conditions.

The sitting posture, especially the sitting posture with hip and knee joints at 90° flexion position set in this study, is the basic posture for initiating various activities of daily living, and postural stability is essential for the efficient performance of these activities. Body posture is maintained by the sense of equilibrium which consists of vestibular sensation, visual sensation, and somatic sensation [24]. The head contains the visual and vestibular receptors, and stability in head position is indispensable to the control of body posture [20]. The head position is determined by the central nervous system with respect to space and to the coordinates of supporting trunk [25]. Moreover, the trunk has a key role in maintaining the stability of the head because it acts as a low-pass filter and thus stabilizes the visual field and facilitates the integration of vestibular information [26]. Therefore, trunk stabilization is essential for controlling the head's position and stability in space [25].

The present results for the three studied test conditions found that there was a significant positive correlation between head and trunk sways in the quiet sitting position (Tables 1, 2 and 3). Based on the previous findings [20,24-26], this result suggests the following possibility: for the stability of static posture, as in quiet sitting, stability in head position was indispensable, and as a prerequisite for stabilizing the head position, trunk stabilization was essential. Thus, the neuromuscular system may have been governed by intricate postural control mechanisms and may have constantly worked to maintain both trunk and head stabilities and resulted in a significant positive correlation between trunk and head sways in all three studied test conditions.

The results for Spearman's rank correlation coefficients between HSV and TTL-COFP and between HSV and COFP-A, and between TSV and TTL-COSP and between TSV and

COSP-A during chewing gummy jelly (Table 3) indicated that there were also significant positive correlations between head sway and the displacement of COFP and between trunk sway and the displacement of COSP during chewing.

It has been reported that the existence of three-dimensional rhythmic coordinated movements of the head in response to the masticatory rhythm of mandibular movements during chewing [15,27], and that chewing induces head extension-flexion movements due to co-contraction of sternocleidomastoid and trapezius muscles along with jaw muscles [8,28]. On the other hand, there are reports that the center of gravity of the head is in front of the pinna and near the articular tubercle of the temporal bone [29], and that the center of rotation of the head movement in healthy individuals is at the top of the cervical spine [30]. Based on these previous findings, the rhythmic coordinated head movements in response to mandibular movements during chewing may have generated, and its movements may have been mainly larger in the anteroposterior direction because the center of gravity of the head was located at the forward position for the center of rotation of the head movement. The head sways in Figure 3 showed that the head sway during chewing was larger than during rest position and centric occlusion, and that it was larger in the anteroposterior direction than in the lateral direction.

There are reports in the literature that mastication facilitates H reflex in both the pretibial and soleus muscles [7] and that stimulation of the vestibular system by changing head position has a descending influence on the triceps surae muscle and the soleus muscle, both antigravity muscles [17]. Based on these previous reports, one can infer that when subjects masticated gummy jelly compared to when they maintained their mandibles in rest position and centric occlusion, the facilitation of H reflex associated with mastication and changes in head posture due to the coordinated head movements in response to mandibular movements during mastication may have impacted the activity of the lower extremity muscles, the pretibial and soleus muscles and consequently, the displacement of COFP may have been larger compared to that during rest position and centric occlusion. The displacement of COFPs in Figure 3 showed that the displacement of COFP during chewing was larger than during rest position and centric occlusion.

The present results for chewing gummy jelly found that there were also significant positive correlations between head sway and the displacement of COFP during chewing in the quiet sitting position (Table 3). These results suggest that during chewing, the head sway may have been larger, especially in the anteroposterior direction, and a compensatory mechanism of body posture may have acted to maintain postural stability, resulting in dynamic changes in the foot pressure distribution on both soles, the anterior elements of the base of support in sitting posture, and thus in greater displacement of the COFP. Consequently, there were significant positive correlations between head sway and the displacement of COFP during chewing in the quiet sitting position.

The center of mass of the body (COM), which is high [31], must be kept within the narrow base plane consisted of both feet soles to maintain the standing posture [24]. The inverted pendulum model (IP model), in which the COP is the fulcrum and the COM is the pendulum, is often applied to control the standing posture [32-34]. The central nervous system prioritizes postural control to support the body and maintain balance [35], and controls the gap between COM and COP in an anticipatory postural control [36,37]. Mancini et al. [38] found that if the body was thought to be moving like an IP model, a correlation close to 1 would be expected between trunk acceleration and COP displacement during quiet stance. Similarly in the sitting position, Lanzetta et al. [39] reported that in the sitting position, the body, without trunk support, was unstable and its configuration must be controlled through muscle activity: when weight was shifted in any plane, the trunk responds with a movement to counteract the change in the COM. The central nervous system kept the COM within specific spatial boundaries, referred to as stability limits [40].

The present results for chewing gummy jelly found that there were also significant positive correlations between trunk sway and the displacement of COSP during chewing in the quiet sitting position (Table 3). When the IP model concept is applied to the control of sitting posture, it can be inferred that the present results showed the functional integration of the head-neck region (comparable with the mass of an inverse pendulum) into the neuromuscular system of the body contributing in the feedback control mechanism to control the sway during chewing and resulted in a significant positive correlation between trunk sway and the displacement of COSP during chewing.

Collectively, the results of the present study suggest that there were significant positive correlations between head and trunk sways and between head sway and foot pressure distribution, and between trunk sway and sitting pressure distribution during mastication in the sitting position.

This study has some limitations. Simultaneous measurements of head and trunk sways, and sitting and foot pressure distributions were carried out in the present study to evaluate correlation among head and trunk sways, and sitting and foot distributions during mastication in the sitting position. However, analyses were not done on the motion analysis of 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 interrelationships between stomatognathic function including mastication and body posture in more detail. Furthermore, the analytical methods used in this study did not allow us to elucidate the causal relationship among head and trunk sways, and sitting and foot distributions during mastication in the sitting position. Further strategies for analytical methods should be needed. Despite these limitations, this study clarified there are significant positive correlations between head and trunk sways and between head sway and foot pressure distribution, and between trunk sway and sitting pressure distribution during mastication in the sitting position.

It is unknown to our knowledge whether postural dynamics in sitting behave the same as in standing or walking. This knowledge is critical for people who exhibit deficits in posture control (i.e. cerebral palsy, spinal cord injury, etc.). These populations often require assistance for sitting, standing, and/or functional activities. To begin addressing this problem, we analyzed the correlation among head and trunk sways, and sitting and foot pressure distributions during mastication in the sitting position in healthy adults to further understand the principles of postural control during sitting.

5. Conclusions

There are significant positive correlations between head and trunk sways, between head sway and foot pressure distribution, and between trunk sway and siting pressure distribution during chewing in the sitting position. This has implication for understanding the interrelationship between chewing and posture control system in the sitting position.

Author Contributions: Conceptualization, K.S., N.R.M. and A.Y.; methodology, K.S., N.R.M., T.M.; software, T.M.; validation, K.S., N.R.M., T.M., L.P.C. and A.Y.; writing-original draft preparation, K.S.; writing-review and editing, N.R.M., L.P.C. and A.Y.; supervision, K.S.: project administration, K.S.; funding acquisition, K.S. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board at Graduate School of Dental Medicine Hokkaido University, Sapporo, Japan, under reference number 2019-No.2, dated 18 March 2019.

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: Original data supporting these results are available on reasonable request from the corresponding author.

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Conflicts of Interest: The authors declare no conflict of interest.

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