Japanese Journal of Comprehensive Rehabilitation Science (2016)

Original Article

Retest reliability of ultrasonic geniohyoid muscle measurement

Sayako Shimizu, MD,[1] Kozo Hanayama, MD, PhD,[1] Hiromichi Metani, MD, PhD,[1] Takefumi Sugiyama, MD,[1] Hiromasa Abe, MD, PhD,[1] Sosuke Seki, MD, PhD,[1] Takashi Hiraoka, MD, PhD,[1] Akio Tsubahara, MD, PhD[1]

[1]Department of Rehabilitation Medicine, Kawasaki Medical School, Kurashiki, Okayama, Japan

ABSTRACT
Shimizu S, Hanayama K, Metani H, Sugiyama T, Abe H, Seki S, Hiraoka T, Tsubahara A. Retest reliability of ultrasonic geniohyoid muscle measurement. Jpn J Compr Rehabil Sci 2016; 7: 55−60.
Objective: Ultrasonography can be used to assess both the morphology and movement of the muscles of deglutition. This study investigated the intratester, intertester, and retest reliability of ultrasonic assessments of the suprahyoid muscle group.
Methods: Three testers performed ultrasonographic measurements of the length and area of the geniohyoid muscle in 10 healthy adults, and the contraction ratio during swallowing. Results were compared using intraclass correlation coefficients (ICCs) to determine intratester, retest, and intertester reliabilities.
Results: Intratester and retest reliabilities were very good, with ICCs ≥0.8 for all assessment parameters. In intertester reliability, ICCs were ≥0.8 for geniohyoid muscle length and area during swallowing and ≥0.6 for geniohyoid muscle length at rest and contraction ratio.
Discussion: These results indicate high reliability of this assessment method for assessments made by the same individual, with reliability of the method remaining high for assessments performed at intervals.
Key words: ultrasonography, geniohyoid muscle, retest reliability, intertester reliability

Introduction

The suprahyoid muscles play an extremely important role in swallowing, moving the hyoid bone anterosuperiorly, and contributing to epiglottic inversion and wide opening of the esophageal orifice [1−3]. These muscles are generally assessed using videofluorography to measure vertical and horizontal hyoid bone movement [4−6]. X-rays can thus be used to assess muscle function by measuring bone movement, but cannot be used to assess the thickness, cross-sectional area, or other aspects of muscle morphology. Computed tomography (CT), magnetic resonance imaging (MRI), or other imaging modalities can be used for this purpose, but do not provide a means of assessing muscle movement in swallowing [7, 8]. Use of 3-dimensional CT for assessing swallowing movements has recently been reported, but involves limitations in available examination facilities and subject postures, and problems relating to radiation exposure [8, 9].

In contrast, ultrasonography permits ready delineation of muscles and bones in the submental region and assessment of their movements during swallowing. This modality is also minimally invasive and relatively inexpensive, does not limit subject posture, and is suitable for bedside use.

A report of ultrasonographic assessment of swallowing function by Shawker et al. in 1984 [10] led to a number of reports on related techniques and methods [11−25], but little has been reported on reliability, which is essential for both research and clinical applications. For methods of assessment that have not been standardized, reliability must be investigated prior to clinical application. Although Macrae et al. [15] reported high levels of intratester and intertester reliability for ultrasonic assessment of the geniohyoid muscle length and shortening ratio during swallowing, reliability was determined with the testers all measuring the same sonogram and thus did not include ultrasonographic reproducibility. Hsiao et al. [13] reported high intra- and intertester reliabilities in the use of ultrasound to measure the distance from the hyoid bone to the mandible in swallowing, but did not include determinations of reliability on retesting. Retesting is a means of investigating the stability of a test method, by

Correspondence:Sayako Shimizu, MD
Department of Rehabilitation Medicine, Kawasaki Medical School, 577 Matsushima, Kurashiki, Okayama 701−0192, Japan.
E-mail: s-shimizu@med.kawasaki-m.ac.jp
Accepted: July 7, 2016
This study was supported by JSPS KAKENHI Grant Number 15K01402. There is no conflict of interest in this study.

performing the same test at intervals in the same subjects, and this value is important in terms of assessment reproducibility. In many cases, assessment of swallowing function is repeated over time for the same patient to investigate changes in signs or symptoms or the effects of training.

The present study was performed to investigate the intratester, intertester, and retest reliabilities for ultrasonographic assessment of suprahyoid muscles.

Methods

1. Subjects

The subjects in this study comprised 10 healthy volunteers (5 men, 5 women; age, 21−27 years; mean age, 21.7 years) with no history of eating or swallowing disorder, respiratory dysfunction, or otorhinolaryngologic disease. All subjects received a full explanation of the study and agreed to participate prior to enrolment.

This study was approved by the Research Ethics Committee of Kawasaki Medical School and Hospital (Approval No. 1917).

2. Testers

Three testers participated in this study. Tester 1 was a physician with 7 years of clinical experience, and Testers 2 and 3 were speech-language-hearing therapists with 7 and 10 years of clinical experience, respectively. All three testers received a full explanation and sufficient practice in performing the assessment method in advance of study initiation.

3. Ultrasonography

Ultrasonography was performed based on the methods described by Macrae et al. [15], with minor modifications. The subject assumed a comfortable posture on a reclining bed with a backrest angle of 30°. A pillow measuring 30×44×7 cm was placed in contact with the subject's shoulder to stabilize the head and neck.

A 2- to 5-MHz convex probe (SonoSite M turbo; FUJIFILM SonoSite, Tokyo, Japan) was placed in alignment with the midline of the floor of the mouth and perpendicular to the lower chin surface of the subject (Figure 1). The probe was positioned at a height that enabled delineation of the hyoid bone while avoiding contact between the face of the probe and the thyroid cartilage. Ultrasound gel was liberally applied and care was taken to avoid compression of submental soft tissues. The hyoid bone and mandible accompanying the acoustic shadow together with the adhering geniohyoid muscle at rest were delineated in the midsagittal plane in B-mode (frequency, 3.5 MHz) on a single screen (Figure 1a), recorded three times, and saved as still images. With the submental ultrasonographic probe remaining in place, the subject next swallowed 3 mL of apple jello (Engelead®; Otsuka Pharmaceutical Factory, Tokushima, Japan) at room temperature. The swallowing was tipper-type and was performed on command. Contraction of the geniohyoid muscle and movement of the hyoid bone during swallowing were clearly observable during swallowing (Figure 1b). Swallowing was performed, recorded, and saved as videos three times.

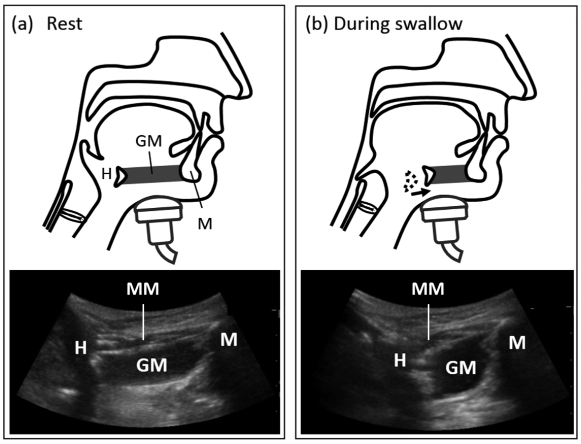

Figure 1. Ultrasonic probe positions (upper frame) and ultrasonic image of the midsagittal plane (lower frame). (a) At rest; (b) at maximum geniohyoid muscle contraction in swallowing. H, hyoid bone; M, mandible; GM, geniohyoid muscle; MM, mylohyoid muscle.
With the ultrasonic probe aligned with the mouth-floor midline and perpendicular to the submental surface, the hyoid bone (H) and mandible (M) are delineated by their acoustic shadows. Between the hyoid bone and mandible, the mylohyoid muscle (MM) is seen in the surface layer and the geniohyoid muscle (GM) in the deep layer.

The three testers each performed ultrasonography for all 10 subjects. Tester 1 repeated the procedure for the same subjects 1 week later. The measurement results obtained in the assessments by any one of the three testers were carefully controlled to prevent disclosure to the other two testers, and the results obtained by a tester in the first session of assessments were kept unknown to that tester through the second series.

4. Data reduction

Parameter measurements were made on a personal computer using the saved ultrasonographic images. All of the following video analyses and measurements were performed by Tester 1. Data processing was performed on the same day as the ultrasonography. Image J version 1.43 software (NIH, Bethesda, MD, USA) was used for measurements, and videos were played and edited at 15 frames/s using Adobe Premiere Elements version 4.0® software (Adobe Systems Inc., San Jose, CA, USA).

4.1 Length of the geniohyoid muscle at rest

Still images of the rest state were used. Length of

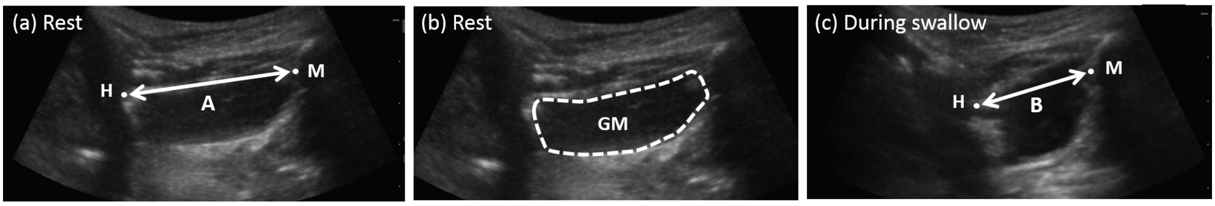

Figure 2. Submental ultrasonic still images: (a), (b) at rest and (c) at maximum geniohyoid muscle contraction. The images show: measurement landmarks in the regions of the surface layer attachment of the geniohyoid muscle to the hyoid bone (H) and mandible (M); the distance between these two points, taken as the length of the geniohyoid muscle at rest (A) and at maximum contraction (B); and the area of geniohyoid muscle at rest, as the region (dashed line) enclosing the muscle and fascial membrane boundary. H, hyoid bone; M, mandible; GM, geniohyoid muscle.

the geniohyoid muscle was measured as the distance between landmarks on the hyoid bone and mandible in their respective surface-layer regions of geniohyoid muscle attachment (Figure 2a).

4.2 Area of geniohyoid muscle at rest

The area enclosing the muscle and fascial boundary of the geniohyoid muscle was measured using still images of the rest state (Figure 2b).

4.3 Length of geniohyoid muscle in swallowing

The time of maximal geniohyoid muscle contraction was identified by frame-advance playback of the swallowing video, and the image at that time was extracted as a still image (Figure 2c) and used to measure the distance between landmark points on the hyoid bone and the mandible.

4.4 Geniohyoid muscle contraction ratio

With the length of the geniohyoid muscle at rest and at the time of maximal contraction in swallowing denoted by A and B, respectively, the contraction ratio was calculated as $(A - B)/(A \times 100)$.

5. Analysis

Reliability was determined using intraclass correlation coefficients (ICCs). Intratester reliability was determined from the values of three measurements in the first session by Tester 1, as ICC (1,1). Retest reliability was determined from the values obtained in the first and second sessions of measurement by Tester 1, as ICC (1,1). Intertester reliability was determined from the results of measurements by the three testers, as ICC (2,1). Each measurement value was obtained as the average of three measurements. The level of significance was 0.05. All statistical analysis was performed using SPSS Statistics version 22 (IBM, New York City, NY, USA).

Results

Clear ultrasonographic images were obtained for all subjects. Interference of the ultrasonic probe with larynx elevation in swallowing was eliminated in cases where this occurred by increasing the amount of ultrasound gel applied.

Intratester reliability (single-measure ICC) was ≥0.9 for geniohyoid muscle length at rest and in swallowing, shortening ratio, and area at rest (Table 1). Retest reliability was ICC=0.83 for the geniohyoid muscle length at rest, ICC=0.87 for the geniohyoid muscle area at rest, and ICC≥0.9 for all other parameters (Table 2).

Intertester reliability was ICC=0.66 for geniohyoid muscle length at rest, ICC=0.87 for geniohyoid muscle length in swallowing, ICC=0.68 for geniohyoid muscle shortening ratio, and ICC=0.88 for the geniohyoid muscle area at rest (Table 3).

Discussion

In ICC for assessing reliability in continuous data, ICC ≥0.6 is considered necessary and ICC ≥0.8 is considered preferable [26]. In the present study, intratester reliability for the assessment method was ≥0.9 for all assessment parameters and thus extremely good, showing that the reliability is high in single measurements by the same tester. Intratester reliability on retesting was also found to be good (ICC ≥0.8) and

Table 1. Intratester reliability (Tester 1).

	ICC	95% CI	*p* Value
GM length at rest	0.916	0.742–0.983	0.000
GM length at maximum contraction	0.938	0.829–0.984	0.000
GM contraction ratio	0.938	0.802–0.988	0.000
GM area at rest	0.941	0.812–0.988	0.000

GM, geniohyoid muscle.

therefore in the category of "almost perfect reliability". This shows that the reliability of the method remains high when assessments are performed at intervals, which is highly important in clinical applications.

An intertester reliability of ICC ≥0.6, a level known as "substantial reliability", was found for the assessment method and was thus lower than the intratester and retest reliabilities. This indicates an overall decrease in the reliability of this assessment method when performed by different testers. Performance of multiple assessments by the same tester is thus desirable.

Further increases in the reliability of this method will require consistency in subject posture, type and amount of simulation food, and swallowing pattern. Changes in subject posture during swallowing (e.g., sitting or recumbent position and cervicofacial angle or rotation) are known to affect the results of swallowing assessment [14, 21, 27−30]. In some reports, head, neck, and ultrasonic probe positions have been fixed during swallowing assessment with ultrasound [20, 22, 25], but immobilization of the head and neck region may strongly affect swallowing movements. Furthermore, use of an immobilization system is generally impracticable in clinical settings. In the present study, which used a reclining bed as a backrest together with a pillow rather than an immobilization system, high reliability was obtained when multiple assessments were performed by the same tester. For application to bedridden patients, similar consideration must be given to fixing the backrest angle and pillow type.

Swallowing movements have also been reported to vary with the amount, food texture, taste, and temperature of the food bolus to be eaten and swallowed [31, 32]. The present study was performed throughout using the same jelly type, amount, and temperature.

Finally, swallowing movements are known to vary with swallowing pattern. For example, tongue pressure and hyoid bone and laryngeal movements reportedly differ between command swallowing and non-command swallowing, and between tipper and dipper types of oral swallows [33, 34]. Throughout the present study, the oral phase was tipper-type with swallowing initiation on command. This consistency presumably tended to increase assessment reliability.

Comparisons between the assessment reliabilities found for the different parameters are also of interest. Intertester ICCs were lower for geniohyoid muscle length at rest and contraction ratio in swallowing than for the other parameters. This was presumably related to the absence of a system to fix head and neck positions in the present study, and differences between testers in the angle of the subject's neck region during testing may thus have affected length of the geniohyoid muscle at rest and the contraction ratio. In contrast, good intertester reliability was found for assessments of geniohyoid muscle area at rest and length at maximum shortening. The high reliability found for muscle area suggests that large variations in muscle area were effectively precluded by variations in muscle thickness accompanying the variation in muscle length. The high reliability found for geniohyoid muscle length at maximum shortening suggests that with fixed food types and amounts, reproducibility can be obtained for movements of swallowing-related muscles. In summary, intertester reliability was generally found to be inferior to intratester reliability, but the ICCs of ≥0.8 for geniohyoid muscle area at rest and length at maximum contraction indicate that high reliability is retained for these parameters despite application of the assessment method by different testers.

In many cases, assessment of suprahyoid muscle

Table 2. Retest reliability (Tester 1).

	ICC	95% CI	*p* Value
GM length at rest	0.834	0.491−0.955	0.000
GM length at maximum contraction	0.970	0.884−0.993	0.000
GM contraction ratio	0.950	0.791−0.990	0.000
GM area at rest	0.869	0.580−0.965	0.000

GM, geniohyoid muscle.

Table 3. Intertester reliability (Testers 1−3).

	ICC	95% CI	*p* Value
GM length at rest	0.658	0.304−0.889	0.000
GM length at maximum contraction	0.869	0.665−0.965	0.000
GM contraction ratio	0.677	0.327−0.904	0.000
GM area at rest	0.880	0.627−0.970	0.000

GM, geniohyoid muscle.

mass is performed by CT. Feng et al. [7] reported measurement of the cross-sectional area of the geniohyoid muscle by CT, and geniohyoid muscle atrophy was associated with aging and aspiration. In contrast, reports on the use of ultrasonography for measurement of muscle mass relating to swallowing have generally focused on the tongue, with little investigation of the peripheral muscles associated with the hyoid bone. This may be related to the difficulty of identifying the bellies of these muscles because of their small size despite the relative ease of muscle delineation by ultrasonography, and also to the difficulty of placing the probe vertically in alignment with the muscle fibers. Macrae et al. [14] reported that the cross-sectional area of the anterior belly of the digastric muscle can be measured using ultrasound, that the results correlated closely with measurement on MRI, and that muscle cross-sectional areas varied with posture, but did not include investigations of assessment reliability. Feng et al. [21] measured the cross-sectional area of the geniohyoid muscle using ultrasound, again without investigating assessment reliability.

The present study measured the area of the geniohyoid muscle in the median sagittal plane. Identification was more readily obtained than measurement of the cross-sectional area. The assessment reliability for this parameter was found to be high, and clinical application as a method for determining the mass of the suprahyoid muscles seems likely to be effective.

One limiting factor in the present study was the incomplete verification of the measurement methods. Hsiao et al. [13] reported a high correlation between ultrasonographic and videofluorographic measurements of the distance from the hyoid bone to the mandible in 12 stroke patients. Ultrasonographic measurement of this distance in the present study appears valid, but definitive verification awaits further study.

Further studies will be necessary to clarify means of increasing the intertester assessment reliability. We are also contemplating extending this method to measurement of the speed of hyoid bone movement in swallowing as an indicator of muscle performance, and echo intensity as an indicator of disuse muscle atrophy.

Acknowledgments

I would like to express the deepest appreciation to Yasuhiro Miyazaki and Masahiro Ikeno.

References

1. Steele CM, Bailey GL, Chau T, Molfenter SM, Oshalla M, Waito AA, et al. The relationship between hyoid and laryngeal displacement and swallowing impairment. Clin Otolaryngol 2011; 36: 30−6.
2. Kendall KA, Leonard RJ. Hyoid movement during swallowing in older patients with dysphagia. Arch Otolaryngol Head Neck Surg 2001; 127: 1224−9.
3. Ekberg O, Sigurjónsson SV. Movement of the epiglottis during deglutition. A cineradiographic study. Gastrointest Radiol 1982; 7: 101−7.
4. Paik N, Kim SJ, Lee HJ, Jeon JY, Lim JY, Han TR. Movement of the hyoid bone and the epiglottis during swallowing in patients with dysphagia from different etiologies. J Electromyogr Kinesiol 2008; 18: 329−35.
5. Logemann JA, Pauloski BR, Rademaker AW, Colangelo LA, Kahrilas PJ, Smith CH. Temporal and biomechanical characteristics of oropharyngeal swallow in younger and older men. J Speech Lang Hear Res 2000; 43: 1264−74.
6. Kim Y, McCullough GH. Maximum hyoid displacement in normal swallowing. Dysphagia 2008; 23: 274−9.
7. Feng X, Todd T, Lintzenich CR, Ding J, Carr JJ, Ge Y, et al. Aging-related geniohyoid muscle atrophy is related to aspiration status in healthy older adults. J Gerontol A Biol Sci Med Sci 2013; 68: 853−60.
8. Inamoto Y, Kagaya H, Saitoh E, Kanamori D, Shibata S, Fujii N, et al. Inter-rater and intra-subject reliability for the evaluation of swallowing kinematics using 320-row area detector computed tomography. Jpn J Compr Rehabil Sci 2012; 3: 59−65.
9. Fujii N, Inamoto Y, Saitoh E, Baba M, Okada S, Yoshioka S, et al: Evaluation of swallowing using 320-detector-row multislice CT. Part I: single- and multiphase volume scanning for three-dimensional morphological and kinematic analysis. Dysphagia 2011; 26: 99−107.
10. Shawker TH, Sonies B, Hall TE, Baum BF. Ultrasound analysis of tongue, hyoid, and larynx activity during swallowing. Invest Radiol 1984; 19: 92−6.
11. Huang YL, Hsieh SF, Chang YC, Chen HC, Wang TG. Ultrasonographic evaluation of hyoid-larynx approximation in dysphagic stroke patients. Ultrasound Med Biol 2009; 35: 1103−8.
12. Kuhl V, Eicke BM, Dieterich M, Urban PP. Sonographic analysis of laryngeal elevation during swallowing. J Neurol 2003; 250: 333−7.
13. Hsiao MY, Chang YC, Chen WS, Chang HY, Wang TG. Application of ultrasonography in assessing oropharyngeal dysphagia in stroke patients. Ultrasound Med Biol 2012; 38: 1522−8.
14. Macrae PR, Jones RD, Myall DJ, Melzer TR, Huckabee ML. Cross-sectional area of the anterior belly of the digastric muscle: comparison of MRI and ultrasound measures. Dysphagia 2013; 28: 375−80.
15. Macrae PR, Doeltgen SH, Jones RD, Huckabee ML. Intra- and inter-rater reliability for analysis of hyoid displacement measured with sonography. J Clin Ultrasound 2012; 40: 74−8.
16. Yabunaka K, Konishi H, Nakagami G, Sanada H, Iizaka S, Sanada S, et al. Ultrasonographic evaluation of geniohyoid muscle movement during swallowing: a study on healthy adults of various ages. Radiol Phys Technol 2012; 5: 34−9.
17. Yabunaka K, Sanada H, Sanada S, Konishi H, Hashimoto

T, Yatake H, et al. Sonographic assessment of hyoid bone movement during swallowing: a study of normal adults with advancing age. Radiol Phys Technol 2011; 4: 73−7.
18. Sonies BC, Wang C, Sapper DJ. Evaluation of normal and abnormal hyoid bone movement during swallowing by use of ultrasound duplex-Doppler imaging. Ultrasound Med Biol 1996; 22: 1169−75.
19. Chi-Fishman G, Sonies BC. Effects of systematic bolus viscosity and volume changes on hyoid movement kinematics. Dysphagia 2002; 17: 278−87.
20. Chi-Fishman G, Sonies BC. Kinematic strategies for hyoid movement in rapid sequential swallowing. J Speech Lang Hear Res 2002; 45: 457−68.
21. Feng X, Cartwright MS, Walker FO, Bargoil JH, Hu Y, Butler SG. Ultrasonographic evaluation of geniohyoid muscle and hyoid bone during swallowing in young adults. Laryngoscope 2015; 125: 1886−91.
22. Tamura F, Kikutani T, Tohara T, Yoshida M, Yaegaki K. Tongue thickness relates to nutritional status in the elderly. Dysphagia 2012; 27: 556−61.
23. Butler SG, Stuart A, Leng X, Wilhelm E, Rees C, Williamson J, et al. The relationship of aspiration status with tongue and handgrip strength in healthy older adults. J Gerontol A Biol Sci Med Sci 2011; 66: 452−8.
24. Van Den Engel-Hoek L, Van Alfen N, De Swart BJ, De Groot IJ, Pillen S. Quantitative ultrasound of the tongue and submental muscles in children and young adults. Muscle Nerve 2012; 46: 31−7.
25. Peng CL, Jost-Brinkmann PG, Miethke RR, Lin CT. Ultrasonographic measurement of tongue movement during swallowing. J Ultrasound Med 2000; 19: 15−20.
26. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977; 33: 159−74.
27. Sia I, Carvajal P, Carnaby-Mann GD, Crary MA. Measurement of hyoid and laryngeal displacement in video fluoroscopic swallowing studies: variability, reliability, and measurement error. Dysphagia 2012; 27: 192−7.
28. Ekberg O. Posture of the head and pharyngeal swallowing. Acta Radiol Diagn 1986; 27: 691−6.
29. Ertekin C, Keskin A, Kiylioglu N, Kirazli Y, On AY, Tarlaci S, et al. The effect of head and neck positions on oropharyngeal swallowing: A clinical and electrophysiologic study. Arch Phys Med Rehabil 2001; 82: 1255−60.
30. Castell JA, Castell DO, Schultz AR, Georgeson S. Effect of head position on the dynamics of the upper esophageal sphincter and pharynx. Dysphagia 1993; 8: 1−6.
31. Butler SG, Postma GN, Fischer E. Effects of viscosity, taste, and bolus volume on swallowing apnea duration of normal adults. Otolaryngol Head Neck Surg 2004; 131: 860−3.
32. Gatto AR, Cola PC, Silva RG, Spadotto AA, Ribeiro PW, Schelp AO, et al. Sour taste and cold temperature in the oral phase of swallowing in patients after stroke. Codas 2013; 25: 163−7.
33. Dodds WJ, Taylor AJ, Stewart ET, Kern MK, Logemann JA, Cook IJ. Tipper and dipper types of oral swallows. AJR Am J Roentgenol 1989; 153: 1197−9.
34. Daniels SK, Foundas AL. Swallowing physiology of sequential straw drinking. Dysphagia 2001; 16: 176−82.