Rehabilitation Practice and Science

Volume 40
Issue 1 *Taiwan Journal of Physical Medicine and Rehabilitation (TJPMR)*

Article 1

12-31-2012

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Yang, Tsui-Fen; Chan, Rai-Chi; Lee, Shinn-Shing; and Wang, Jia-Chi (2012) "Quantitative Investigation of Effect of Age and Bolus Characteristics on Laryngeal Movement during Swallowing," *Rehabilitation Practice and Science*: Vol. 40: Iss. 1, Article 1.
DOI: https://doi.org/10.6315/2012.40(1)01
Available at: https://rps.researchcommons.org/journal/vol40/iss1/1

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Original Article

Quantitative Investigation of Effect of Age and Bolus Characteristics on Laryngeal Movement during Swallowing

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Objective: The purpose of this study was to investigate the physiologic changes of swallowing along with normal aging, and to study the influences on swallowing of gender and food consistency.

Methods: One hundred adult men and women aged 24 to 80 participated. Each subject underwent a swallowing evaluation, in which a surface transducer was placed on the neck to detect laryngeal movement when they performed a dry swallow and wet swallow for different food consistencies. Main outcome measures included mean onset, mean amplitude and mean duration of the deglutition wave.

Results: In this study, the onset of the dry swallow deglutition wave reached statistical difference with warm water, ice water and cookie swallows, but not with a pudding swallow. Prolonged onset and largest amplitude of deglutition wave were actually observed during dry swallow. There was no significant difference between the onset of the deglutition wave following the ice water and warm water swallow for each age group. The onset of deglutition for the subjects aged 61-80 was slower than for the younger subjects. The male subjects revealed significantly larger amplitude of deglutition wave than the females for each food consistency. The 21-40 year-old male subjects had significantly larger deglutition wave amplitude with the dry swallow; warm water and cookie swallow than the female groups.

Conclusion: Our results suggest that even among normal populations, dry swallowing is not an easy task to do. Slowing of the initiation of swallowing reflex might begin as early as 60 years old. And, aging alone does not significantly affect the strength of oral pharyngeal muscles particularly in female population. (Tw J Phys Med Rehabil 2012; 40(1): 1 - 7)

Key Words: deglutition, aging, food consistency

INTRODUCTION

A substantial number of elderly adults experiences difficulties in the oral, pharyngeal and esophageal phases of swallowing. Only when the nervous system is intact and the deglutitive musculature in the oral cavity, pharynx, larynx, and esophagus is in good order can a well-coor-

Submitted date: 31 August 2011 Revised date: 9 December 2011 Accepted date: 15 December 2011
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dinated, successful swallow take place. [1,2] Various studies to date on swallowing and aging suggest that some of the difficulties experience with swallowing are direct results of normal aging, which include physiological changes of respiratory control and motor performance during the oral, pharyngeal and esophageal phases of swallowing. [3,4] Some of these changes may occur as early as 45 years old.[5] Sonies et al have suggested that minor oral neuromotor and subclinical changes occur with normal aging. They have likewise established that a pattern of multiple lingual gestures arises after 55 years old in both sexes and particularly in women. [6] Humbert et al have demonstrated that older adults produce more cortical involvement than younger adults when swallowing, as indicated by an increase in their Blood-Oxygen-Level-Dependent (BOLD) signals. [7] Higashijima has found that physiological aging of the respiratory and swallowing muscles of older women relates to decline in their swallowing functions. [8] Caruso and Max have identified that elderly adults experience a lessening of sensitivity in their oral and pharyngeal cavities. [9] Changes in sensory perception, including smell, taste and decreased muscle strength in related oral pharyngeal structure due to alterations in mass and contractility are also frequently observed. [10-14] Notwithstanding such findings; however, aging alone has not conclusively been confirmed as cause of dysphagia. Nilsson et al have, for instance, indicated that while the overall coordination of swallowing does undergo change in aging adults, primary aging does not affect the coordination of the oral and pharyngeal phases of swallowing. [15] Shaker and Lang have concluded that in the pharynx, physiological adaptation, rather than decline, occurs with normal aging, with structural change of the upper esophageal sphincter. [16] There likewise remains strong disagreement over what constitutes normal swallowing in elderly persons. [17]

As swallowing is the outcome of a complex series of events, and given that not only aging but other medical issues may possibly account for swallowing difficulties [9,18,19] further research on physiologic and other changes in swallowing patterns of normal populations is needed to establish a basis for comparing subjects with swallowing disorders. Moreover, only a few studies have addressed time issues, such as the age at which physiological changes do commence, and whether gender and food consistency do make any difference or not to swallowing. The present study therefore investigated physiologic changes of swallowing with normal aging, and examined the influences on swallowing functions of gender and food consistency.

METHODS

Participants

One hundred healthy adults, comprising 50 males and 50 females aged 24 to 80 (mean 51.2±17.4), met the inclusion criteria and were enrolled in this study. None had any history of neurological impairments (including stroke, Parkinson disease, traumatic brain injury, motor neuron disease or head and neck cancer, etc.) or took any medication that would interfere with orofacial motor and sensory performance. Each subject completed a questionnaire that looked into their regular eating habits and swallowing performance. No subject was included who reported swallowing difficulties or was judged to have structural or functional problems over the orofacial area. For study purposes, the subjects were grouped into three age categories (Group 1: aged 21-40; Group 2: aged 41-60; Group 3: aged 61-80, respectively). The Ethics Committee of the Veterans General Hospital approved this study and every subject provided their written informed consent.

Equipment and Methods

Each subject underwent a swallowing evaluation using a Computerized Laryngeal Analyzer (CLA) system. They were asked to sit upright comfortably in a chair with back and arm support. A surface transducer was placed on the neck, and held against the thyroid cartilage by a neckgear device (Figure 1) to detect laryngeal movement, since this is believed to play a pivotal role in the pharyngeal phase of swallowing. [20] The subjects were then asked to dry swallow and then wet swallow three times in a row for each food consistency (10ml ice water and warm water, a spoon of pudding and 4cm^2 cookies, respectively), with five minutes' rest in between. For consistency, the temperature of ice water and pudding was around 4°C, and temperature of warm water was around 45°C (The temperature of each food consistency

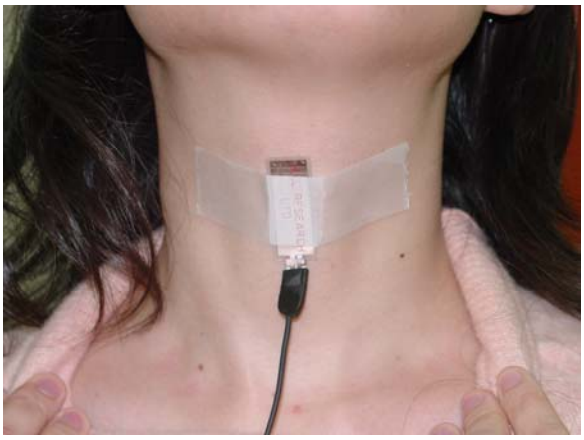

Figure 1. A surface transducer was placed on the neck and held against the thyroid cartilage to sense laryngeal motion during deglutition.

was controlled by the same thermometer). The piece of cookie was chewed to form a cohesive bolus before swallowing. The signals collected by the CLA were generated by an electromechanical (pressure responsive) transducer that senses changes of forces and motions caused by the larynx during deglutition. The measured signals were amplified and isolated by the communication interface unit, converted to digital information and transferred to an IBM-compatible personal computer for real-time display on the screen. The main outcome measures included mean onset, mean amplitude and mean duration of the deglutition wave of the three swallows, which were collected and calculated automatically.

Statistical Analysis

Data were presented as the mean ± standard deviation. The Mann-Whitney *U* test was used to investigate the difference between two groups and the Kruskal-Wallis test was used to investigate the difference between three and more groups. All statistical analyses were conducted with SPSSx software (SPSS, Inc., Chicago, IL, USA). A *p* value of less than 0.05 was considered statistically significant.

RESULTS

The amplitude of the deglutition wave for the ice and warm water swallow reached statistical difference with the dry swallow and cookie swallow (p=0.001, 0.007 for IC and 0.007, 0.038 for WC respectively), but not with the pudding swallow (p=0.065). The onset of the deglutition wave for the dry swallow reached statistical difference with the warm water, ice water and cookie swallows (p=0.016, 0.010, 0.002 respectively), but not with the pudding swallows (p=0.087) (Table 1). Prolonged onset and largest amplitude were actually observed during dry swallow. No significant difference was shown between food consistencies in terms of the duration of the deglutition waves (p=0.365) (Table 1).

The influence of gender was mainly on the amplitude of the deglutition waves, but not on the onset (p=0.055, 0.668. 0.189, 0.065 and 0.218 for DS, WW, IW, PS, CS respectively) and duration of the swallow (p=0.380, 0.548, 0.056, 0.051, 0.128 for DS, WW, IW, PS, CS respectively) (Table 2). The male subjects had significantly larger amplitude of deglutition wave than the female subjects for each food consistency.

The three groups consisted of 32, 33 and 35 subjects, respectively. Mean age of group 1 was 30.53±4.27, group 2 was 50.36±5.75, group 3 was 70.83±6.15. The onset of the deglutition wave for the ice water swallow reached significant difference for the three age groups, with subjects in group 3 reaching a slower onset of deglutition than the younger subjects (p=0.004 and 0.039 respectively) (Table 3). However, when swallowing warm water, the onset of the deglutition wave of group 3 reached statistical difference with group 1 only and not with group 2 (p=0.048 and 0.343 respectively). In each age group, there was no significant difference between the onset of the deglutition wave for the ice water and the warm water swallow (p=0.543, 0.342 and 0.668 respectively). The amplitude of the deglutition waves for the water swallow and the pudding swallow reached significant difference for all three age groups, with the youngest group demonstrating larger amplitude of deglutition compared with the older subjects (p=0.039, 0.005 and 0.043 for WW, IW and PS respectively) (Table 3). Since gender also exerted a certain influence on deglutition wave amplitude, as shown in Table 2, the subjects were further categorized for comparison into six groups by both gender and age. The group of 21-40 year-old male subjects had a significantly larger deglutition wave amplitude in the dry swallow; warm water and cookie swallow as compared with the female groups (*p*=0.004, 0.010 and 0.05 respectively). The 21-40 year-old male group also had a significant larger amplitude in the ice water and pudding swallows than the 41-80 year-old female groups (p=0.001 and 0.013 respectively). This would imply that the major contribution to the gender difference on deglutition wave amplitude came from the group of 21-40 year-old male subjects. After 40 years, the gender difference of deglutition amplitude appeared less obvious than at the earlier ages (Table 4).

Table 1. Characteristics of deglutition wave during dry swallow and bolus swallow

	Latency (second)	Amplitude (mV)	Duration (second)
DS	0.42±0.28	57.95±30.36	1.16±0.52
WW	0.35±0.27	52.05±25.39	1.61±0.81
IW	0.34±0.26	50.69±27.15	1.54±0.65
PS	0.37±0.29	54.40±25.76	1.56±0.64
CS	0.36±0.26	57.75±27.66	1.76±0.92
P value	0.018*	0.038*	0.365

* p<0.05

Abbreviation: DS, dry swallow; WW, warm water; IW, ice water; PS, pudding swallow; CS, cookie swallow.

Statistical analysis: by Kruskal-Wallis test.

Table 2. The amplitude of the deglutition wave reached statistical difference between different genders for each food consistency

	Male (mV, mean± SD)	Female (mV, mean±SD)	*P* value
DS	67.76±30.30	47.98±27.26	0.001*
WW	61.04±27.53	43.06±19.49	0.001*
IW	60.32±27.15	41.06±23.75	0.000*
PS	62.42±26.99	46.38±0.94	0.002*
CS	66.08±29.13	49.42±23.57	0.003*

* P<0.05

Abbreviation: DS, dry swallow; WW, warm water; IW, ice water; PS, pudding swallow; CS, cookie swallow.

Statistical analysis: by Mann-Whitney *U* test.

Table 3. The onset and amplitude of deglutition wave according to three age groups

	Latency (second)				Amplitude (mV)			
Group (No)	Group 1 (33)	Group 2 (32)	Group 3 (35)	*P* value	Group 1 (33)	Group 2 (32)	Group 3 (35)	*P* value
DS	0.34±0.24	0.43±0.27	0.49±0.33	0.108	62.66±31.48	57.94±29.45	57.94±29.45	0.498
WW	0.28±0.15	0.35±0.25	0.42±0.26	0.023*	61.72±26.99	45.94±21.35	48.97±25.50	0.039*
IW	0.26±0.19	0.31±0.19	0.44±0.33	0.024*	62.94±26.73	42.88±21.34	46.86±29.19	0.005*
PS	0.32±0.25	0.39±0.30	0.39±0.33	0.638	63.97±26.31	50.21±23.40	49.60±25.68	0.043*
CS	0.31±0.22	0.31±0.26	0.46±0.37	0.488	61.75±25.01	57.09±28.19	54.71±29.75	0.462

* *p<0.05*

Abbreviation: DS, dry swallow; WW, warm water; IW, ice water; PS, pudding swallow; CS, cookie swallow.

Statistical analysis: by Kruskal-Wallis test.

Table 4. Amplitude of deglutition wave according to age group and gender

Group (No.)	Group1 (11)	Group 2 (25)	Group 3 (14)	Group 4 (21)	Group 5 (8)	Group 6 (21)	*P* value
DS	40.00±27.42	51.52±27.93	47.92±26.49	74.52±27.03	78.00±26.12	57.10±32.71	0.004*
WW	49.55±22.11	41.12±18.56	41.43±19.33	68.10±27.56	61.00±23.67	54.00±28.22	0.010*
IW	54.55±29.82	39.64±20.37	33.00±21.18	67.33±24.57	53.00±22.46	56.10±30.55	0.001*
PS	55.82±29.45	45.64±20.56	40.29±15.84	68.24±24.15	64.50±27.31	55.81±29.28	0.013*
CS	46.36±16.99	53.60±25.68	44.36±24.21	69.81±25.03	68.00±34.54	61.62±31.59	0.050*

* $p<0.05$

Group 1: age 21-40 female; group 2: age 41-60 female; group 3: age 61-80 female; group 4: age 21-40 male; group 5: age 41-60 male; group 6: age 61-80 male.

Abbreviation: DS, dry swallow; WW, warm water; IW, ice water; PS, pudding swallow; CS, cookie swallow.

Statistical analysis: by Kruskal-Wallis test.

DISCUSSION

In daily clinical practice, patients with a high risk of aspiration and still using tube feeding are always instructed to repeatedly practice dry swallowing during their treatment sessions before they take any food by mouth. However, based on our observation here, dry swallowing is almost the most difficult task to perform compared to the others. Our results showed that it takes longer to initiate and more force needs to be generated during each swallow (Table 1). The amplitude of deglutition waves of dry swallowing was found to be almost equal to the amplitude of cookie swallowing. As expected, owing to their softer consistency, the water and pudding swallowing took less effort. This finding was compatible with research by Humbert et al which found that saliva swallowing elicits significantly higher BOLD responses in regions important for swallowing, compared with water and barium swallowing.[7] The greater effort required for dry swallowing is probably owing to a lack of strong sensory input during the swallow as compared with other situations, which makes dry swallowing more difficult to perform. However, for patient at high risk of aspiration, dry swallowing is definitely a safer task for treatment sessions. Moreover, a patient's ability to handle reasonably well the skill of dry swallowing may indicate they are able to progress to other food consistencies and thus make good progress in treatment sessions.

In this study, we were surprised to observe that for each age group, there was no significant difference between the onset of deglutition wave with ice water and warm water swallowing. Despite a trend of earlier onset of deglutition waves with ice water swallowing in the 21-60 year-old subjects, an opposite trend was observed in the 61-80 year-old subjects (Table 3). Progressively decreased sensory sensitivity in the oral pharyngeal region of the aged subjects might account for this unexpected observation. Also, subjects aged 61 to 80 demonstrated a slower onset of deglutition waves during water swallowing as compared to the younger subjects. Our observation here is compatible with previous findings that younger subjects had a lower threshold for triggering a protective pharyngeal swallow.[1,18] It is also compatible with clinical observations that in normally ageing people, even where there are no significant complaints of eating difficulty, there is still an increasing incidence of choking episodes when they are drinking water. They are also prone to choking on their saliva if not very alert. Subconsciously, this tendency would possibly keep them from drinking enough water to maintain hydration to avoid the unpleasantness of choking. This ongoing physiological decline would no doubt impact upon aged subjects whenever they encountered a major life event, such as a cerebrovascular accident.

The amplitude of deglutition waves for water swallowing and pudding swallowing reached significant difference for three age groups, with the youngest group showing a larger amplitude of deglutition compared with the elder subjects (Table 3). On further investigating these figures, however, we found that the major contribution to this finding was the larger amplitude generated during swallowing from the 21-40 year-old male subjects. According to our findings, ageing itself did not have a significant effect on the amplitude of deglutition waves for the 21-80 year-old female subjects or for the 41-80 year-old male subjects (Table 4). The possible explanation for this is that, after all, swallowing a well-prepared small bolus after the oral phase is not a heavy task for most normal aging subjects; or that aging itself does not much affect the strength of those oral pharyngeal muscles responsible for swallowing.

CONCLUSION

Certain subclinical neuromotor changes do occur alongside normal aging, as indicated by Sonies et al[6] and reinforced by our own findings. This study revealed several observations. Firstly, dry swallowing is not an easy task to do even for normal population. Secondly, the slowing of swallowing reflex initiation might begin as early as age of 60 years. Thirdly, aging does not significantly affect the strength of oral pharyngeal muscles. Further information in terms of physiologic changes in swallowing patterns of normal populations is mandatory so there can be a basis for comparisons of subjects with swallowing disorders.

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年齡及食物種類對吞嚥時喉部動作之影響

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目的：本研究擬探討正常老化、性別以及食物種類對吞嚥功能造成的影響。

方法：總共有 100 位年齡介於 24 歲到 80 歲的個案參與本研究,男女各半。研究使用固定在喉頭的表面記錄電極記錄乾吞口水及吞食不同種類食物時喉頭的位移狀況。主要的評估參數包括吞嚥波的平均潛伏期、振福及間期。

結果：研究顯示，所有個案乾吞口水時吞嚥波的平均潛伏期與喝水及吃餅乾時有顯著差異，但與吃布丁時沒有差别。事實上，乾吞口水時吞嚥波的平均潛伏期及振幅均大於進食其他種類的食物。喝冰水及溫水時吞嚥波的平均潛伏期不管在年輕及年長個案組均無顯著差異。61-80 歲這組個案吞嚥時的平均潛伏期顯著比年輕的個案來得長。而男性不管在吞食何種食物黏度的吞嚥波振福均顯著大於女性，其中又以 21-40 歲的年輕男性這組與女性的差異最爲明顯。

結論：吞嚥治療時常用的乾吞口水並不是容易進行的技巧，而吞嚥反射在 60 歲以上的個案顯著慢於年輕的個案；另外，正常的老化並不太影響吞嚥的力量，尤其是女性個案。（台灣復健醫誌 2012；40(1)：1 - 7）

關鍵詞：吞嚥(deglutition)，老化(aging)，食物黏度(food consistency)

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