Influence of food viscosity on velocity of bolus transport in the pharyngeal phase

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Abstract

There are many ways to heal the dysphagia or difficult swallowing symptom. Self swallowing of right food is an alternative to heal as well as to cure the dysphagia effectively besides regular surgery. However viscosity of foods can be an obstacle for patients in swallowing. Understanding influence of food viscosity to velocity of bolus transport can help nutritionists in preparing appropriate and healthy food for patients. Studying this work, effect of the viscosity of shear thinning food on velocity of bolus transport was investigated. Two values of food viscosity, i.e. 95cP and 1368cP, were used. Volunteer were classified into 2 groups, 18-25 years old and more than 40 years old. Each group consisted of 3 male and 3 female volunteers. Each volunteer was subjected to 3 tests for food swallowing for each viscosity. Videofluorographic recording was performed to measure bolus velocity. The velocities of bolus transport in the younger group were found to be $9.75^{+1.55}_{-2.12}$ cm/s in low viscosity food and $11.08^{+0.41}_{-0.51}$ cm/s in high viscosity food and 7.80 ± 1.0 cm/s in low viscosity food and 7.97 ± 1.6 cm/s in high viscosity food, for female and male volunteers, respectively. Those for the older group were $9.98^{+2.92}_{-2.69}$ cm/s in low viscosity food and $9.80^{+0.99}_{-1.14}$ cm/s in high viscosity food and 9.73 ± 0.6 cm/s in low viscosity food and $9.44^{+0.48}_{-0.57}$ cm/s in high viscosity food, for female and male volunteers, respectively. Consequently, the velocity of bolus transport in female is higher than that in male for both food viscosities. Therefore the food of male patients should be prepared rarely viscosity more than female and the food of elder patients should be prepared rarely viscosity more than younger patients.

Keyword: Food viscosity, Swallowing, Pharyngeal phase, Dysphagia

1. Introduction

Swallowing is a complex human physiology. Understanding of this physiology is advantageous to heal patients encountering difficulty in swallowing or *Dysphagia*. The swallowing of food from mouth to stomach occurs in 3 phases. In the first and early phase, called *Oral Phase*, food is mixed with saliva to form a bolus by teeth and tongue before it travels down to the pharynx, in the *Pharyngeal Phase* when the bolus is pushed from the mouth by tongue, and plate is elevated for the bolus to pass by. When the bolus moves to the pharynx, the plate bends downwards to close the space between the nasopharyngeal and pharyngeal zone. The bolus moves downwards to pharyngeal by the elevation of hyoid bone and the closing of larynx. During this step the body stops to breathe for a few seconds. The epiglottis is deformed to push the bolus to the upper esophageal sphincter (UES). Finally, in the *Esophageal Phase*, UES is opened and allows the bolus move to esophageal by peristalsis wave of pharyngeal. When the bolus completely moves to the esophageal, UES is then closed. The bolus is then moved by peristalsis wave of esophageal and flows into stomach [1, 2, 3].

Dysphagia is usually a problem [4, 5]. It has been found to occur to the newborn babies to the elderly. High performance of new medical techniques help to care a child preborns has increase a life [6]. The survival from accident, high brain deformation and the new social structure have the elder add shapely .There are going back retreats and oldness of nervous system and muscle [7].These reason, dysphagia add to more in nowadays. Currently, dysphagia affects estimated 15 million Americans [8]. In Thailand, Dysphagias had recorded 604 patients at Songklanakarin hospital during 1994-2004 [9]. There are many ways to treat the dysphagia including self swallowing of appropriate food is an alternative to heal as well as to cure the dysphagia effectively besides regular surgery [10, 11]. However viscosity of foods can be an obstacle to patients in swallowing. Understanding influence of food viscosity to velocity of bolus transport can help nutritionists in preparing appropriate and healthy food for patients.

The purpose of this study is to investigate and optimize the effect of the viscosity of shear thinning foods on velocity of the bolus transport for dysphagia.

2. Materials and Methods

2.1 Subject

Twelve healthy adults (six females and six males) were classified in two groups; the first group consisted of three males and three females in the age of 18-25 years old. The second group consisted of three males and females ages over 40 years old. All subjects had no history or symptoms of dysphagia.

2.2 Food preparation

The testing foods were indicted by their apparent viscosity at shear rate of 50 s^{-1}. Main ingredients of the testing food were BLENDERA® (patient powder food), sodium carboxymethyl cellulose (SCMC), Milo® (coco powder), and boiled water.

Formula#1

100 mg of SCMC was dissolved in 10 ml of the boiled water. After 12 hours, the solution became 1% w/v SCMC. 25 g of BLENDERA® and 8 g of Milo® 8 g were added into the 70 ml of 70°C boiled water, and it was mixed homogenously with the SCMC solution by viscometer for 15 minutes.

Formula#2

650 m g of SCMC was dissolved in 65 ml of the boiled water. After 12 hours, the solution became 1% w/v SCMC. 25 g of BLENDERA® and 8 g of Milo® 8 g were added into the 70 ml of 70°C boiled water, and it was mixed homogenously with the SCMC solution by viscometer for 15 minutes.

2.3 Food viscosity

Viscosity of the foods was measured by a rotational viscometer (Brookfield, DV-II+) at a constant temperature of 37±0.1°C. Food viscosity was measured 3 times for each experiment.

Results of the viscosity of both formulas are shown in Figures 1 and 2. The relationships can be represented by the power-law equation with R^2 equal to 93% for both cases. The foods behaved as psudoplastic (shear thinning fluid). The values of the apparent viscosity are 95 and 1,368 cP, for formulas 1 and 2, respectively, as also shown in Table 1.

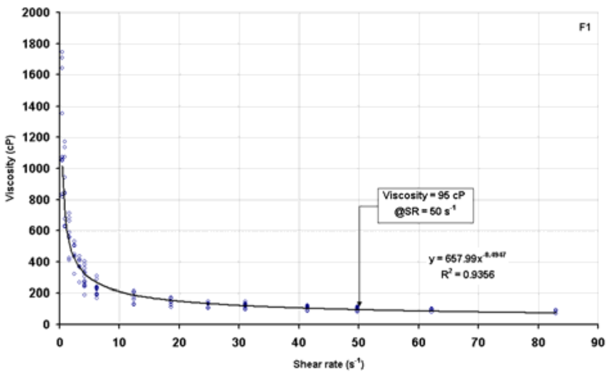

Fig.1 Relationship between viscosity and shear rate of the testing food formula #1.

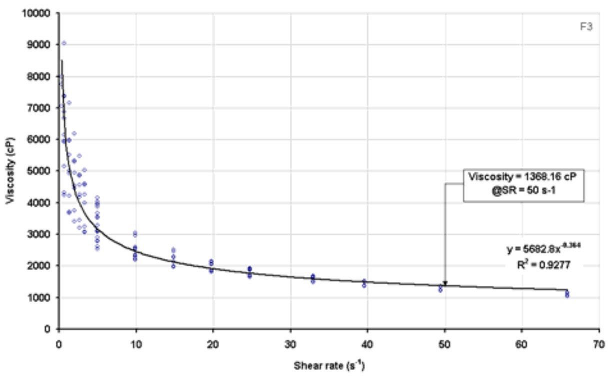

Fig.2 Relationship between viscosity and shear rate of the testing food formula #2.

Test Food	Cons Index(K)	Flow index, n	R^2	Apparent viscosity at shear rate 50 s^{-1}
F# 1	658	0.5053	0.938	95
F# 2	5683	0.6360	0.975	1368

Table. 1 All parameter in power-law non-Newtonian equation.

Eventually, comparison the viscosity of testing food formula #1 are arranged in nectar consistency level. Whereas the testing food formula #2 are arranged in honey consistency level [12].

2.4 Videofluoroscopy Equipment

X-ray M/C schematic

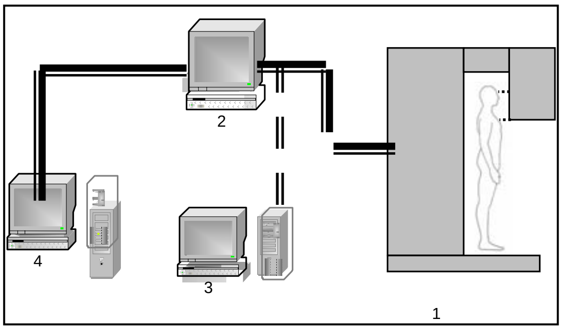

Fig.3 Schematic of instrumentation of VFG

1. X-ray station
2. Monitor inner x-ray room
3. Recording station (Labview programming)
4. Monitor outer x-ray room and recorder

Main line

Signal line- connect to recording station

A signal line is connected to main line of the X-ray recorded system for to bring the signal videofluoroscopy go to recoding station and Labview programming change that to swallow figure file in 25 frame/second show in schematic X-ray M/C figure 3.

2.4.1 Procedure of bolus swallowing testing

The volunteers swallowed 5 cc of each sample of the food following by 15 cc of water. The next swallowings were performed after two minute breaks until all the swallowings were completed. The testing began with the less viscous food.

2.4.2 Videofluoroscopy analysis

The movement of bolus in oropharyngeal and hypopharyngeal were recorded by videofluoroscopy (X-ray) at a rate of 25 frames/second and data was analyzed by Labview 8.0 programming to determine the pharyngeal length and the time of swallowing in pharyngeal zone. Pharyngeal length from the end of base tongue to upper esophageal sprincher (UES) was measured using PhotoShop software and the bolus movement time was calculated by frame counting of bolus movement in pharyngeal length (rate of frame counting was 1 frame/0.04second). The data was used to determine average velocity of bolus transport in pharyngeal zone.

3. Result and discussion

The velocity of bolus movement for young females swallowing low and high viscosity foods were $9.75^{+1.55}_{-2.12}$ and $11.08^{+0.41}_{-0.51}$ cm/s, respectively. The trend of velocity of this group sharply increased the most affective all group. Next group is a young male group in low viscosity food is 7.80 ± 1.0 cm/s and another viscosity food is 7.97 ± 1.6 cm/s. Next group is an elder female group in low viscosity food is $9.98^{+2.92}_{-2.69}$ cm/s and another viscosity food is $9.80^{+0.99}_{-1.14}$ cm/s. The last group, in case swallow low viscosity food is 9.73 ± 0.6 cm/s and another viscosity food is $9.44^{+0.48}_{-0.57}$ cm/s.

The young group, female bolus velocity has a sharply increasing velocity when the viscosities of food add value when male bolus velocity has a continuously increase velocity of food when high viscosity in show figure 4.In the elder group, the velocity of bolus movement in this group has a continuously decrease when high viscosity and in case elder male have result same as them. It is continuous drops drown when viscosities of food add show in figure 5.In case comparison of velocity between male and female on effective on aged. For female in swallow low viscosity food, elder velocity of bolus movement faster than young velocity but additional viscosity toward the velocity of bolus movement of younger increase more than elder bolus velocity show in figure 6. For male in swallow low viscosity food, elder velocities of bolus movement faster than younger in all viscosities of foods show in figure 7.

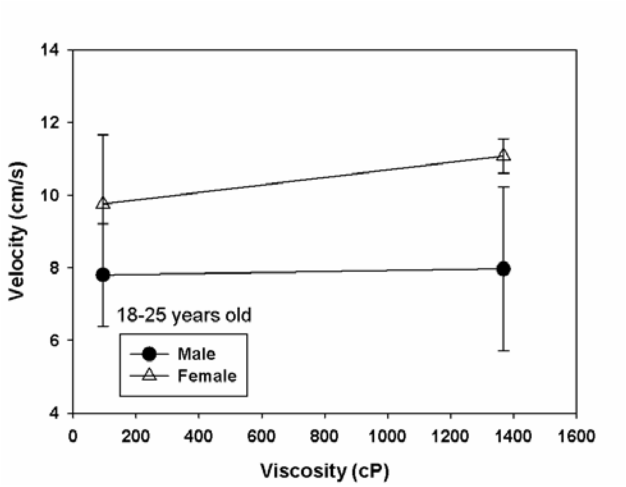

Fig.4 Comparison between male and female in group 18-25 years old.

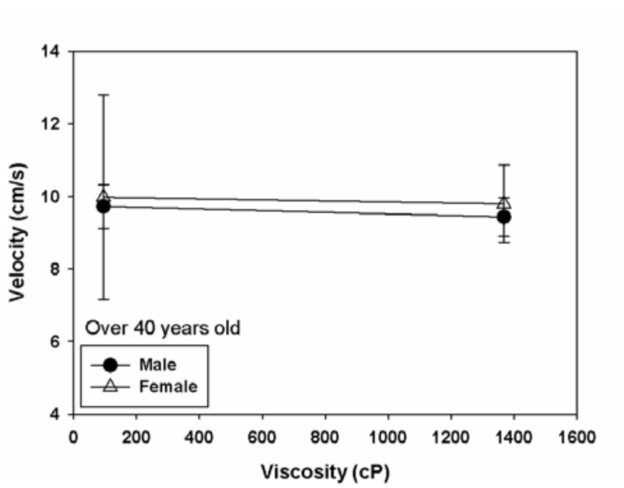

Fig.5 Comparison between male and female in group more than 40 years old.

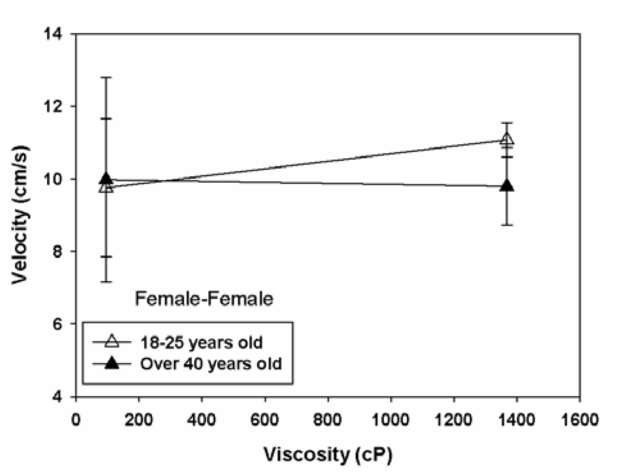

Fig.6 Comparison between 18-25 group and 40 more than 40 years old in female sex.

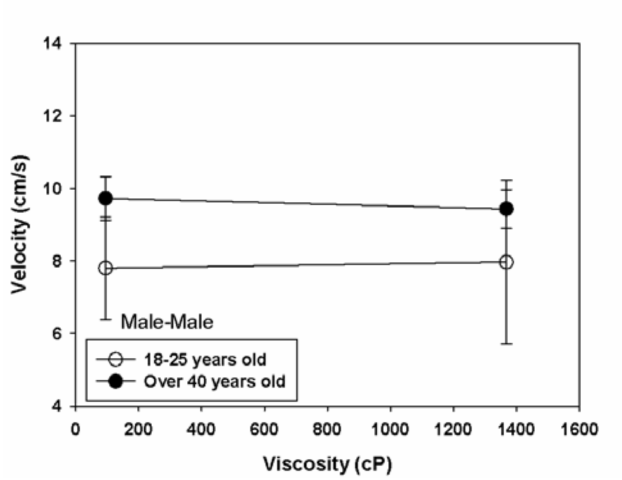

Fig.7 Comparison between 18-25 group and 40 more than 40 years old in male sex.

4. Conclusion

In 18-25 years generation, Male and female can swallow high viscosity food better than low viscosity food but in over 40 years generation can swallow low viscosity food better than high viscosity food. For comparison female and male, female can swallow faster than male all viscosity food. However female elder has very drop down velocity of bolus movement.

Therefore the food viscosity for young generation patients should be prepared high viscosity. Conversely the food viscosity for elder generation patients should be prepared low viscosity.

5. Acknowledgement

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6. Reference

[1] Scanlon, C. V. and Sander, T. (2007). Essentials of anatomy and physiology, 5th edition, F.A. Davis Company, Philadelphia. pp. 370-373

[2] Sopade, P. A. Halley, P. J. Cichero, J. A. Y. and Ward, L.C. (2006). Rheological characterization of food thickeners marketed in Australia in various media for the management of dysphagia I, Journal of food engineering. Inpress.

[3] Chen, J. (2007). Food oral processing-A review, Food hydrocolloids, vol. 23, pp.1-27

[4] Ramsey, D. J. Smithard, D. G. (2004). Assessment and management of dysphagia, Journal of Hospital Medicine, vol.65, pp. 274-279

[5] Murray, T. Carrau, R.L. and Eibling, D.E. (2003). Comprehensive management of swallowing disorders, Singular publishing, San Diego. pp. 3-7

[6] Brodsky, L. and Arvedson, J. (1993). Pediatric swallowing and feeding: assessment and management, Whurr publishing, San Diego. pp. 1-4

[7] Logemann, J. A. (1990). Effect of aging on the swallowing mechanism. Otolalyngologic Clinics of North America. pp.1045-1056

[8] Adeleye, B. (2007). Comparison of the rheological properties of ready-to-serve and powered instant food-thickened beverages at different temperatures for dysphagia patients, Journal of the American dietetic association, Inpress.

[9] Leelamanit, V. (2005). Dysphagia and aspiration, Chanmuang publication, Songkhla. pp. 159

[10] Huang, J. Y. Zhang, D. Y. Yao, Y. Xia, O. X. and Fan, Q.Q. (2006). Training in swallowing prevents aspiration pneumonia in stroke patients with Dysphagia. Journal of international medical research. vol.34, pp. 303-306

[11] Germain, I. Dufresne, T. and Ramaswamy, H.S. (2005). Rheological characterization of thickened beverages used in the treatment of dysphagia, Journal of food engineering, vol.73, pp. 64-74

[12] Steele, M. C. Van Lieshout, P. H. H. M. and Goff, H. D. (2003). The Rheology of liquids: A comparison of Clinician's subjective Impressions and Objective Measurement, Dysphagia, vol.18, pp. 182-195