The effects of head rotation and tilt on oral pressure and muscle activity

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Abstract: We present basic data on head positions that can serve as compensatory interventions for patients with weak tongue and buccinator muscles. We studied 30 Korean adults (15 males, 15 females; mean age, 23 years; range, 20–30 years). A TPS-100 instrument was used to measure tongue and cheek pressures and suprahyoid and buccinator muscle activities at various head rotations and tilts, as independent variables. The data were subjected to one-way analysis of variance and post-hoc (linear contrast) testing. Tongue elevation pressures differed significantly when the head was flexed or extended compared to the neutral position (P<0.01). Suprahyoid muscle activity varied significantly when the head was rotated left or right compared to neutral, or tilted with the tongue elevated (P<0.01). Cheek pressure varied significantly when the head was rotated left or right compared to neutral, or tilted (P<0.01). Both tongue and cheek pressures increased significantly when the head was extended or rotated contralaterally compared to the neutral position. Suprahyoid muscle activity increased when the head was flexed or extended, or contralaterally or ipsilaterally rotated compared to the neutral position. Therefore, we suggest that head rotation or tilting could be used to vary oral pressure and muscle activity.

Key words: Head position, Suprahyoid muscles, Buccinator, Oral pressure, Muscle activity

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Introduction

Tongue muscles change in shape and position during speaking and swallowing [1]. Reductions in tongue muscle strengths trigger problems in both the pharyngeal and oral phases, particularly in terms of poor bolus formation during chewing and swallowing [2]. Tongue strength and accuracy must be improved if such problems develop; the TPS-100 device measures the maximum tongue isometric strength [3, 4]. The buccinator muscle presses the cheek against the teeth, sending food to tooth occlusal surfaces to aid mastication [5].

Muscle strength and co-ordination may improve with training; normal functioning may resume. The strengths and activities of the tongue and buccinator muscles have been studied. However, the relationships between the muscles remain unclear.

Postural techniques improve swallowing safety by controlling food and liquid flow and reducing the aspiration risk. For example, in patients who have suffered cerebrovascular accidents, the head should be turned toward the more-involved side to close off the weaker pharyngeal wall, which makes swallowing safer [6]. In patients with pharyngeal disorders, head rotation toward the paralyzed side reduces the volume of the pyriform sinus, after which the bolus descends down the non-affected side [7], reducing pressure on the upper esophageal sphincter and pressurizing the thyroid cartilage. This in turn promotes the closure of the vocal cords [8]. Oral cancer patients who have undergone partial tongue resection can move a bolus from the mouth to the pharynx by extend-
ing the head [6]. Most stroke patients are at risk of food aspiration because the swallowing reflex is delayed. Head flexion reduces this risk by holding the bolus temporarily in the vallecula [9]. Thus, head rotations and tilts are often prescribed by occupational therapists. However, most prior studies have not explored individual swallowing physiologies. Few Korean studies have biomechanically analyzed oral pressures or suprahyoid/buccinator muscle activities.

Electromyography (EMG) is commonly used to explore movements of the upper and lower limbs. Commencing in 2017, oral pressure-measuring equipment has been increasingly used in clinics. However, no study has yet explored how head position affects oral pressure and associated muscle activities. Preliminary work with healthy adults is essential prior to studying patients with weak tongue or buccinator muscles. We thus gathered basic data on how head positioning might aid such patients, exploring how head rotation and tilt affect oral pressure and muscle activities.

**Materials and Methods**

**Oral pressure measurement**

The TPS-100 device (Cybermedic, Iksan, Korea) is used to analyze and strengthen tongue (front and rear) movements in patients with swallowing disorders. Tongue coordination enhances bolus movement and oral pressurization during deglutition. The device features an air bulb, a tube, a sensor, and a pressure-measuring device. We measured tongue and cheek pressures three times, and calculated averages in hPa (Fig. 1).

**Surface EMG**

We used a surface EMG device (2EM 4D-MT, Relive, Gimhae, Korea) to measure suprahyoid and buccinator muscle activities. The signals were bandpass-filtered, preserving only those of 25–300 Hz. Skin resistance was minimized by removing hair and wiping the skin with an ethanol swab. The interelectrode distance was 1 cm. To measure suprahyoid activity, two electrodes were attached to the skin over the midline of the submental triangle; the ground electrode was placed on the right mastoid process. To assess right buccinator muscle activity, the first electrode was attached lateral to the mouth and the second just lateral to the first (Fig. 1) [10, 11]. To measure the percentage reference voluntary contraction (%RVC), each subject was asked to swallow saliva three times at intervals of 3 minutes.

**Subjects**

We briefed recruited subjects on oral anatomical structures, our experimental plan, and the clinical significance of the study. We enrolled only volunteers. We excluded those with surgical injuries to the tongue and cheek. The subjects included 30 Korean adults (15 males, 15 females; mean age, 23 years; range, 20–30 years). The study was approved by the Dongseo University Institutional Review Board (No. 1041493-A-2019-004) and we obtained informed consent from the subjects.

![Fig. 1. Measurement of oral pressure and muscle activity using TPS-100 and 2EM 4D-MT devices. (A) The air bulb of TPS-100 is located in the oral cavity. The electrodes of 2EM 4D-MT are attached to the suprahyoid and buccinator muscles. (B) The TPS-100 device is consist of an air bulb, a tube, a sensor, and a pressure-measuring device. The patients provided written informed consent for the publication and the use of their images.]
Experimental procedures

Head rotation and tilt served as independent variables. The tongue pressure applied to the front of the palate when the tongue was elevated was measured, and the activities of the suprahyoid and buccinator muscles were recorded. Next, the air bulb was positioned between the right upper and lower first molars and the right buccal mucosa, and cheek pressure and suprahyoid and buccinator muscle activities were recorded during cheek contraction. All tests were run three times at 3-minute intervals. The order of the head positions tested was randomized.

Statistical analysis

The SPSS software ver. 24 (IBM Corp., Armonk, NY, USA) was used to compare all data. The level of statistical significance (α value) was set to 0.05. The following items were analyzed via one-way analysis of variance accompanied by post-hoc (linear contrast) testing: (1) oral pressures of the tongue tip and cheek in the neutral position, and after left and right head rotation; (2) oral pressures of the tongue tip and cheek in the neutral position, and after head flexion and extension; (3) buccinator and suprahyoid muscle activities in the neutral position, and after left and right head rotation; (4) buccinator and suprahyoid muscle activities in the neutral position, and after head flexion and extension.

Results

Oral pressure in relation to head position and tongue elevation

The tongue pressure after tongue elevation did not differ when the head was in the neutral position or rotated to the left or right (F=2.95, P>0.05). When the tongue was elevated, the pressure differed significantly when the head was in the neutral position versus when it was flexed or extended (F=8.25, P<0.05). On post-hoc analysis, the difference when the head was extended compared to the neutral position remained significant (P<0.01), but the difference when the head was flexed did not (P>0.05) (Table 1, Fig. 2).

Oral pressure in relation to head position and cheek constriction

In terms of head rotation with cheek constriction, the cheek pressures differed significantly between the neutral position and upon left or right rotation (F=3.48, P<0.05). On post-hoc analysis, the difference between the neutral position and left rotation was maintained (P<0.01), but the effect of right rotation (compared to no or left rotation) was not (both P>0.05). The cheek pressure differed significantly when the head was in the neutral position versus flexed or extended (F=10.34, P<0.01). Post-hoc analysis showed that the differ-

Table 1. Oral pressure according to head position and oral movement (n=30)

| Head Position | Tongue Elevation | Cheek Compression |
|---------------|------------------|------------------|
| LR | 216.98±143.62 | 130.55±110.84 |
| RR | 218.07±94.39 | 98.59±50.77 |
| NH | 139.46±57.26 | 72.84±24.37 |
| HF | 213.44±118.86 | 102.11±55.61 |
| HE | 331.22±233.63 | 144.65±63.79 |

Values are presented as mean±SD (hPa). LR, left rotation; RR, right rotation; NH, neutral head; HF, head flexion; HE, head extension.
ence upon extension (compared to neutral/flexed) ($P<0.05$) was maintained, but the difference upon flexion was not (both $P>0.05$) (Table 1, Fig. 3).

**Buccinator muscle activity in relation to head position and tongue elevation**

When the head was rotated with the tongue elevated, no significant difference in buccinator muscle activity between the neutral and left- or right-rotated positions was evident ($F=0.33, P>0.05$). In terms head flexion or extension with the tongue elevated, the buccinator muscle activity did not vary ($F=0.74, P>0.05$) (Table 2, Fig. 4).

**Buccinator muscle activity in relation to head position and cheek constriction**

No significant difference in buccinator muscle activity was noted when the head was in the neutral position versus rotated left or right ($F=3.02, P>0.05$). No significant difference in buccinator muscle activity was noted when the head was in the neutral position versus extended or flexed ($F=1.27, P>0.05$) (Table 2, Fig. 4).

**Suprathyroid muscle activity in relation to head position and tongue elevation**

In terms head rotation with the tongue elevated, the supra-

**Suprathyroid muscle activity in relation to head position and cheek constriction**

The suprathyroid muscle activity differed significantly ($F=4.29, P<0.05$) when the head was in the neutral position versus rotated left or right ($P<0.05$). The suprathyroid muscle activity differed significantly ($F=4.30, P<0.05$) when the head was in the neutral position versus flexed or extended ($P<0.05$) (Table 3, Fig. 7).

**Discussion**

The tongue is critical in terms of food movement, and the buccinator muscles of the cheek serve as lateral retainers that prevent food particles from falling into the sulcus between the jaw and cheek [12]. Postural interventions for those ex-

Table 2. Muscle activity of the buccinator according to head position and oral movement (n=30)

|                  | LR                  | RR                  | NH                  | HF                  | HE                  |
|------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Tongue elevation | 123.86±133.66       | 110.46±78.25        | 100.48±52.92        | 119.88±56.64        | 127.02±101.78       |
| Cheek compression| 308.70±213.86       | 206.54±128.67       | 204.69±128.42       | 286.29±196.92       | 252.27±174.74       |

Values are presented as mean±SD (%RVC). LR, left rotation; RR, right rotation; NH, neutral head; HF, head flexion; HE, head extension.

![Fig. 4. Muscle activity of the buccinator according to head position with tongue elevation. %RVC, percentage reference voluntary contraction; LR, left rotation; RR, right rotation; NH, neutral head; HF, head flexion; HE, head extension.](https://doi.org/10.5115/acb.19.191)

![Fig. 5. Muscle activity of the buccinator according to head position with cheek constriction. %RVC, percentage reference voluntary contraction; LR, left rotation; RR, right rotation; NH, neutral head; HF, head flexion; HE, head extension.](https://doi.org/10.5115/acb.19.191)
hibiting swallowing impairments have traditionally sought to functionally modify the tongue and cheek biomechanics [13]. EMG has been used to aid patients with chronic dysphagia, affording useful biofeedback on oral muscle tone, thus improving swallowing [14]. We found that the tongue and cheek pressures increased significantly when the head was extended; specifically, the cheek pressure increased on contralateral (left) head rotation. When the muscle fibers and soft tissues are stretched, the tongue and cheek pressures change; passive pressure develops when the muscle and elastic components are stretched beyond their resting lengths [15]. If a patient exhibits low tongue or cheek tension, head extension or contralateral rotation is helpful. Passive tension induced by stretching increases internal pressure, and active tensioning on contraction enhances EMG activity. Suprathyroid muscle activity increases on ipsilateral (right) rotation because the pyriform sinus volume is reduced and the bolus descends on the opposite side; the suprathyroid muscles contract [16]. These muscles elevate the hyoid either anteriorly or posteriorly. When the swallowing response is triggered, the tongue base rises to direct the bolus into the pharynx and the hyoid becomes elevated and moves anteriorly [17]. We found that the suprathyroid muscle activity was higher when the head was flexed or extended, rather than neutral. Head flexion directly moves the hyoid upward and forward because of the length-tension relationship; the force produced by the contractile elements (lying parallel to the elastic components) of the suprathyroid tendons increases [18]. Head extension widens the laryngeal vestibule and narrows the vallecular space; physiological difficulties may follow [17]. However, if oral transfer is impaired in patients who have undergone supraglottic resection, head extension is a useful postural remedy [19]. In dysphagic patients, head flexion expands the vallecular space, pushes the tongue base toward the pharynx, and protects the epiglottis. Therefore, head flexion is frequently used during deglutition training [20].

We found that the suprathyroid muscle activity increased upon contralateral (left) head rotation. Such rotation would be less favored than the neutral position in healthy adults, who use the suprathyroid muscles symmetrically. However, many stroke patients use the perioral muscles asymmetrically [21]. In left hemiplegic patients, left rotation would increase right-side muscle activity and decrease left-side muscle activity. Thus, head rotation would compensate for the suprathyroid muscle weakness of the involved side. Turning the head toward that side eliminates that region of the pharynx from muscle activation, rendering the non-impaired side more active [22].

The buccinator muscle is used to position food for chew-

### Table 3. Muscle activity of the suprathyoid according to head position and oral movement (n=30)

|          | LR       | RR       | NH       | HF       | HE       |
|----------|----------|----------|----------|----------|----------|
| Tongue elevation | 75.25±7.85 | 97.71±6.69 | 41.05±10.28 | 124.71±9.24 | 197.45±61.69 |
| Cheek compression | 127.47±116.85 | 119.95±104.71 | 51.91±29.75 | 157.91±161.55 | 164.62±178.27 |

Values are presented as mean±SD (%RVC). LR, left rotation; RR, right rotation; NH, neutral head; HF, head flexion; HE, head extension.

![Fig. 6. Muscle activity of the suprathyoid according to head position with tongue elevation (**P<0.01). %RVC, percentage reference voluntary contraction; LR, left rotation; RR, right rotation; NH, neutral head; HF, head flexion; HE, head extension.](https://doi.org/10.5115/acb.19.191)

![Fig. 7. Muscle activity of the suprathyoid according to head position with cheek constriction. %RVC, percentage reference voluntary contraction; LR, left rotation; RR, right rotation; NH, neutral head; HF, head flexion; HE, head extension.](https://www.acbjournal.org)
ing and to control the bolus. We found that the cheek pressure increased significantly on contralateral head rotation and extension, compensating for buccinator weakness. Cheek pressure is influenced by cheek space between fixed part (teeth, alveolar bone) and unfixed part (buccinator muscle). Head position (contralateral rotation, extension) reduced the space and pressure was increased consequently. However, there were no significant changes in the buccinator muscle activity. We assumed the origin and insertion of the muscle was hardly affected by head position [5].

We measured oral pressure and suprahyoid and buccinator muscle activities related to head position. Both the tongue and cheek pressure increased on head extension or contralateral rotation. The suprahyoid muscle activity increased upon head flexion and extension, and contralateral and ipsilateral rotation. In conclusion, head extension or contralateral rotation would aid those with poor tongue or cheek pressure. Head flexion/extension, or contralateral/ipsilateral rotation, increase suprahyoid muscle activity; the optimal head position will vary individually in patients with functional dysphagia or who have undergone supraglottic resection.

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Conceptualization: THK. Data acquisition: THK, DHK. Data analysis or interpretation: THK. Drafting of the manuscript: THK, DHK. Critical revision of the manuscript: THK, DHK. Approval of the final version of the manuscript: all authors.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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Arch Oral Biol 1999;44:557-73.

16. Burbidge AS, Cichero JA, Engmann J, Steele CM. "A day in the life of the fluid bolus": an introduction to fluid mechanics of the oropharyngeal phase of swallowing with particular focus on dysphagia. Appl Rheol 2016;26:64525.

17. Walton J, Silva P. Physiology of swallowing. Surgery 2018;36:529-34.

18. Okeson JP. Management of temporomandibular disorders and occlusion: e-book. 7th ed. St. Louis, MO: Elsevier Health Sciences; 2014.

19. Cohen EE, LaMonte SJ, Erb NL, Beckman KL, Sadeghi N, Hutcheson KA, Stubblefield MD, Abbott DM, Fisher PS, Stein KD, Lyman GH, Pratt-Chapman ML. American Cancer Society head and neck cancer survivorship care guideline. CA Cancer J Clin 2016;66:203-39.

20. Ertekin C, Keskin A, Kiylioglu N, Kirazli Y, On AY, Tarlaci S, Aydogdu I. The effect of head and neck positions on oropharyngeal swallowing: a clinical and electrophysiologic study. Arch Phys Med Rehabil 2001;82:1255-60.

21. Schimmel M, Leemann B, Christou P, Kiliaridis S, Herrmann FR, Muller F. Quantitative assessment of facial muscle impairment in patients with hemispheric stroke. J Oral Rehabil 2011;38:800-9.

22. Logemann JA. Treatment of oral and pharyngeal dysphagia. Phys Med Rehabil Clin N Am 2008;19:803-16.