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Effect of Age, Gender, and Consistency in Normal Swallowing

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Purpose : The purpose of this study was to determine the effects of age and gender on the oral and pharyngeal transition durations of three consistencies of the bolus in normal subjects.

Methods : Temporal measurements of swallowing were obtained from 40 normal subjects. The subjects were divided into two groups. This included 20 younger and 20 older subjects, with each age group consisting of males and 10 females. The videofluoroscopic swallowing examination of each subject was analyzed for two 5㎖ thin and nectar thick liquids, and one 5㎖ puree swallows. Two temporal measurements of oropharyngeal swallowing were measured: oral transition time (OTT) and pharyngeal transition time (PTT). Statistical comparisons were made by a three-way analysis of variance ($p<.05$).

Results : Age and gender did not have a significant effect on the oral transition of the bolus. However, older subjects exhibited longer pharyngeal transition than younger subjects. Longer OTT and PTT were recorded in puree swallows than liquid swallows.

Conclusions : Longer oral and pharyngeal transition of the bolus was recorded for puree than two liquids. The elderly showed an increased pharyngeal transition during the swallow. Although age alone does not put an individual at risk for dysphagia, the elderly populations are in fact more vulnerable to suffer from age related illness dysphagia is frequently accompanied with.

Keywords : Swallowing, age, gender, pharynx, consistency

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Ⅰ. Introduction

Swallowing occurs as an orderly process that transports saliva or ingested material from the mouth to the stomach (Dodds, 1989). Swallowing is a significant part of our lives considering that the average person swallows around once per minute and approximately 1000 times a day (Cook, 1991). However, successful execution of a swallow requires appropriate coordination between cortical and subcortical control, several cranial nerves, and around forty muscles of the face, mouth, pharynx, and esophagus (Jones, 2003). Dysphagia, swallowing disorder, can affect one's well-being and can involve morbidity and mortality because of nutritional and respiratory conditions (Cook, 1991). Pneumonia, malnutrition, and dehydration are all potential complications of dysphagia.

To understand normal physiological process of swallowing, a substantial amount of research has been conducted examining the effects of aging. The swallowing mechanism shows significant difference as people age, even in healthy individuals. This is because age related changes in muscles and nerves can affect the muscle strength and coordination for swallowing (Nilsson et al., 1996). This includes a reduction in muscle mass and connective tissue elasticity which results in a loss of strength and speed of movement; these changes may affect the head and neck and therefore swallowing performance (Crary & Groher, 2003).

There has been recent increased interest in whether gender differences are present in the normal physiological swallowing process. Limited research has been done in this area compared to research on gender effects of swallowing. Logemann et al. (2002) conducted a study on the oropharyngeal swallows of eight healthy young women and

eight healthy older women and compared the results to a similar study on men (Logemann et al., 2000). They reported a gender difference in cricopharyngeal opening duration for a 10㎖ bolus with women's opening lasting longer. Likely related, older men had reduced hyolaryngeal excursion compared to women, who tended to remain stable or increased. They hypothesized that women also maintained greater muscular reserve than men. In addition, differences in the pharyngeal phase of swallowing have been reported due to anatomical differences between men and women (Butler et al., 2009; McKee et al., 1998). Males have a longer pharynx than female.

Oropharyngeal transit time of a bolus has been used to investigate normal swallowing processes. Studies have found age related effects on the oropharyngeal transition times of the normal physiological swallowing process; however, the findings of oral transit time are not consistent and limited to thin liquids thus far. Tracy et al. (1989) reported oral transit time (OTT) in three different age groups including the older subjects. They found that older subjects held the bolus more posteriorly in the oral cavity and also completed oral transit of the bolus head more quickly compared to younger subjects. In contrast, Sonies et al. (1988) reported longer OTT in older subjects for large bolus volumes. Older subjects showed increased swallow duration for both dry and wet swallows when compared to younger subjects. The older subjects also took more time to move the hyoid forward during the swallows. For pharyngeal transit time (PTT), Robbins et al. (1992) measured the total duration of an oropharyngeal swallow in four age groups and reported that the duration was significantly longer in the oldest age group; they attributed this result to a delay in hyolaryngeal excursion. Kendall et al. (2000) examined the age effects on pharyngeal transit time (PTT) and found no difference between younger and older groups. In relation to PTT, Mckee et al. (1998) reported the pharyngeal cavity during a swallow begins earlier and lasts longer in older subjects.

There has also been increasing interest in age and gender differences in the oral and pharyngeal phase of swallowing with different consistencies. A surplus of research on normal swallowing focusing on measurements pertaining to airway protection and hyolaryngeal excursion has been obtained. However, it is also important to have age and gender difference data relating to the bolus transfer. The purpose of this study was to examine the effect of both age and gender on two oropharyngeal transition times of the bolus during the normal oropharyngeal swallow using videofluoroscopic swallowing examinations. Three bolus consistencies, thin liquid, nectar thick liquid, and puree consistency were used for analysis. The oropharyngeal transition times included oral transition time (OTT) and pharyngeal transition time (PTT).

II. Methods

1. Subjects

Forty normal subjects' videofluoroscopic swallowing examinations (VFSEs) were reviewed at the Ohio University Swallowing Lab in the Communication Sciences and Disorders. The subjects were divided into two groups consisting of 20 younger subjects (mean: 36 years old, range: 18 to 23) and 20 older subjects (mean: 75 years old, range: 60 to 83). Each age group included 10 males and 10 females. All subjects were screened for neurological or structural abnormalities which would interfere with normal swallowing function. Each subject completed a comprehensive questionnaire and passed a cranial nerve examination and an oral motor/structural examination prior to participation.

2. Videofluoroscopic Swallowing Examination (VFSE)

During VFSE, the subject was seated upright in a stretcher chair for the duration of the study. VFSEs were conducted with a mobile, C-arm x-ray (model 7600) system. Each study was digitized with an attached 100ms digital video timer (TEL Video Products Model VC 436). Subjects were seated and viewed radiographically in the lateral plane. Th fluoroscopic tube was focused on the oral cavity from the lips anteriorly to the pharyngeal wall posteriorly and from the nasopharynx superiorly to just below the upper esophageal sphincter (UES) area. The subjects were instructed to swallow after the bolus was placed in the mouth. For this analysis of data only these consistencies are being examined: 5㎖ thin (International Dysphagia Standardization Initiative: IDDSL, Level 0) and nectar thick liquids (IDDSI, Level 2, Mildly think liquid) and 5㎖ puree bolus (IDDSI, Level 4).

3. Procedures for Temporal Measurements

Temporal measurements were obtained for each subject from the VFSE videos. The highest quality VFSE's for each age group were analyzed to assist the accuracy of the

temporal measurements. This study measured two bolus transit times in oropharyngeal swallowing: Oral transit time (OTT) and pharyngeal transit time (PTT). Oral Transit Time (OTT) was measured as the time between the onset of posterior movement of the bolus head and the bolus head passing the ramus of the mandible. Pharyngeal Transit Time (PTT) was measured as the time between the head of the bolus passing the ramus of the mandible and the tail of the bolus passing the UES. The temporal measurements of OTT and PTT were obtained by a frame-by-frame analysis using the Adobe Premier Pro, 1.5 and a 100ms video timer. These measurements were obtained from 5㎖ thin and nectar thick consistency swallows as well as a 5㎖ puree consistency swallow; resulting in five swallows to examine per subject. Total 200 swallows were submitted for the analysis.

4. Statistical Analysis

Statistical comparisons were made by three-way analysis of variance (ANOVA) with independent variables being the age, gender, and the three consistencies of bolus. Significance level was set on $p<.05$. Post-hoc test (Tukey) was performed to test significant main consistency differences in each temporal measure. All of the swallows for each subject on each bolus volume were analyzed separately.

Ⅲ. Results

1. Reliability of Measurements

For inter-judge reliability, a second independent judge re-analyzed the designated swallows of 20% randomly selected participants (8 subjects). The second judge is a graduate student who has undergone training on temporal measures for another investigation. The measurements of the investigator and second judge were found to have a significant correlation via the interclass correlation coefficient (ICC) (.98, $p<.01$). For intra-judge reliability, the investigator re-analyzed the same 20% participants a second time. A significant correlation was observed between the first and second set of measurements (.99, $p<.01$).

2. Age

The OTT value did not differ significantly between younger and older subjects ($F_{(1, 187)}=2.87$, $p=.15$). Table 1. Figure 1.

Table 1. Mean OTT values and standard deviations of young and old subjects in three different bolus consistencies

Group	Consistency	*M*	*SD*
Young	Thin liquid	.43	.22
	Nectar thick liquid	.46	.15
	Puree	.53	.32
Old	Thin liquid	.38	.17
	Nectar thick liquid	.37	.18
	Puree	.53	.31

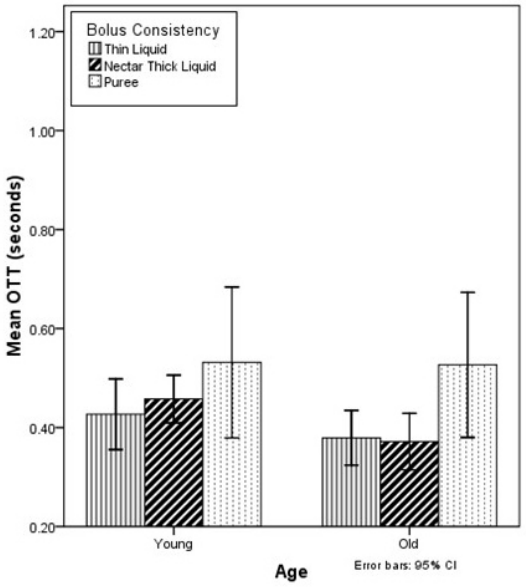

Figure 1. Mean oral transition time values and 95% confidence interval for the three bolus consistencies among young and old subjects

The PTT value was significantly longer for older subjects compared to younger subjects ($F_{(1, 186)}=28.84$, $p<.01$). It indicated that age does have a significant effect on the time to transit the bolus through the pharynx. Table 2. Figure 2.

Table 2. Mean PTT values and standard deviations of young and old subjects in three different bolus consistencies

Group	Consistency	*M*	*SD*
Young	Thin liquid	.61	.10
	Nectar thick liquid	.63	.10
	Puree	.78	.25
Old	Thin liquid	.72	.12
	Nectar thick liquid	.71	.13
	Puree	1.03	.41

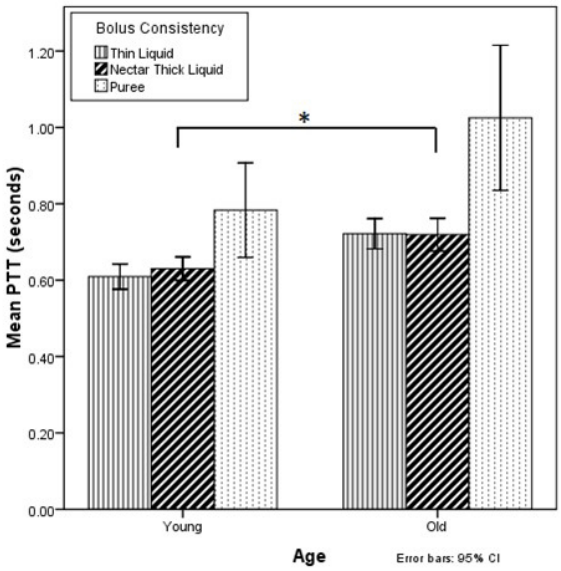

Figure 2. Mean pharyngeal transition time values and 95% confidence interval for the three bolus consistencies among young and old subjects

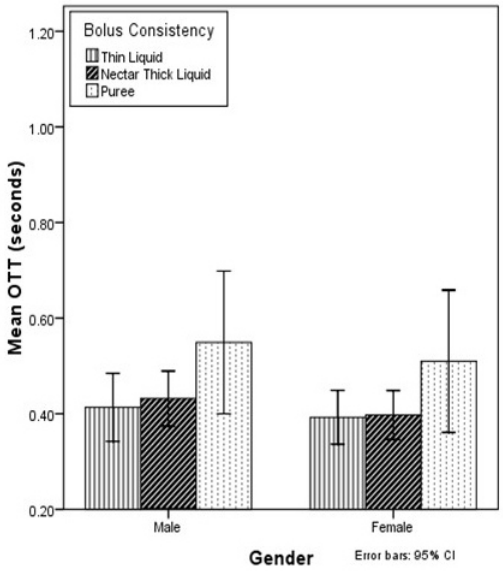

Figure 3. Mean oral transit time values and 95% confidence interval for the three bolus consistencies among male and female subjects

3. Gender

The OTT value did not differ significantly between male and female subjects ($F_{(1, 187)}$=.96, p=.33). The PTT value did not differ significantly between male and female subjects ($F_{(1, 186)}$=.57, p=.45). Table 3 and 4. Figure 3 and 4.

Table 3. Mean OTT values and standard deviations of male and female subjects in three different bolus consistencies

Group	Consistency	*M*	*SD*
Male	Thin liquid	.41	.22
	Nectar thick liquid	.43	.18
	Puree	.55	.31
Female	Thin liquid	.39	.18
	Nectar thick liquid	.40	.16
	Puree	.51	.32

Table 4. Mean PTT values and standard deviations of male and female subjects in three different bolus consistencies

Group	Consistency	*M*	*SD*
Male	Thin liquid	.67	.10
	Nectar thick liquid	.68	.15
	Puree	.94	.38
Female	Thin liquid	.66	.12
	Nectar thick liquid	.67	.10
	Puree	.88	.34

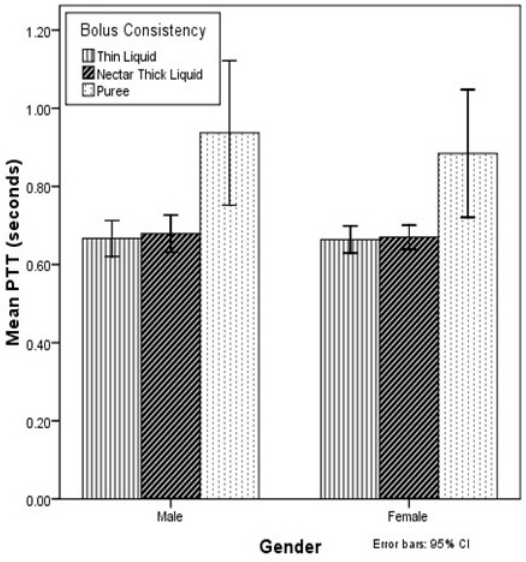

Figure 4. Mean pharyngeal transit time values and 95% confidence interval for the three bolus consistencies among male and female subjects

4. Consistency

The values for OTT were significantly longer for puree consistency compared to thin and nectar thick liquids ($F_{(1.187)}$=4.95, p<.01). This indicated that regardless of age or gender puree consistency boluses take longer time to transit through the oral cavity after oral initiation of the swallow.

The values for PTT were also significantly longer for puree consistency swallows compared to thin and nectar

thick liquid swallows ($F_{(1.186)}$=25.40, p<.01). This indicated that regardless of age or gender puree consistency boluses take longer to transit through the pharynx in normal swallowing.

Ⅳ. Discussion

The objective of this study was to determine if age and gender have significant effects on two transition times in normal oropharyngeal swallowing. The study also aimed to determine the effects of the consistency of the bolus (5㎖ thin, nectar thick, and puree) on the transition times in normal oropharyngeal swallowing. This study found that neither age nor gender has a significant effect on the OTT of the bolus. In addition, gender differences were not found in the PTT of the bolus. However, older subjects displayed significantly longer PTT than younger subjects. No interaction was found between age or gender and the consistency of the bolus and gender, but significantly longer OTTs and PTTs were recorded for puree consistencies than thin and nectar thick liquids regardless of age or gender. The findings and clinical implications of the effects of age, gender, and consistency on the oropharyngeal transition of the bolus are discussed below.

1. Age

In the current study, the older subjects tended to, on average, have shorter OTT of the bolus for thin and nectar thick consistency swallows than younger subjects. However, this difference was not found to be significant. These findings are consistent with that of Tracy et al. (1989) where older subjects consistently held the bolus more posteriorly in the oral cavity, therefore, completing oral transition of the bolus more quickly. However, the age-related change of posterior placement of the bolus is not enough to significantly affect the oral transition duration of the bolus. Posterior placement of bolus may put these older subjects in risk of penetration or aspiration due to premature spillage, as the bolus may enter the pharynx and the airway before laryngeal closure. However, the older subjects in this study showed mild penetration (penetration aspiration scale (PA scale): 〈3) but did not show deep penetration (PA scale 4 or 5) and aspiration. They may compensate or overcome possible airway invasion. It is important to find out how these older subjects compensate for premature spillage during the swallow.

Sonies et al. (1988) a study on age and bolus transition using ultrasound, found that oral transition time of the bolus increases with age. These results are inconsistent with the results of the current study. However, timing events of oral transition of the bolus in the current study cannot directly be related to the Sonies' study because there is a difference between bolus volume and consistency between the two studies. Sonies et al. (1988) used dry swallows and 20㎖ wet swallows and did not control for consistency. A 20㎖ bolus is a large enough volume to required increased effort and stress on the swallowing mechanism, which could affect the duration of the bolus (Cook et al., 1989).

It is most likely that OTT findings in this investigation were not significantly different due to the range of variation in the measurements within the older subjects. For example, the longest OTT of the bolus for a thin liquid swallow reported in the old subject group was .77 seconds and the shortest reported was .10 seconds. This is significant range considering the average duration for oral transition of the bolus is approximately .50 seconds to 1.0 seconds. Similarly, the longest reported duration for nectar thick liquids was .90 seconds and the shortest being .17 seconds. Lastly, for puree consistency swallows, the longest duration for OTT for older subjects was 1.43 seconds and the shortest .20 seconds.

It is important to consider that each individual experience different physical age related changes. In this study, the older individuals as a group do not differ significantly in oral transition of the bolus. But it is possible for significant differences to occur on an individual basis. For example, consider an old female subject. Her OTT were: thin liquid consistency swallows: .10 seconds, nectar thick consistency swallows: .17 seconds, and puree consistency swallow: .43 seconds. She exhibited considerably shorter oral transition of the bolus compared to younger subjects. This is because the subject consistently held the bolus more posteriorly in the oral cavity like the older subject in the Tracy et al. (1989), which created a quick transition of the bolus in the oral cavity. She also showed limited range of tongue motion.

In this study, increased pharyngeal transition with increased age may lead to several clinical implications. The longer pharyngeal transition in older subjects is likely related to the reduction in sensory and neuromuscular function as age increases. A longer PTT places the elderly at higher risk of dysphagia, particularly when a long PTT is accompanied by a pharyngeal swallow delay such as stage transition duration (STD, Kim et al., 2005). Robbins et al.,

(1992) found increased duration of the total oropharyngeal swallow in older subjects. It reported that findings were likely due to delays in hyolaryngeal excursion. STD refers to the time between the bolus passing the ramus of the mandible until initiation of excursion of the hyoid (Robbins et al., 1992). Delayed STD leads to a high risk of pharyngeal dysphagia, such as penetration and aspiration. In addition, a long PTT requires the elderly to extend their laryngeal closure as the bolus remains in the pharynx for a longer time. It may be a burden to maintain long hyolaryngeal excursion and to hold his or her breath for an extended time. Thus, a long PTT may make the elderly fatigue easily and lengthen the overall swallowing duration. It has even been reported that increased incidence of aspiration pneumonia in several populations have been associated with longer than normal pharyngeal transition times (Johnson et al., 1992).

Although a prolonged PTT for thin liquids increases the odds of aspiration, the elderly population has not been found to be more predisposed to penetration or aspiration. As a part of routine VFSE analysis in the research laboratory, the principal investigator had access to information of penetration and aspiration scale in all participants in this investigation. None of the subjects in this study exhibited deep penetration or aspiration. It can be concluded the elderly can compensate for their longer PTT. This is a significant finding because how the elderly compensate for an increased PTT could be useful to develop clinical compensatory strategies for patients with oropharyngeal dysphagia. Although age alone does not put an individual at risk for dysphagia, it is important to note that the elderly populations are in fact more vulnerable to suffer from stroke, Parkinson's disease, Alzheimer's or other age related illnesses and diseases which dysphagia is frequently accompanied with (Logemann, 1987, 1988).

2. Gender

The results of this study indicate that men and women do not significantly differ in OTT or PTT. Both temporal measurements were slightly longer on average for males than females, but differences were not significant. The small difference can be attributed to the difference between men and women anatomically, including the fact that men typically have a longer pharynx than women (Fitch & Giedd, 1999). Differences have been reported previously, however Dantas et al. (2009) reported that women showed significantly longer oral transit time and pharyngeal clearance than men and indicated that women tend to swallow smaller volumes at lower flow rates. Regueiro et al. (2018) reported size differences in that taller men had longer PTT than shorter female. Sonies et al. (1988) reported age differences in that longer mean swallowing durations were observed in older women compared to older men. The results of this study were similar to McKee et al. (1998) who reported no significant gender effects on the speed of pharyngeal contraction. Research to date, has not been able to provide a significant amount of evidence to create differences between men and women for normative bolus transition data, and it may very well be that mixtures of age, size, and other factors influence results of individual studies. It remains important to control for gender in swallowing studies to help gain a better understanding of what gender differences exist.

3. Consistency

The significant differences found for both OTT and PTT in all subjects between puree consistency and thin and nectar thick liquids may be attributed to increase in viscosity of the puree consistency bolus. The thicker bolus will move slowly through oral and pharyngeal cavities, thus resulting in increased bolus transition duration. The increase in oral and pharyngeal transition as viscosity increases can potentially be useful information for determining safe bolus consistencies for patients with dysphagia (Nascimento et al., 2015). Although increases in the duration of bolus transition in thin and nectar thick liquids are presumed to be dangerous, this is not necessarily the case for puree consistency. The increased viscosity of the puree consistency stays cohesive and decreases the risk for misdirection in the larynx, therefore penetration and/or aspiration. In clinical setting, when a patient has difficulty swallowing thin liquid, thickened liquids are preferred because they form a cohesive bolus (Garcia et al., 2005).

4. Limitations and Future Directions

The study consisted of a small number of subjects with only 40 subjects divided by age and gender. Future studies should use a greater amount of subjects when attempting to replicate these results including middle age group. In addition, only one bolus volume of 5㎖ was analyzed, thus different bolus volumes were not taken into consideration. Age and gender effects on oropharyngeal transition of the bolus could potentially vary depending on the bolus volume. The future studies should investigate different bolus

volumes. The findings of this study suggested that the older individuals compensate for their increased pharyngeal transition of the bolus. It is necessary to discover how this compensation is achieved in the older individuals. It is necessary to investigate relationship among clinical signs and neuromuscular and physiological factors related to age differences. It is our intention to explore other physiological measurements to compare to outcomes of this investigation.

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