Journal of Food and Nutrition Research, 2019, Vol. 7, No. 7, 543-548
Available online at http://pubs.sciepub.com/jfnr/7/7/9
Published by Science and Education Publishing
DOI:10.12691/jfnr-7-7-9

The Effects of Contrast Medium on Food Viscosity and Muscle Activity of the Submental Muscle Group

Jong-Hyun Park[1,3], So Young Ahn[2], Min-Woo Choi[1], Bum-Keun Kim[4], Kang Hee Cho[1,2,5,*]

[1]Institute of Biomechanical Engineering, Chungnam National University, Daejeon, South Korea
[2]Department of Rehabilitation Medicine, Chungnam National University Hospital, Daejeon, South Korea
[3]Department of Rehabilitation Medicine, The Graduate School, Chungnam National University, Daejeon, South Korea
[4]Research Group of Food Processing, Research Division of Strategic Food Technology, Jeollabuk-do, South Korea
[5]Department of Rehabilitation Medicine, School of Medicine, Chungnam National University, Daejeon, South Korea
*Corresponding author: khcho@cnu.ac.kr

Received June 17, 2019; Revised July 21, 2019; Accepted July 29, 2019

Abstract A videofluoroscopic swallowing study (VFSS) is utilized for diagnosis of dysphagia or to determine dysphagia diets. For the evaluation of swallowing function via VFSS, contrast medium needs to be added to the food. The purpose of this study was to assess the effects of contrast medium on food viscosity and the muscle activity of the submental muscle group. Viscosity measurements were performed using a viscometer and a line spread test (LST), after adding contrast medium into water, yogurt, and porridge to 0%, 12.5%, 25.0%, and 37.5% v/v concentrations. Surface electromyography (sEMG) was performed on 20 healthy adults by attaching EMG electrodes to the submental muscle group. Diet consisted of non-contrast medium food and food containing 37.5% v/v contrast medium. There were significant differences in viscometer and LST results between non-contrast medium food and food with contrast medium (p < 0.001). There was a significant negative correlation between viscometer and LST outcomes (water r = - 0.889, p < 0.001; yogurt r = - 0.952, p < 0.001; porridge r = - 0.837, p < 0.001). Finally, there was a significant difference in muscle activity between non-contrast medium water (2.5 cc) and water containing contrast medium 37.5% v/v (2.5 cc) (p = 0.025). These findings suggest that, when performing VFSS, clinicians should consider changes in food viscosity due to contrast medium in order to provide accurate diagnoses and dysphagia diet plans.

Keywords: *food, dysphagia, contrast medium, viscosity, muscle activity*

Cite This Article: Jong-Hyun Park, So Young Ahn, Min-Woo Choi, Bum-Keun Kim, and Kang Hee Cho, "The Effects of Contrast Medium on Food Viscosity and Muscle Activity of the Submental Muscle Group." *Journal of Food and Nutrition Research*, vol. 7, no. 7 (2019): 543-548. doi: 10.12691/jfnr-7-7-9.

1. Introduction

Diet modification is an intervention method for dysphagia patients to ensure safe swallowing and appropriate nutrition [1,2]. Diet should be determined based on the swallowing capability and should be regularly assessed and controlled [3]. Viscosity should be considered when determining diet modifications for dysphagia patients [4]. The National Dysphagia Diet (NDD) suggested to classify liquids as follows: thin (1 to 50 cP), nectar-like (51 to 350 cP), honey-like (351 to 1,750 cP), and spoon-thick (greater than 1,750 cP) [4]. In Korea, viscometry and the Line Spread Test (LST) are used to classify viscosity in clinical settings: water (1 to 9 cP, greater than 4.0 cm), fluid-type yogurt (10 to 99 cP, 3.0 to 3.9 cm), honey (100 to 9,999 cP, 1.1 to 2.9 cm), and porridge (greater than 10,000 cP, 0 to 1.0 cm) [5].

A previous study assessing the effects of food viscosity on swallowing function in normal adults using a videofluoroscopic swallowing study (VFSS) reported that there were differences in terms of the duration of pharyngoesophageal sphincter (PES) opening, PES opening relative to bolus arrival, and extent of PES opening [6]. In dysphagia patients who aspirate while swallowing thin-fluid, difference in food viscosity had effects on the latency of epiglottis contact, latency of upper esophageal sphincter opening, latency of peak laryngeal elevation, and rise time of laryngeal elevation [7]. Another study utilizing surface electromyography (sEMG) demonstrated that differences in food viscosity in normal adults affected maximum electromyography (EMG) activity and average EMG activity of the submental muscle and infrahyoid muscle groups [8]. Moreover, sEMG outcomes have shown differences in the maximum amplitude and durations for the orbicularis oris inferior region, the submental muscle group, and the infrahyoid muscle group [9].

VFSS is a technique that allows visualization of the entire swallow, and it is considered the standard technique for comparative assessment of the accuracy of other techniques [10]. To observe the swallowing process via VFSS, radiopaque elements (i.e. contrast medium) need to be mixed in the food [11]. However, fluid mixed with contrast medium exhibits density, yield stress, and viscosity that differ from those of the non-contrast medium fluid [12]. Similarly, in puree-type food, mixed contrast medium and its dose resulted in different sensory and rheological characteristics [13]. When performing VFSS, there were differences in stage-transition duration, pharyngeal transit time, and upper esophageal sphincter opening duration while swallowing 22% or 40% w/v contrast medium [11]. Therefore, when performing VFSS, adding contrast medium is an important factor to consider when selecting the evaluation strategy and interpreting the outcomes [14].

The LST can be made readily available in treatment rooms and hospital wards in place of highly priced viscometers and can be used to easily and rapidly measure viscosity in the clinical setting. However, there have been very few studies assessing changes in viscosity of various food items after adding various doses of contrast medium. Furthermore, changes in muscle activity of the submental muscle group while swallowing between non-contrast medium food and food containing contrast medium has been rarely studied. This study aimed to quantitatively assess changes in food viscosity based on the dose of contrast medium added to food using viscometry and LST. We also investigated the effects of changes in viscosity on the maximum muscle activity of the submental muscle group.

2. Materials and Methods

2.1. Participants

This study was conducted at the Chungnam National University Hospital in Daejeon, South Korea. The subjects were healthy adults without symptoms of dysphagia. There were 8 males and 12 females with an average age of 23.65 ± 2.01 years. The study was conducted with approval of the institutional review board of Chungnam National University Hospital (IRB no. CNUH 2014-09-021). All participants gave written informed consent prior to participation.

2.2. Viscosity Measurements

Water (Jeju Province Developmental Co., Jeju, Korea), yogurt (Dongwon Corp., Seoul, Korea), and porridge (CJ Corp., Seoul, Korea) were used as test food items. The contrast medium used in this study was barium sulfate (Dongin-dang Co., Ltd., Gyeonggi-do, Korea). The doses of contrast medium used for each food item were as follows: 0%, 12.5%, 25.0%, and 37.5% volume/volume using a 250 mL beaker.

The changes in food viscosity between non-contrast medium food and food containing contrast medium (at various concentrations) were measured using a viscometer (Brookfield Engineering Inc., Middleboro MA, USA). The shear rate used was 50^{s-1}, and raw data were analyzed using Rheo 3000 software (Brookfield Engineering Inc., Middleboro MA, USA).

For LST, paper with concentric circles at 0.5 cm intervals were placed under glass slides. Next, a tube of 2-cm diameter and height was placed at the center of paper and 5 mL of the food was placed within it. After tube removal, the food was allowed to spread for 1 minute and the spreading radius was measured in all directions to quantify viscosity. For all assessments of food viscosity, the temperature of each food product was set at room temperature (25 ± 2°C) and the average measurement of 10 independent measurement was calculated.

2.3. Surface Electromyography (sEMG) Measurements

The subject was asked to sit on a chair with a backrest (90°), in a seated position with the hip joint and knees bent at 90° and both feet touching the floor. Their arms were comfortably positioned on top of the armrests. To perform electromyography, a surface electromyogram WEMG-8 (Laxtha Inc., Deajeon, Korea) was used. EMG electrodes were attached to the submental muscle group, including the anterior belly of the digastric, the mylohyoid, and the geniohyoid. The Frankfort plane was parallel to the floor. The first task was effort swallowing saliva. Subsequently, the subject was provided with water (2.5 cc, 5.0 cc), yogurt 5.0 cc, and porridge 5.0 cc without contrast medium. For the food items containing contrast medium, equal amounts were given after mixing the food with contrast medium (37.5% v/v, in a 250 mL beaker). The average value of maximum muscle activity from three total measurements (once every minute) was calculated for swallowing saliva and for each food item. EMG signals were measured using Telescan software (Laxtha Inc., Deajeon, Korea) at a 1024 Hz sampling rate. This EMG signal was filtered using a 10–400 Hz band pass filter and was corrected using root mean square. sEMG data were normalized in each subject, using the submental maximum muscle activity of effort swallowing saliva as a baseline.

2.4. Statistical Analysis

All statistical analyses were performed using SPSS 20.0 (SPSS, Inc., Chicago, IL, USA). Shapiro-Wilk tests evaluated data distributions. The changes in food viscosity measured using viscometry and LST were analyzed using ANOVA, and Tukey's HSD test was performed for post-hoc analysis. The correlations between viscometry and LST were assessed using Pearson correlation coefficients. The differences in maximum muscle activity of the submental muscle group between swallowing non-contrast medium food and food containing contrast medium were compared using independent t-tests. The level of statistical significance was set at $p < 0.05$.

3. Results

3.1. Changes in Viscosity

Viscosity of contrast medium measured via viscometry was 349.2 ± 6.6 cP, while non-contrast medium water, yogurt, and porridge had viscosity values of 1.3 ± 0.1 cP, 600.6 ± 15.1 cP, and 5,781.1 ± 158.8 cP, respectively.

Addition of contrast medium to water at 12.5%, 25.0%, and 37.5% v/v increased the viscosity by 230.8%, 638.5%, and 1392.3%, respectively ($p < 0.001$). Similarly, addition of contrast medium to yogurt to 12.5% and 25.0% v/v increased the viscosity by 72.1% and 23.2%, respectively ($p < 0.001$). However, addition of contrast medium to 37.5% v/v resulted in a significantly decreased viscosity by 50.9% ($p < 0.001$). Meanwhile, addition of contrast medium to porridge resulted in significantly decreased viscosity, by 21.0%, 28.3%, and 35.1%, respectively ($p < 0.001$). The changes in viscosity according to the dose of contrast medium added to each food item, measured using viscometry, are displayed in Figure 1.

Viscosity of contrast medium measured via LST was 4.7 ± 0.2 cm, while the viscosity of non-contrast medium water, yogurt, and porridge was 5.2 ± 0.1 cm, 2.2 ± 0.1 cm, and 0.6 ± 0.1 cm, respectively. Addition of contrast medium to water to 12.5%, 25.0%, and 37.5% v/v resulted in significantly decreased spread radius by 9.6%, 13.5%, and 19.2%, respectively ($p < 0.001$). When contrast medium was added to yogurt to 12.5% and 25.0% v/v, the spread radius significantly decreased by 27.3% and 18.2%, respectively ($p < 0.001$); however, addition of contrast medium to 37.5% v/v resulted in a significantly increased spread radius by 31.8% ($p < 0.001$). For porridge, addition of contrast medium by these concentrations resulted in a significantly increased spread radius by 66.7%, 133.3%, and 316.7%, respectively ($p < 0.001$). The changes in viscosity according to the dose of contrast medium added to each food item, measured via LST, are displayed in Figure 2.

3.2. Correlation between Viscometry and Line Spread Test (LST)

We assessed the correlation between the values of viscometry and LST, measuring the changes in food viscosity according to the dose of contrast medium added. For all food items, there was negative correlation between viscometer measurements and LST measurements: water (r = - 0.889, $p < 0.001$), yogurt (r = - 0.952, $p < 0.001$), and porridge (r = - 0.837, $p < 0.001$).

3.3. Changes in the Maximum Muscle Activity of the Submental Muscle Group

The muscle activity of submental muscle group was 39.9% when swallowing 2.5 cc of non-contrast medium water, which significantly increased to 51.9% when swallowing 2.5 cc of water containing contrast medium ($p = 0.025$). For 5.0 cc of water, the muscle activity was 52.3% for non-contrast medium water and 62.2% for water containing contrast medium, exhibiting significantly increased muscle activity ($p = 0.059$). For yogurt, the muscle activity while swallowing 5.0 cc of non-contrast medium yogurt was 68.7%, decreasing to 66.0% while swallowing 5.0 cc of yogurt containing contrast medium ($p = 0.341$). Finally, muscle activity while swallowing 5.0 cc of porridge was 82.9%, decreasing to 72.1% while swallowing porridge with contrast medium added ($p = 0.056$). The changes in the muscle activity of submental muscle group according to the dose of contrast medium added are displayed in Figure 3.

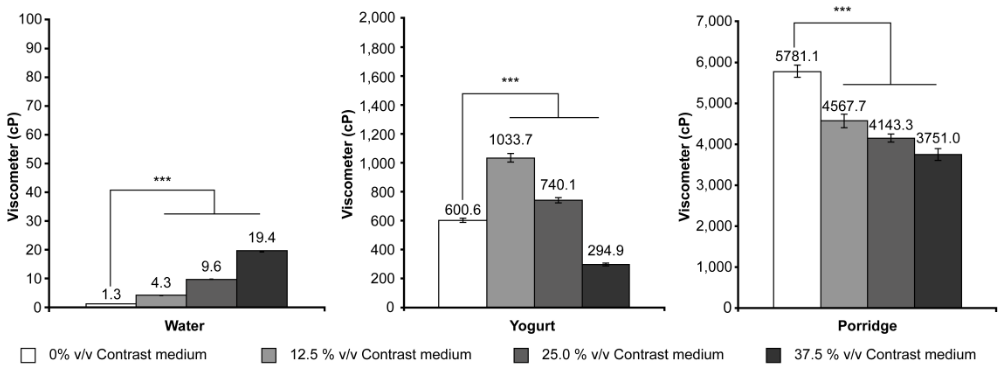

Figure 1. Changes in food viscosity according to the dose of contrast medium added, measured with a viscometer ***$p < 0.001$ by ANOVA

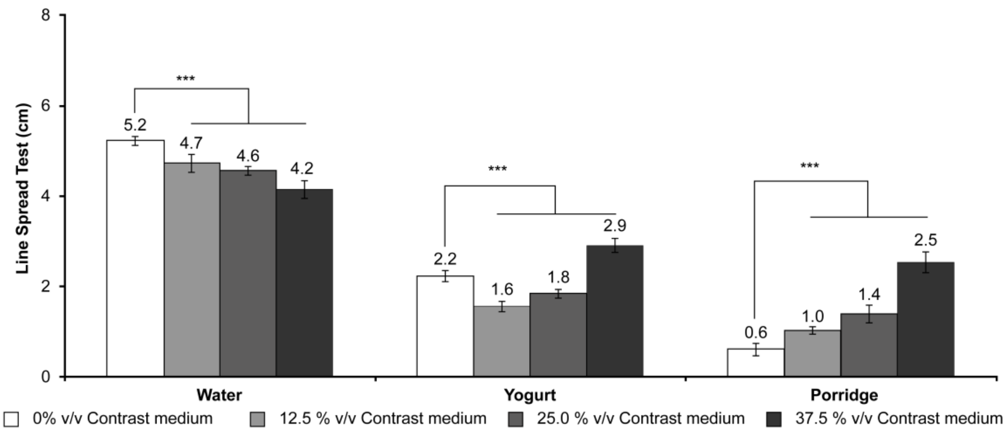

Figure 2. Changes in food viscosity according to the dose of contrast medium added, measured via LST ***$p < 0.001$ by ANOVA

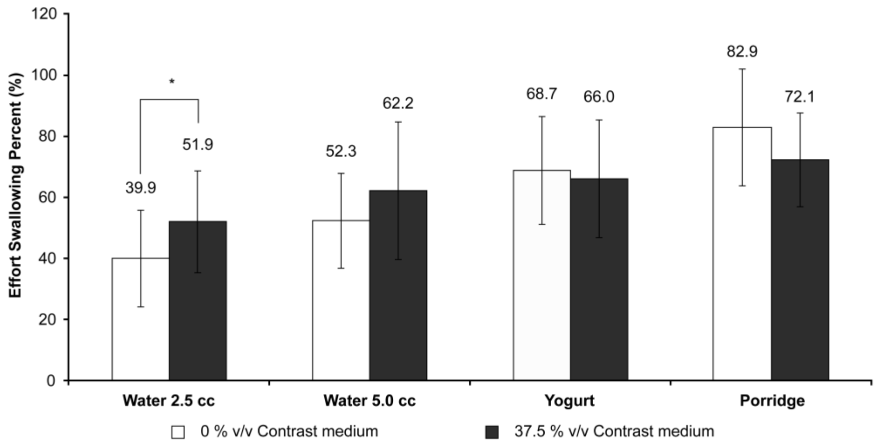

Figure 3. Changes in the maximum muscle activity of submental muscle group after addition of contrast medium *$p < 0.05$ by independent t-test

Table 1. Changes in the classification of food viscosity according to the dose of contrast medium added by the National Dysphagia Diet (NDD)

	Water + Contrast Medium (% v/v)				Yogurt + Contrast Medium (% v/v)				Porridge + Contrast Medium (% v/v)			
	0	12.5	25.0	37.5	0	12.5	25.0	37.5	0	12.5	25.0	37.5
Thin	o	o	o	o								
Nectar-like								o				
Honey-like					o	o	o					
Spoon-thick									o	o	o	o

3.4. Changes in the Classification of Viscosity

Non-contrast medium water and water with contrast medium added (to 12.5%, 25.0%, and 37.5% v/v) were all within the same category of “thin” (1 to 50 cP). Similarly, non-contrast medium yogurt and yogurt with contrast medium added (to 12.5% and 25.0% v/v) were within the same category of honey-like (351 to 1,750 cP). Meanwhile, the category of yogurt with contrast medium added by 37.5% v/v changed to “nectar-like” (51 to 350 cp). Finally, non-contrast medium porridge and all porridge with contrast medium added (to 12.5%, 25.0%, and 37.5% v/v) were all within the same category of “spoon-thick” (>1,750 cP). The changes in classification of viscosity according to the dose of contrast medium added to each food, based on the classification standard of viscosity suggested by NDD, are displayed in Table 1.

4. Discussion

In the present study, we confirmed the effect of contrast medium on the viscosity of foods and the muscle activity of the submental muscle group. Fluid used for VFSS contains small doses of contrast medium in order to ensure rheological matching with the mealtime fluid normally provided to the patient [12]. In this study, the proportion of contrast medium in each food item (water, yogurt, and porridge) was increased in a step-wise manner to assess the changes in food viscosity. Cichero et al. [12] reported poor correlations between mealtime fluids and viscosity of videofluoroscopy fluids. Similarly, in this study, addition of contrast medium—which has higher viscosity than that of water—to non-contrast medium water resulted in an increased viscosity of the mixture as the proportion of contrast medium increased. Addition of contrast medium (12.5% and 25.0% v/v) to yogurt resulted in an increased viscosity compared to the non-contrast medium yogurt. Addition of contrast medium to 37.5% v/v caused a decrease in the viscosity in comparison to the non-contrast medium yogurt. Finally, addition of contrast medium to porridge—with the highest viscosity—resulted in decreased viscosity as the proportion of contrast medium increased. Ekberg et al. [13] evaluated changes in viscosity by adding contrast medium (0%, 12.5%, 25.0%, and 37.5% w/w) to mango puree, and demonstrated that addition of contrast medium resulted in increased viscosity. As shown in this study and previous studies, the dose of contrast medium added to food can change the overall viscosity, and this change may vary depending on the general characteristics of contrast medium or food.

The most objective method for viscosity measurement is viscometry. However, in clinical settings, it is impractical to use the viscometer as it is expensive and complex to use. Paik et al. [5] reported that LST, which can be easily utilized in clinical settings, and viscometry significantly correlated, and they utilized LST outcomes to classify diets for dysphagia patients. Budke et al. [15] suggested that clarifying the measurement protocol of LST and accurately performing LST allowed detection of small differences in viscosity. In this study, the correlation between viscometry and LST results was confirmed. Furthermore, we confirmed that LST could be utilized to measure changes in food viscosity according to the dose of contrast medium added.

sEMG is a non-invasive, simple, and reliable tool for evaluation of the physiology of swallowing [16]. The data normalized using the maximum effort task as a baseline is thought to be the optimal method to analyze EMG signals [17]. In this study, the value of maximum muscle activity for effort swallowing saliva was converted to percentage values, in order to calculate the ratio of muscle activity for each food item. A previous study showed that addition of fluid with contrast medium did not change the muscle activity of the submental muscle group [18]. However, in this study, there was significant difference in muscle activity when swallowing 2.5 cc of non-contrast medium water versus 2.5 cc of water containing contrast medium (37.5% v/v). Although there were no other significant changes observed for other food items, addition of contrast medium resulted in either an increased or a decreased maximum muscle activity of the submental muscle group.

Groher et al. [19] suggested that it is best to make the fulids for VFSS and mealtime fluids as similar as possible. According to the findings of our study, addition of contrast medium to water resulted in an increased viscosity of water. Therefore, the minimal dose of contrast medium enough to detect in VFSS should be added to water. For yogurt, although there were significant changes in the viscosity for various doses of contrast medium added, the difference in viscosity was minimal when 25.0% v/v of contrast medium was added. Finally, addition of contrast medium to porridge resulted in decreased viscosity. Therefore, the minimal dose of contrast medium sufficient to detect on VFSS should be added to porridge.

Clinicians must not assume that diet provided to patients in their daily life would have the same viscosity as diet used for VFSS test. Stroke-associated pneumonia may cause dysphagia and persistent bolus aspiration [20]. Numerous precedent studies have reported on changes in swallowing physiology due to difference in viscosity of diet [6-9]. Robertson et al. [21] demonstrated that a small difference in viscosity between orange juice and tomato juice can affect safe swallowing in dysphagia patients. In this study, there were significant differences in the viscosity of every food item tested, between the non-contrast medium food item and the food item containing contrast medium. More specifically, addition of contrast medium (37.5% v/v) to water resulted in an increased viscosity of water by 1392.3%, while the addition to yogurt and porridge resulted in decreased viscosity (50.9% and 35.1%, respectively). Based on the classification standards suggested by NDD, water and porridge, with or without contrast medium added, were within the same category. However, addition of contrast medium (37.5% v/v) to yogurt resulted in the change of classification from “honey-like” to “nectar-like”. Therefore, even if the patient safely swallowed yogurt containing 37.5% v/v contrast medium, it is not safe to assume that the patient would be able to swallow the non-contrast medium yogurt without any issue. Moreover, although there were no changes in classification for water and porridge (with addition of contrast medium at 12.5%, 25.0%, and 37.5% v/v) or for yogurt (with addition of contrast medium 12.5% and 25.0% v/v), the outcomes for VFSS should be interpreted after considering the rheological changes of food due to the addition of contrast medium.

The International Dysphagia Diet Standardisation Initiative (IDDSI) classified liquid thickness into 0-4 stages according to the amount remaining in a 10 ml syringe after 10 seconds of flow [22]. Based on the IDDSI classification standards, Ong et al. [23] differentiated liquids using xanthan gum and cornstarch base with or without barium added. In the present study, the viscosity of diet according to the amount of contrast medium added to water, yogurt, and porridge was differentiated by LST. Accordingly, it would be necessary to provide an intervention that selects therapeutic diet in stepwise manner according to quantified classification standards for diet used in VFSS test and diet provided to patients based on methods easily applicable in clinical settings, such as IDDSI and LST.

There are a few limitations of this study. First, other aspects of food (i.e. taste, density, or yield stress) containing contrast medium could not be measured. However, since the changes in food viscosity according to the dose of contrast medium added were measured in a controlled environment and designed experimental methods, the effects of potential confounding variables (i.e. temperature, the time passed after addition of contrast medium) could be controlled. Second, VFSS outcomes while swallowing the food containing contrast medium were not compared. Nevertheless, the change in maximum muscle activity of the submental muscle group between swallowing non-contrast medium food and food containing contrast medium was confirmed using sEMG. Future studies should aim to standardize the dose of contrast medium for each food item: the minimum dose required for observation in VFSS; and the dose that will result in a viscosity similar to that of the non-contrast medium food.

5. Conclusions

Our data demonstrated the difference in viscosity between non-contrast medium food and food containing contrast medium. In addition, the change in maximum muscle activity of the submental muscle was confirmed by the effect of the contrast medium. Therefore, our findings can be utilized for diagnosis of dysphagia patients using VFSS and for determining appropriate diets. Moreover, in clinical settings, LST, which is a relatively simpler method, should be used instead of viscometry when measuring food viscosity.

Acknowledgements

This study was funded by Main Research Program (E0145102-05) of the Korea Food Research Institute (KFRI) funded by the Ministry of Science and ICT.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

[1] Martin, A.W, “Dietary management of swallowing disorders,” *Dysphagia,* 6 (3). 129-134. Sep.1991.

[2] Garcia, J.M., Chambers, E.T., Matta, Z. and Clark, M, “Viscosity measurements of nectar- and honey-thick liquids: product, liquid, and time comparisons,” *Dysphagia,* 20 (4). 325-335. Oct.2005.

[3] Garcia, J.M. and Chambers, E, "Managing dysphagia through diet modifications," *Am J Nurs,* 110 (11). 26-33. Nov.2010.

[4] Clayton, J, *The National Dysphagia Diet: Standardization for Optimal Care,* American Dietetic Association Publishers, Chicago, 2002, 10-20.

[5] Paik, N.J., Han, T.R., Park, J.W., Lee, E.K., Park, M.S. and Hwang, I.K, "Categorization of dysphagia diets with the line spread test," *Arch Phys Med Rehabil*, 85 (5). 857-861. May.2004.

[6] Kendall, K.A., Leonard, R.J. and McKenzie, S.W, "Accommodation to changes in bolus viscosity in normal deglutition: a videofluoroscopic study," *Ann Oto Rhinol Laryn,* 110 (11). 1059-1065. Nov. 2001.

[7] Lee, S.I., Yoo, J.Y., Kim, M. and Ryu, J.S, "Changes of timing variables in swallowing of boluses with different viscosities in patients with dysphagia," *Arch Phys Med Rehabil,* 94 (1). 120-126. Jan.2013.

[8] Reimers-Neils, L., Logemann, J.A. and Larson, C, "Viscosity effects on EMG activity in normal swallow," *Dysphagia,* 9 (2). 101-106. Mar.1994.

[9] Ding, R., Logemann, J.A., Larson, C.R. and Rademaker, A.W, "The effects of taste and consistency on swallow physiology in younger and older healthy individuals: a surface electromyographic study," *J Speech Lang Hear Res,* 46 (4). 977-989. Aug.2003.

[10] Martino, R., Foley, N., Bhogal, S., Diamant, N., Speechley, M. and Teasell, R, "Dysphagia after stroke: incidence, diagnosis, and pulmonary complications," *Stroke,* 36 (12). 2756-2763. Dec.2005.

[11] Stokely, S.L., Molfenter, S.M. and Steele, C.M, "Effects of barium concentration on oropharyngeal swallow timing measures," *Dysphagia,* 29 (1). 78-82. Sep.2013.

[12] Cichero, J.A., Jackson, O., Halley, P.J. and Murdoch, B.E, "How thick is thick? multicenter study of the rheological and material property characteristics of mealtime fluids and videofluoroscopy fluids," *Dysphagia,* 15 (4). 188-200. Feb.2000.

[13] Ekberg, O., Bulow, M., Ekman, S., Hall, G., Stading, M. and Wendin, K, "Effect of barium sulfate contrast medium on rheology and sensory texture attributes in a model food," *Acta Radiol,* 50 (2). 131-138. Mar.2009.

[14] Dietsch, A.M., Solomon, N.P., Steele, C.M. and Pelletier, C.A, "The effect of barium on perceptions of taste intensity and palatability," *Dysphagia,* 29 (1). 96-108. Feb.2014.

[15] Budke, J., Garcia, J.M. and Chambers, E.T, "Comparisons of thickened beverages using line spread measurements," *J Am Diet Assoc,* 108 (9). 1532-1535. Sep.2008.

[16] Vaiman, M., Eviatar, E. and Segal, S, "Surface electromyographic studies of swallowing in normal subjects: a review of 440 adults. Report 2: Quantitative data Amplitude measures," *Otolaryngol Head Neck Surg,* 131 (5). 548-555. Nov.2004.

[17] Fee, JW. Jr. and Miller, F, *A critical review and proposed improvement in the assessment of muscle interactions using surface EMG,* InTech Publishers, Croatia, 2012. 3-16.

[18] Nagy, A., Steele, C.M. and Pelletier, C.A, "Barium versus nonbarium stimuli: differences in taste intensity, chemesthesis, and swallowing behavior in healthy adult women," *J Speech Lang Hear Res,* 57 (3). 758-767. Jun.2014.

[19] Groher, M.E., Crary, M.A., Carnaby, G., Vickers, Z. and Aguilar, C, "The impact of rheologically controlled materials on the identification of airway compromise on the clinical and videofluoroscopic swallowing examinations," *Dysphagia,* 21 (4). 218-225. Oct.2006.

[20] Sura, L., Madhavan, A., Carnaby, G. and Crary, M.A, "Dysphagia in the elderly: management and nutritional considerations," *Clin Interv Aging,* 7. 287-298. Jul.2012.

[21] Robertson, H.M. and Pattillo, M.S, "A strategy for providing food to the patient with neurologically based dysphagia," *J Can Diet Assoc*, 54 (4). 198-201. 1993.

[22] Cichero, J.A., Lam, P., Steele C.M., Hanson, B., Chen, J., Dantas R.O., Duivestein, J., Kayashita, J., Lecko, C., Murray, J., Pillay, M., Riquelme, L. and Stanschus, S, "Development of international terminology and definitions for texture-modified foods and thickened fluids used in dysphagia management: the IDDSI framework," *Dysphagia,* 32 (2). 293-314. April.2017.

[23] Ong, J.J.X., Steele, C.M. and Duizer, L.M, "Sensory characteristics of liquids thickened with commercial thickeners to levels specified in the International Dysphagia Diet Standardization Initiative (IDDSI) framework," *Food Hydrocoll*, 79. 208-217. June. 2018.