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Original Article

Improper sitting posture while eating adversely affects maximum tongue pressure

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Abstract *Background/purpose:* Although many studies have examined the efficacy of neck and trunk positioning during eating, few studies have examined how the positioning of the lower extremities affects swallowing function. The purpose of this study was to examine how tongue pressure, which is an important factor during swallowing, is affected by eating postures in bed and wheelchair.

Materials and methods: A total of 43 healthy adults (13 men and 30 women; 29.0 ± 5.9 years) and 33 elderly individuals requiring long-term care (14 men and 19 women; 83.6 ± 7.8 years) participated.

In both healthy and elderly participants, tongue pressure was measured in four different postures: a good and poor postures in bed (postures 1 and 2, respectively), and a good and poor postures in a reclining wheelchair (posture 3 and 4, respectively).

Results: Among the healthy participants, the mean tongue pressure was significantly higher in posture 1 (40.2 ± 7.24 kPa) than in posture 2 (37.6 ± 8.68 kPa) or posture 4 (38.2 ± 8.14 kPa) ($P < 0.05$). Tongue pressure was also significantly higher in posture 3 (41.3 ± 7.75 kPa) than in either posture 2 or 4 ($P < 0.05$).

Among the elderly participants, the median tongue pressure in posture 1 (16.9 kPa; interquartile range [IQR], 9.4—21.6 kPa) was significantly higher than that in posture 2 (14.1 kPa; IQR, 9.2—21.6 kPa). Tongue pressure in posture 3 (18.5 kPa; IQR, 14.2—26.0 kPa) was significantly higher than that in either posture 1 or 2, and posture 4 (15.9 kPa; IQR, 10.6—22.9 kPa).

Conclusion: Posture during eating can potentially affect tongue pressure.

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Introduction

Patients are forced to eat while in bed or in a reclining wheelchair when they have difficulty maintaining posture due to circumstances such as markedly reduced physical strength associated with acute illness or decreased muscle strength associated with sarcopenia. Compared with those who can control their posture and take their meals on a regular chair, patients who have difficulty controlling their posture often have meals while in wheelchair or bed. These patients also have a difficulty keeping the same posture, and it becomes easy for them to have poor posture in the wheelchair or bed.

Improper sitting deteriorates the patient's posture, resulting in sacral sitting. Tilting of the trunk while sitting and sacral sitting increase systemic enhancement of muscle tension, coughing, and difficulty in expectoration; reduce swallowing function; and increase the risk of aspiration. Although many studies have examined the efficacy of neck and trunk positioning during eating, few studies have examined how the positioning of the lower extremities, which are connected to the pelvis, trunk, and neck via the musculoskeletal system, affects swallowing function.

Muscles related to swallowing are found not only in the oral cavity and throat, but also in the anterior and posterior regions of the neck. Muscles related to swallowing in the anterior region of the neck are anchored to the hyoid bone and are associated with elevation of the larynx, whereas muscles related to swallowing in the posterior region of the neck are anchored to the head and neck. Like other muscles, these muscles weaken with age.[1] The omohyoid and sternohyoid muscles are attached to the shoulder girdle and anterior surface of the trunk, respectively; whereas the posterior muscles of the neck are attached to the posterior surface of the trunk and pelvic girdle. The position of the hyoid bone is determined by the balance of muscles attached to it from several different directions and is thus greatly affected by posterior neck muscle tension and posture. Changes in the position of the hyoid bone affect tongue movement, which may therefore also be affected by changes in posture.

Tongue pressure, which is the maximum voluntary pressure with which the area from the tip to the middle of the tongue comes into contact with the hard palate, is said to be closely involved in the oral preparatory and oral transit phases of swallowing. Methods of measuring tongue pressure have been established.[2] According to multiple studies, reduced tongue pressure is associated with the clinical symptoms of dysphagia.[3–5]

Therefore, to demonstrate the importance of maintaining appropriate posture, the present study examined how tongue pressure, which was an important factor during swallowing, was affected by positioning various parts of the body to correct eating posture.

Materials and methods

The present study investigated the effects of good and poor posture, while eating in bed or in a reclining wheelchair on tongue pressure by examining healthy adults with no problems in physical functioning and elderly individuals with reduced physical functioning and diminished capacity to maintain posture and under long-term care.

Participants

The participants were 43 healthy adults (13 men and 30 women; age range, 20–39 years; mean age, 29.0 ± 5.9 years) and 33 elderly individuals requiring long-term care (hereafter referred to as elderly participants; 14 men and 19 women; age range, 67–96 years; mean age, 83.6 ± 7.8 years). They applied for the participation of this study by watching poster and advertise sheet in a hospital in Hiroshima City (Hospital X) from May 1st to September 30th, 2016. Healthy participants, who works and/or attended the clinical training of dysphagia rehabilitation in Hospital X, had normal occlusion and no complaints of dysphagia. Elderly participants were patients hospitalized in the chronic recuperation ward of Hospital X, could visit a dentist in Hospital X, and experienced stroke or other systemic disorders. Although some elderly participants demonstrated cognitive decline, they were capable of temporarily understanding instructions and participating in tongue pressure measurement. The patients who could not sit in the postures that we ordered because of their general conditions were excluded.

The present study was conducted with the approval of the XXX Institutional Review Board with Declaration of Helsinki. Written consent was obtained from the participants prior to the start of the study.

Measurement postures

In both healthy and elderly participants, tongue pressure was measured in four different postures: good and poor postures in bed (posture 1 and 2, respectively), and good and poor postures in a reclining wheelchair (posture 3 and 4, respectively). Good posture in bed or wheelchair was described as placing the center of gravity on the participant's pelvis, with the participant's parietal region on a pillow or headrest and the participant's posture is maintained by own weight and gravity even when the contact area between the participant's body and the bed or wheelchair's backrest is tried to become increased, and the participant's posture was maintained by own weight and gravity basically. On the other hand, the meaning of bad posture was the condition that the participant's weight was put on the sacred bone, trunk became bending position,

and cervical region turned into extension position. This bad posture was said that migration length of laryngeal movement during swallowing became longer than the good posture, continuous activity time of suprahyoid muscles, and this bad situation leaded to the patients' feeling of swallowing difficulty. In the good posture in bed (Posture 1), subjects moved from a supine position to a reclining position, and their postures were then adjusted (Fig. 1). In the poor posture in bed (Posture 2), the misaligned seating of subjects was not corrected after taking a reclining position (Fig. 2). In the good and poor postures in a reclining wheelchair (Posture 3 and Posture 4, respectively), as with the postures in bed, either the postures of subjects were adjusted (Fig. 3), or their misaligned seating was not corrected (Fig. 4).

The postures of participants were adjusted in all cases by the same physical therapist and the same speech therapist who were working together.

Tongue pressure measurement

Tongue pressure was measured with a JMS tongue measurement device (TPM-01; JMS Co Ltd., Hiroshima, Japan) comprising a digital tongue pressure manometer, an attached tube, and a tongue pressure probe (Fig. 5). As in a previous study of ours,[2] the operator held the tongue pressure probe, lightly lodged the hard ring between the participant's maxillary and mandibular anterior teeth while pressing the balloon against the rugae of the hard palate, closed the participant's lips, and instructed the participant to push their palate with their tongue as strongly as possible to compress the balloon for 5—7 s. In each posture, tongue pressure was measured three times, and the mean of these three measurements was used in analysis. First, tongue pressure measurement was practiced several times. Afterwards, tongue pressure was measured in each posture following a five-minute rest.

Statistical analysis

In the healthy participants group, parametric pairwise multiple comparisons were performed using one-way repeated-measures analysis of variance (ANOVA), because the data were normally distributed. Comparisons were then made for each pair in the four postural conditions based on the estimated marginal mean. Additionally, due to presumed multiplicity, P-values and confidence intervals were adjusted using the Bonferroni correction. The results are presented as mean $\pm$ standard error.

In the elderly participants group, non-parametric pairwise multiple comparisons were performed using Friedman's test, because the data in this group were not normally distributed. Post-hoc comparisons were performed using the Wilcoxon signed-rank test. In addition, due to presumed multiplicity, P-values and confidence intervals were adjusted using the Bonferroni correction. The results are presented as medians and interquartile ranges.

As a preliminary analysis, the Shapiro—Wilk test was performed to confirm the normality of the data. Statistical analyses were performed using IBM SPSS Statistics software version 22.0 for Windows (IBM, Chicago, IL, USA). The statistical significance level was set at $< 5\%$.

Results

As a result of sufficient intake of nutrition under guidance from a dietitian and stable physical conditions, none of the elderly subjects demonstrated undernutrition (body mass index (BMI): 13.5—27.7 kg/m^2).

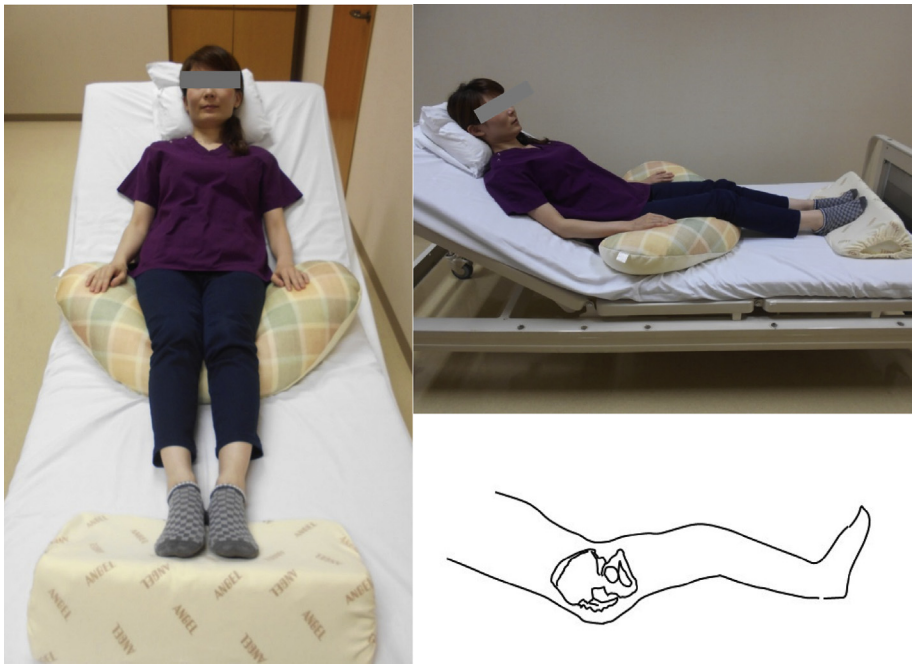

Figure 1 Posture 1; Good posture in bed.

Figure 2 Posture 2; Poor posture in bed.

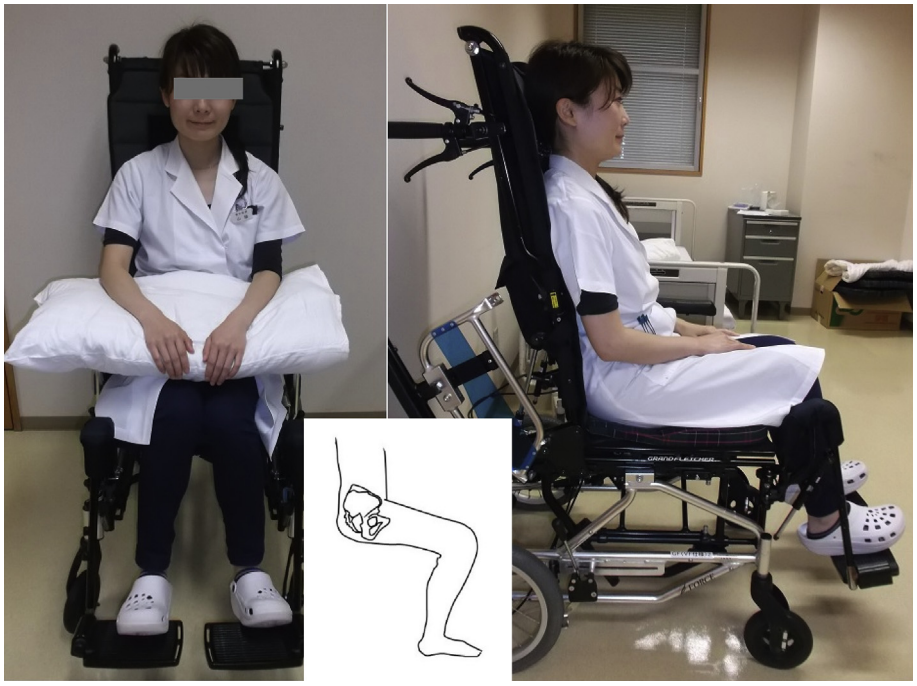

Figure 3 Posture 3; Good posture in a reclining wheelchair.

Among the healthy participants (Table 1), tongue pressure was significantly higher in Posture 1 (mean ± standard error: 40.2 ± 7.24 kPa) than in Posture 2 (37.6 ± 8.68 kPa) or Posture 4 (38.2 ± 8.14 kPa) ($P < 0.05$). Tongue pressure was also significantly higher in Posture 3 (41.3 ± 7.75 kPa) than in either Posture 2 or 4 ($P < 0.05$).

Among the elderly participants, tongue pressure in Posture 1 (16.9 kPa, 9.4—21.6 kPa) was significantly higher than that in Posture 2 (14.1 kPa, 9.2—21.6 kPa). Tongue pressure in Posture 3 (18.5 kPa, 14.2—26.0 kPa) was significantly higher than that in either Posture 1 or 2, and Posture 4 (15.9 kPa, 10.6—22.9 kPa).

Discussion

Among both healthy individuals and elderly patients requiring long-term care, adjustment of posture in bed resulted in a significantly higher tongue pressure. The same results were observed in both groups of subjects with posture in a wheelchair. These results indicate that sitting on the pelvis and placing the feet on a surface enabled participant to exert stable tongue pressure.

Many elderly patients who require long-term care are forced to lie in bed or sit in a wheelchair all day, making it difficult for them to maintain good posture. Therefore, in

Figure 4 Posture 4; Poor posture in a reclining wheelchair.

Figure 5 JMS tongue measurement device ™.

clinical settings, physical therapists, occupational therapists, and speech therapists often use positioning and seating to determine what constitutes a comfortable posture. Similarly, appropriate posture while eating must also be examined in order to enable patients to eat in a stable position. Elderly patients requiring long-term care who have dysphagia often experience difficulty during proactive swallowing function rehabilitation due to worsening of their general condition and progressive cognitive deterioration. Therefore, to enable such patients to eat and to receive nutrition safely and appropriately, their environment must often be adapted to them in terms of posture during eating, utensils, and the physical properties of their food. Postural adjustment is an effective form of compensatory intervention for dysphagia and plays a role in preventing aspiration pneumonia. Improving swallowing function requires consideration of how to improve overall posture, motor function, and activity.

In bed, Fowler's position is considered to be effective for patients with severe dysphagia; however, it is also believed to be associated with a variety of problems such as reduced arousal, loss of appetite, difficulty in recognizing food, coughing, and difficulty with expectoration. When sitting in a wheelchair, the risks of systemic enhancement of muscle tension, sputum, difficulty with expectoration, reduced swallowing function, and aspiration are also elevated by tilting the trunk and sitting on the sacrum. Few studies have examined how the positioning of the lower extremities, which connect to the pelvis, trunk, and neck via the musculoskeletal system, affects swallowing function.

Tongue pressure, though only one aspect of the motor function of the tongue, can easily be assessed and

Table 1 Tongue pressures (kPa) in healthy participants (mean and SD), and elderly participants (median and interquartile range).

Mean (SD)		Median (Interquartile range)
Healthy participants (n = 43)		Elderly participants (n = 33)
Posture 1	40.2 (7.24)[a,b]	16.9 (9.4–21.6)[e,f]
Posture 2	37.6 (8.68)[c]	14.1 (9.2–21.6)[g]
Posture 3	41.3 (7.75)[d]	18.5 (14.2–26.0)[h]
Posture 4	38.2 (8.14)	15.9 (10.6–22.9)

[a] $P < 0.05$; ANOVA between Posture 1 and 2.
[b] $P < 0.05$; ANOVA between Posture 1 and 4.
[c] $P < 0.05$; ANOVA between Posture 2 and 3.
[d] $P < 0.05$; ANOVA between Posture 3 and 4.
[e] $P < 0.05$; Wilcoxon signed-rank test between Posture 1 and 2.
[f] $P < 0.05$; Wilcoxon signed-rank test between Posture 1 and 4.
[g] $P < 0.05$; Wilcoxon signed-rank test between Posture 2 and 3.
[h] $P < 0.05$; Wilcoxon signed-rank test between Posture 3 and 4.

quantified.[2] In medicine and caregiving, tongue pressure measurement can also improve cooperation among staff and yield a synergistic effect. In Europe and the United States, tongue pressure is measured using devices such as a balloon-based tongue pressure manometer (the Iowa Oral Performance Instrument: IOPI);[6] a device, which has been incorporated into the PENTAX swallowing workstation, consisting of three air-filled bulbs which are attached to the midline of the hard palate;[7] and the Madison Oral Strengthening (MOST) Device,[8] which similarly involves five air-filled bulbs that are attached to the hard palate. Now, tongue pressure measurement is becoming the one of the examinations for eating and swallowing disorders. Tongue pressure values measured using the IOPI and using a device manufactured by the KAY Company have been confirmed to be consistent with values yielded by the JMS tongue pressure measurement device.[9] Therefore, tongue pressure, a parameter which assesses one aspect of the motor function of the tongue, and is safe and simple to measure, was used in the present study as an assessment indicator.

The four postures used in the present study are often observed in clinical settings during eating. Posture 1 involved the subject reclining on a bed at a 30° angle with the positions of the trunk and the pelvis corrected by a physical therapist and a speech therapist; whereas Posture 2 is the presumed posture of a person simply lying in bed without the adjustments described earlier. Posture 3 involved transfer from a bed to a wheelchair followed by correction of the positions of the trunk, pelvis, head, and neck; whereas Posture 4 is simply the posture of a person transferred from a bed to a wheelchair without the above adjustments. Unfortunately, Postures 2 and 4 are frequently observed not only among patients receiving home care, but even at medical and caregiving facilities with specialists as staff.

Many studies have been conducted on the positioning of the neck and trunk during eating.[10–12] The efficacy of postural adjustment as a compensatory intervention for dysphagia has also been described in a book.[13] The results of the present study confirm the results of previous studies and reiterate the importance of adjusting posture while eating. These results should be greatly appealing to staff in medical and caregiving settings.

In normal swallowing, esophageal pressure temporarily decreases when the glottis closes during the pharyngeal phase.[14] Reduction in esophageal pressure leads to further increase in the pressure gradient and increase in the pharyngeal pressure with the upper esophageal sphincter as a border, and as a result, is considered to increase bolus propulsion force.[15]

Due to the presence of soft tissues such as muscles and ligaments attached to the femur and pelvic girdle, the lower extremities are affected by changes in the alignment of the pelvic girdle and in turn affect the neck via the trunk. Not planting the lower extremities on the floor or a board as in Postures 2 and 4 results in a state similar to leg raise, which increases esophageal pressure[16] and thus makes food boluses difficult to transport under normal swallowing pressure.[17] When tongue pressure is reduced due to poor posture, as the results of the present study showed, increasing pharyngeal pressure becomes more difficult, and food boluses are consequently predicted to be more difficult to transport. However, this prediction can only be proven using a chronometric assessment which involves a videofluoroscopic swallowing exam. Therefore, further examination is necessary.

The participants varied greatly in terms of age and sex, and were few in number. Therefore, we plan to conduct further examination with a larger number of participants. Additionally, we did not assess the effects on actual eating. Therefore, in the future, we must also examine the amounts of food consumed and improvements in nutrition. However, the results of the present study showed that tongue pressure, which is important during swallowing, is affected by posture. Poor posture, which can be quite easy to overlook in daily life, includes postural misalignment resulting from the incline of a bed or sitting in a wheelchair, which were examined in the present study. The findings of the present study suggest that poor posture may prevent individuals from eating safely and enjoyably. We thus believe that we have demonstrated the importance of postural alignment and the need for specialization in this area.

Posture during eating was shown to potentially affect tongue pressure. Adjusting the position of the trunk in addition to the position of the head was shown to potentially be important in enabling exertion of maximum tongue pressure. Appropriate postural adjustment is advisable for eating safely.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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Not applicable.

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