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<td>Author(s)</td>
<td>Chan, Doris; 陳婷婷</td>
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Validation of a tongue pressure measurement tool as a screening tool of oropharyngeal dysphagia in Hong Kong geriatric population

Chan Doris

(2008058235)

A dissertation submitted in partial fulfillment of the requirements for the Bachelor of Science (Speech and Hearing Sciences), The University of Hong Kong, June 30, 2012.
Abstract

This study aimed at validating Iowa Oral Performance Instrument (IOPI), a tongue pressure measurement tool, as a screening tool of oropharyngeal dysphagia in Hong Kong geriatric population. 8 dysphagic and 26 non-dysphagic elderly who aged 60 or above were recruited for oral motor examinations, trial swallow tests and the measurements of tongue peak pressure with IOPI. The results showed a significant difference in the tongue peak pressure between dysphagic and non-dysphagic group, a high inter- and intra-rater reliability of the measurement and a strong correlation between tongue peak pressure and the rating of oral motor examination. The result supported that the measurement of tongue peak pressure is a valid and reliable screening method of oropharyngeal dysphagia.
Introduction

Dysphagia is defined as the difficulty in the transition of food from oral cavity to stomach (Logemann, 1998). Impairment can occur in any one of the oral preparatory phase, oral transit phase, pharyngeal phase and esophageal phase of swallowing (Logemann, 1998). Oropharyngeal dysphagia specifically refers to the difficulty occurring at the oral phase, oral transition phase and the pharyngeal phase of swallowing (Robinovitch et al., 1991). It is a disorder that deserves great and immediate attention as it may lead to fatal consequence due to suffocation or aspiration pneumonia. This fact can be reflected by the statistics that hospitalized patients with dysphagia had a risk of mortality thirteen folds higher than those without dysphagia. Particularly, frail elderly, which refers to aged elderly who are prone to vulnerability, disease and poor outcome, were found to be exposed to a higher fatal risk due to dysphagia when compared to healthy elderly (Rofes et al., 2010). Despite of this fact, this thread can be minimized with the help of early identification and management. Therefore, a quick, valid and reliable way for the screening of oropharyngeal dysphagia is in need in geriatric population in order to ensure early identification and thus intervention of dysphagia.

Two types of screening methods have been developed to meet the need of early identification. They are direct assessments (for example, trial swallow test) and indirect assessments (oral motor examination) (Logemann, 1998). However, evidence on their reliability and sensitivity was limited at present. Concerning direct assessments, a currently available screening method for oropharyngeal dysphagia is the 3-oz water swallow test, in
which cup-drinking of 3-oz water is done and any coughing and wet voice during or after swallowing is observed (DePippo, Holas, & Reding, 1992). However, no inter-rater reliability was established in its validation process. The study was replicated the water swallow test to one hundred individuals (Garon, Engle, & Ormiston, 1995). The result showed that as high as 65% of the individuals who got silent aspiration, a condition in which food enter the airway below the vocal fold without cough reflex, were not identified by 3-oz water swallow test. Another criticized direct screening test is the simple swallowing provocation test, in which the time required for the triggering of swallowing reflex is measured (Teramoto & Fukuchi, 2000). But the sensitivity of the test for detecting aspiration was investigated to be low .

Concerning indirect screening methods, oral motor examination constitutes an important part in the screening. While the direct screening methods focus on the signs of aspiration, oral motor examination investigates the abnormal physiology, which is one of the diagnostic markers for oropharyngeal dysphagia (Martino, Pron, & Diamant, 2000). However, again, the validity and inter-rater reliability have been concerned because of its subjective nature (Clark, Henson, Barber, Stierwalt, & Sherrill, 2003). Traditionally, subjective rating is used in oral motor examination . In the study by Clark et al. (2003) investigating the reliability of oral motor examination, two experienced speech pathologist and nine graduated students were recruited to give ratings on the tongue strength of dysphagic individuals. The results showed that the ratings were subject to clinical experience. As the subjectivity of the traditional oral motor examination is likely to affect the validity and
reliability of the examination, an objective measurement of oral motor functioning is in need to raise the reliability of the screening.

One of the possible objective parameters is the tongue peak pressure, which is a correlate of the tongue strength (Clark et al., 2003). It can be measured by Iowa Oral Performance Instrument (IOPI), a small, portable, battery-operated instrument with an air-filled bulb, a control panel and a LCD monitor as shown in Figure 1. When one exerts pressure on the bulb, a value in kilopascal (kPa) will be displayed on the LCD monitor. The instrument is designed to obtain either the tongue peak pressure or the tongue endurance time of an individual.

*Figure 1. Iowa Oral Performance Instrument (IOPI)*
Measuring the tongue peak pressure is a potential way to increase the objectivity and reliability of screening because any tongue weakness is likely to associate with the ability to swallow. The tongue has an important role in deglutition, including bolus formation and the transfer of bolus from the posterior tongue to the pharyngeal area (Robinovitch et al., 1991). Therefore, any abnormality in the tongue can impair one or more of the above processes. To apply the measurement of tongue peak pressure to screening, a database about the tongue strength in people with normal and impaired swallowing must be established to find a diagnostic cut-off point. Several studies have contributed to the establishment of such database (Crow & Ship, 1996; Robin, Goel, Somodi, & Luschei, 1992; Robinovitch et al., 1991; Stierwalt & Youmans, 2007). For examples, Crow and Ship (1996) investigated the tongue strength variation across age and gender; meanwhile Stierwalt and Youmans (2007) collected tongue pressure data from both dysphagic and non-dysphagic individuals.

All of the above studies represented an effort in creating a database of tongue pressure. This shed light on the use of IOPI in the screening of oropharyngeal dysphagia (Crow & Ship, 1996; Stierwalt & Youmans, 2007). However, there have been three main obstacles in applying the data to the screening of oropharyngeal dysphagia for elderly. First, studies which compared tongue peak pressure in normal and dysphagic swallowing specifically in geriatric population were still limited. The study conducted by Stierwalt and Youmans (2007) collected data in both normal and impaired swallowing, but their data was collapsed across age during analysis. included individuals aged from 60 to 79 and from 80 to
96 in their study, but no comparison with any dysphagic individuals was made.

Secondly, previous studies have established database for individuals with oral phase dysphagia, but none has established one for those with oropharyngeal dysphagia. For instance, the study by Stierwalt and Youmans (2007) investigated the relationship between tongue strength and the signs of oral phase dysphagia, and their data could not be applied to individuals with oropharyngeal dysphagia. The study by Robinovitch et al. (1991) also investigated the relationship between tongue force and the impairment in oral phase only. However, the tongue actually takes a role in other phases of swallowing. For example, it assists the squeezing of bolus down the pharynx in the right direction in pharyngeal phase, and any impairment can lead to the presence of residue in the vallecular spaces (Robinovich et al., 1991). So tongue peak pressure has the potential to predict oropharyngeal dysphagia despite the inadequate evidence. Thirdly, most samples in the existing literature were recruited from western population, thus the data may not be applicable to Hong Kong population due to ethnic difference. The study conducted by Crow and Ship (1996) collected normative data in different age groups, but all of the subjects were recruited in the USA.

Concerning the above three issues, although some information could be found in the existing literature, they were not enough to support the screening of oropharyngeal dysphagia in Hong Kong geriatric population. Therefore, this study addressed these issues in order to add data to the existing literature.
Objectives

This study aims at validating IOPI as a screening tool of oropharyngeal dysphagia based on Hong Kong geriatric population (aged 60 or above). By conducting this study, the problem of a lack in localized data specified to elderly can be addressed. Two research questions are highlighted in this study: (1) Can measurement of tongue peak pressure differentiate Hong Kong elderly with oropharyngeal dysphagia from those without dysphagia? (2) Does the objective measurement of tongue peak pressure correlate with the subjective rating in OME? These questions are important because they verify a potential instrument which serves as an objective supplement for the traditional oral motor examination, raises the validity and reliability of the screening procedure and eventually allow early identification of dysphagia in geriatric population. In this study, it is hypothesized that the measurement of tongue peak pressure could differentiate elderly with and without oropharyngeal dysphagia because its validity and reliability has been reported by previous studies. It is also hypothesized that the value of tongue peak pressure correlate the rating in oral motor examination because there are evidence in the existing literature though their targeted population was different from that in this study (Clark et al, 2003).

Method

Participants

Participants were recruited from two care and attention homes according to a set of
inclusion and exclusion criteria. While the inclusion criterion is an age of sixty or above, the exclusion criterion was the inability to follow the commands in the oral motor examination and the measurement of tongue peak pressure. According to these criteria, a total of forty-one individuals were recruited, and seven of them were then excluded. In other words, there were thirty-four individuals participating in the study. All the participants were frail elderly.

Operationally defined in this study, they were elderly with a history of acquired brain impairment, for which their medical diagnoses are listed in Table 1.

The participants were then divided into two groups----- dysphagic and non-dysphagic group--- in order to compare the tongue peak pressure between participants with normal and impaired swallowing. Following the criteria below, twenty-six participants were arranged to non-dysphagic group, and seven participants were arranged to dysphagic group:

**Dysphagic group.** Participants should (1) have no history of esophageal dysphagia or psychological dysphagia, (2) be suggested with a diet other than regular diet as suggested by a speech therapist and recorded in the nursing home OR (2) be diagnosed to have oropharyngeal dysphagia during the trial swallow test in this study.

**Non-dysphagic group.** Participants should (1) have no history of signs or symptoms of dysphagia, (2) be having regular diet currently and (3) be diagnosed to have no oropharyngeal dysphagia during the trial swallow test in this study.
Table 1. Medical diagnoses of the participants

<table>
<thead>
<tr>
<th>Medical diagnosis</th>
<th>Number of participants</th>
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<tbody>
<tr>
<td>Cerebrovascular Accident (CVA)</td>
<td>20</td>
</tr>
<tr>
<td>Dementia</td>
<td>8</td>
</tr>
<tr>
<td>Parkinson Disease</td>
<td>6</td>
</tr>
</tbody>
</table>

**Overview of Methodology**

Informal consent was obtained from each of the participants or their guardians prior to the data collection. Each participant underwent three tasks: (1) oral motor examination, (2) trial swallow test and (3) the measurement of tongue peak pressure. The order of the three tasks was randomized across participants to balance any practice effect such as fatigue. Recommendations based on the assessment results were given to each participant in written form after the three tasks. The tasks were administered in the nursing homes by two final year speech therapy students. Since the trial swallow test might cause hazard of aspiration, the students were supervised by one speech therapist to minimize the risk of aspiration.

**Oral motor examination.** The symmetry, strength, range and speed of lip, tongue, jaw and facial muscles, oral sensation, laryngeal functions, voice quality and any features of oral apraxia of each participant were evaluated. A protocol based on the traditional oral motor examination was developed in order to specify the tasks in the examination (Duffy, 2005).
categorical scale was adopted in this study. A rating of either “0”, “1”, “2” or “3” represented “no abnormality detected”, “mildly impaired ability”, “moderately impaired ability” and “severely impaired ability” respectively. One rating was given to each individual item.

**Trial swallow test.** To evaluate the swallowing ability of each participant, the trial swallow test was carried out. For the dysphagic group, medium-thick orange juice in one teaspoon was selected as the food consistency and volume. As tube-fed participants were subject to high risk of aspiration during the test, no trial swallow test was done in the cases of tube-feeding. For the non-dysphagic group, cup-drinking of water and a 1/4 piece of cracker were tried. For both groups, at each level of consistency, three trials were done. Any sign of aspiration and oral residue, which would fail the corresponding trial, was observed and recorded in the recording sheet.

A rating of swallowing ability was given accordingly. The participants who passed all the trials of cup-drinking and intake of soda cracker in one bite were given a rating of 0; those who failed in only one trial in the set of cup-drinking and/or the set of soda cracker were given a rating of 1; those who failed in more than one trial in the set of cup-drinking and/or the set of soda cracker, or failed less than two trials of medium thick syrup, were rated 2; those who failed in two trials or more in medium thick syrup were rated 3.

**The measurement of tongue peak pressure with Iowa Oral Performance Instrument (IOPI).** The tongue peak pressure of each participant was obtained with the use
of IOPI. Prior to the measurement, the IOPI was set up according to the menu provided by the manufacturer. Then the IOPI was turned on and the peak mode was set. During the measurement, the bulb connected to IOPI was positioned at the central groove of the tongue blade against the hard palate (Chang, Chen, Ko, & Lin, 2008; Lazarus et al., 2000). Each participant was instructed to compress the air-filled bulb against the hard palate with the tongue blade as much as possible. Verbal reinforcement was used when each participant was compressing the bulb in order to prompt maximum their response. After each trial, the maximal pressure was written down on the recording sheet. For each participant, a thirty-second interval was included in between the trials to avoid fatigue (Youmans & Stierwalt, 2006). To examine the test-retest reliability, the measurement of tongue peak pressure was administered again to all of the participants. To examine the inter-rater reliability, the measurement of tongue peak pressure with IOPI was repeated by another researcher with twelve of all the participants.

After the above procedures, each participant should have undergone at least two sets of tongue peak pressure measurement, each set with three trials, with one-minute inter-set interval and bulb repositioning. The highest tongue pressure across all of the six trials was selected as the tongue peak pressure. The highest tongue pressure in each set was selected to be the first and the second intra-rater tongue peak pressure respectively. For each of the twelve participants who underwent an extra set of measurement, the highest tongue pressure
of this set was selected as the inter-rater tongue peak pressure (Stierwalt & Youmans, 2007).

Data Analysis

Computation of Raw Scores

The scores that draw the most attention in this study included: (1) the rating of oral motor examination (i.e. overall OME rating), (2) the tongue strength rating, (3) the swallowing rating, (4) the tongue peak pressure, (5) the first intra-rater tongue peak pressure, (6) the second intra-rater tongue peak pressure, and (6) the inter-rater tongue peak pressure. The overall OME rating was calculated by adding the ratings of all the items (totally twenty-eight items, scoring sixty-six at maximum). The tongue strength rating was calculated by adding the rating of tongue lateralization and protrusion strength. The swallowing rating was given based on (1) their current diets and (2) the result of the trial swallow test. For those who were having diet other than regular diet, their rating depended on their diet type. Puree diet or tube-feeding yielded a rating of 3, and minced diet yielded a rating of 2. For those who were having regular diet, their ratings depended on the result of the trial swallow test, which were given immediately after the test.

Statistical Analysis

Comparison between dysphagic and non-dysphagic group in tongue peak pressure. As the group sizes of the two groups were small, especially for the dysphagic
group (i.e. dysphagic: 8; non-dysphagic: 26), independent t-test was likely to offer less protection against the violation of assumptions. Therefore, the testing of assumptions, including normal distribution and the homogeneity of variance, was done to check any violation of them. The assumption of normal distribution was tested by Shapiro-Wilk test. The significant value of both groups were greater than 0.05, indicating normal distribution in both groups. The assumption of equal variance was tested by Levene’s Test for Equality of Variances. The significant value was greater than 0.05, indicating the homogeneity of variance. As both assumptions were not violated, independent t-test was chosen for the comparison of tongue peak pressure between the dysphagic and non-dysphagic group.

**Reliability of the measurement of tongue peak pressure.** The intra-rater reliability of the measurement of tongue peak pressure was determined by correlating the first and the second intra-rater tongue peak pressure using Pearson product moment correlation, while the inter-rater reliability was determined by correlating the tongue peak pressure and the inter-rater tongue peak pressure using Pearson product moment correlation.

**Correlation between tongue peak pressure and the results of other tasks.** To investigate the relationship between objective and subjective measurement of tongue strength, Spearman’s rank-order correlation was done to examine the correlation between the tongue peak pressure and the tongue strength rating. In addition, to further investigate its use as a supplement of oral motor examination, the correlation between the tongue peak pressure and the overall OME rating was also examined with Pearson product-moment correlation. On
the other hand, to investigate how much the tongue peak pressure could predict the
swallowing ability of an individual, Spearman’s rank-order correlation was done to examine
the correlation between the tongue peak pressure and the swallowing rating. To determine if
tongue peak pressure or oral motor examination could predict the swallowing ability more,
the above correlation was compared with that between overall OME rating and the
swallowing rating.

**Result**

**Testing of Assumptions of Independent t-test**

The results of Shapiro-Wilk test and Levene's Test for Equality of Variances are listed
in Table 2. The results indicated that the assumptions of independent t-test were not violated.

Table 2. Result of Shapiro-Wilk test and Levene’s Test for Equality of Variances.

<table>
<thead>
<tr>
<th></th>
<th>Shapiro-Wilk test</th>
<th>Levene’s Test for Equality of Variances</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Statistic</td>
<td>p</td>
</tr>
<tr>
<td>Dysphagic group</td>
<td>0.962*</td>
<td>0.424</td>
</tr>
<tr>
<td>Non-dysphagic</td>
<td>0.927*</td>
<td>0.485</td>
</tr>
</tbody>
</table>

* Significant level was set at 0.05 level.

**Descriptive Data**

The mean, the standard deviation and the range of the overall OME rating, and the
median and mode of the tongue strength rating and the swallowing rating are listed in Table
3. The tongue peak pressure, the first and second intra-rater tongue peak pressure and the inter-rater tongue peak pressure of the two groups are listed in Table 4 and Table 5.

Table 3. The descriptive statistics of overall OME rating, the tongue strength rating and the swallowing rating of dysphagic and non-dysphagic group.

<table>
<thead>
<tr>
<th></th>
<th>Overall OME rating</th>
<th>Tongue strength rating</th>
<th>Swallowing rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (M) (kPa)</td>
<td>Standard deviation (SD)</td>
<td>Range (R)</td>
</tr>
<tr>
<td>Dysphagic group</td>
<td>6.88</td>
<td>5.54</td>
<td>2-19</td>
</tr>
<tr>
<td></td>
<td>1.50</td>
<td></td>
<td>1 - 3</td>
</tr>
<tr>
<td>Non-dysphagic group</td>
<td>3.46</td>
<td>2.97</td>
<td>0-8</td>
</tr>
</tbody>
</table>

Table 4. The mean, standard deviation and range of tongue peak pressure in dysphagic and non-dysphagic group

<table>
<thead>
<tr>
<th></th>
<th>Mean (M) (kPa)</th>
<th>Standard deviation (SD)</th>
<th>Range (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dysphagic group</td>
<td>25.50</td>
<td>11.46</td>
<td>6-47</td>
</tr>
<tr>
<td>Non-dysphagic group</td>
<td>42.96</td>
<td>11.32</td>
<td>15-61</td>
</tr>
</tbody>
</table>
Table 5. The mean, standard deviation and range of intra-rater tongue peak pressures and inter-rater tongue peak pressure in dysphagic and non-dysphagic group

<table>
<thead>
<tr>
<th></th>
<th>The 1\textsuperscript{st} intra-rater tongue peak pressure</th>
<th>The 2\textsuperscript{nd} intra-rater tongue peak pressure</th>
<th>The inter-rater tongue peak pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>R</td>
</tr>
<tr>
<td>Dysphagic group</td>
<td>28.13</td>
<td>13.52</td>
<td>7 - 51</td>
</tr>
<tr>
<td>Non-dysphagic group</td>
<td>41.12</td>
<td>11.51</td>
<td>15 - 57</td>
</tr>
</tbody>
</table>

**Statistical Analysis**

*Comparison between dysphagic and non-dysphagic group in tongue peak pressure.*

To evaluate if the measurement of the tongue peak pressure could differentiate elderly with dysphagia, the mean of the tongue peak pressure of the two groups were compared. Independent t-test was applied to determine if there was any significant difference between them. The results showed that there was a significant difference between the tongue peak pressures of the two groups \( t(32) = 3.806, \text{ 2-tailed}, p < 0.05 \).

*Intra- and inter-rater reliability of the measurement of tongue peak pressure*
with IOPI. To examine the reliability of the measurement of tongue peak pressure, Pearson product-moment correlation was applied to evaluate the correlation among the trials. There was strong intra-rater correlation \( r = 0.925, \) 2-tailed, \( p < 0.001 \) and inter-rater correlation \( r = 0.925, \) 2-tailed, \( p < 0.001 \) as reflected by the results.

**Correlation between tongue peak pressure and the result of other tasks.** To investigate the relationship of tongue peak pressure with the (1) tongue strength rating, (2) overall OME rating and (3) swallowing rating, Spearman’s rank-order correlation and Pearson product-moment correlation were applied. Table 6 shows strong correlations between the tongue peak pressure and the other three measures. Correlation between the overall OME rating and the swallowing rating was also done to compare the correlation in (3), which showed a weak correlation.

Table 6. Correlation of the tongue peak pressure and the (1) overall OME rating (2) tongue strength rating, (3) swallowing rating.

<table>
<thead>
<tr>
<th>Correlation of tongue peak pressure with Rating of tongue strength</th>
<th>Pearson’s correlation (r)</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>-0.557** 0.001</td>
</tr>
<tr>
<td>Spearman’s correlation (( \rho ))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OME total</td>
<td>-0.522** 0.002</td>
<td></td>
</tr>
<tr>
<td>Swallowing rating</td>
<td>-0.510** 0.002</td>
<td></td>
</tr>
</tbody>
</table>

| Correlation of OME total with Swallowing rating | 0.333 0.054 |

** Significant level was set at 0.01 level (2-tailed).
Discussion

This research evaluated the validity and reliability of the measurement of tongue peak pressure as a screening tool of oropharyngeal dysphagia in Hong Kong elderly, with the use of Iowa Oral Performance Instrument (IOPI). The results reflected that the measurement of the tongue peak pressure is valid and reliable for the screening purpose. The following is the discussion about the two main research questions and the implications of these two questions:

Differentiation of Dysphagic and Non-dysphagic Elderly with the Measurement of Tongue Peak Pressure

The first research question was whether the measurement of tongue peak pressure could differentiate Hong Kong elderly with oropharyngeal dysphagia from those without it. The results showed a significant difference in the tongue peak pressure between the dysphagic and non-dysphagic group. This supported the hypothesis that the measurement of the tongue peak pressure could differentiate elderly with and without oropharyngeal dysphagia. Concerning the reliability of the measurement with IOPI, the result showed a strong correlation between the intra-rater trials, as well as the inter-rater trials. This implied that the measurement with IOPI was reliable across time and raters.

Implication on the screening of oropharyngeal dysphagia. The significant difference between the two groups and the high reliability implied that tongue peak pressure measurement is a potential method to screen out the elderly with oropharyngeal dysphagia. Besides the above implication, additional implications could also be yielded by observing the
differences between the results of the current study and the previous studies. These differences were likely to show that populations with different age and types of dysphagia require different tongue pressure normative data and diagnostic cut-off points.

First, the diagnostic cut-off score for the elderly is likely to be different from that for other age range. Stierwalt and Youmans (2007) had compared the tongue strength in normal and impaired swallowing, but, unlike the current study, the results were collapsed across both middle-aged and senior participants. They found a significant difference ($t = 6.48$, 2-tailed, $p < 0.0001$) greater than that in this study. One plausible explanation is that while aged-related decline in tongue strength occurred in non-dysphagic group, none occurred in dysphagic group. Therefore, when comparing the dysphagic and non-dysphagic group at a smaller average age, the larger gap in tongue strength would probably be observed. The age-related decline in tongue strength has been supported by empirical data, and was hypothesized to be due to sacropenia, a reduction in the mass and strength of the skeletal muscles. (Clark et al., 2003; Crow and Ship, 1996; Stierwalt and Youmans, 2007). However, the absence of age-related decline in dysphagic population has yet to be proved. Though the underlying explanation has not been fully supported, the results of this study showed a need for a different cut-off score in tongue peak pressure for screening in the elderly population. A large-scale database of tongue peak pressure across age for both dysphagic and non-dysphagic individuals is needed to further generalize the use of IOPI to individuals with different ages.
Secondly, the results of the current study were likely to show that specific data are needed for different types of dysphagia. Stierwalt and Youmans (2007) recruited individuals with oral phase dysphagia while the current study recruited those with oropharyngeal dysphagia. Some of the dysphagic participants in the current study had a locus of impairment in the pharyngeal area but not the oral cavity and the tongue. Thus the dysphagic group in this study was less likely to differ from the non-dysphagic group in terms of tongue peak pressure. And that was another plausible explanation on the smaller difference between the two groups in the current study than in the study of Stierwalt and Youmans (2007). By comparing the results of the two studies, it can be implied that elderly with oropharyngeal dysphagia will need a cut-off score different from that for oral phase dysphagia, and the data collected in this study may contribute to the establishment of this score.

Concerning the clinical applicability, though all participants were frail elderly and no healthy elderly was recruited in this study, the result of the study was still closely related to clinical practice. First, given the high percentage of frail elderly in the sample collected from nursing homes, it could extrapolate a high percentage of frail elderly in hospitals or out-patient clinics. Secondly, it was expected that healthy non-dysphagic elderly would show a greater tongue peak pressure. Thus, while the difference between dysphagic elderly and non-dysphagic, but frail, elderly was already significant, the difference with non-dysphagic healthy elderly is expected to be even greater, implying an even greater differential ability of the tongue peak pressure measurement.
Correlation between Tongue Peak Pressure and the Ratings in Oral Motor Examination

The second research question was whether the objective tongue peak pressure correlates with the subjective rating in the oral motor examination. Concerning the correlation with the rating of tongue strength alone, the result of this study showed a strong correlation of tongue peak pressure with this rating. The result revealed that tongue peak pressure was a valid objective correlate with the subjective rating of tongue strength.

Concerning its correlation with the overall rating in oral motor examination, a strong correlation was also proved by the result of this study. This proved that the tongue peak pressure is one of the objective correlates of the overall oral motor rating. On the other hand, the correlation between tongue peak pressure and swallowing rating was strong. This supported that the tongue peak pressure is a possible predictor of dysphagia.

Implication on the screening of oropharyngeal dysphagia. The results of this study posed implication related to the screening methods as well as the predictors of dysphagia. Concerning the screening methods of oropharyngeal dysphagia, oral motor examination has long been one of the tradition screening procedures (Clark et al., 2003). However, the reliability of oral motor examination has been criticized and suggested to vary with clinical experience in the existing literature (Clark et al., 2003). The correlations of tongue peak pressure with both tongue strength rating and overall rating of oral motor examination were shown to be strong in this study. Therefore, the measurement of tongue peak pressure has the potential to supplement the oral motor examination and thus increase the reliability of the
Concerning the predictors of oropharyngeal dysphagia, the results revealed that tongue peak pressure may be a stronger predictor than the rating of oral motor examination. The correlation of swallowing rating with the rating of oral motor examination was weaker than that with tongue peak pressure. As orofacial muscles other than tongue were evaluated in oral motor examination, the result might imply a stronger relationship of swallowing ability with tongue than that with other orofacial muscles. The importance of tongue function in swallowing has long been evident (Robinovitch et al., 1991). It is responsible for bolus manipulation and for the transport of bolus with the retraction of posterior tongue against the pharyngeal wall (Robinovitch et al., 1991). If it is true that the tongue is more strongly correlated to the swallowing ability than the overall oral motor ability, then the measurement of tongue strength may take up an important role in the screening. While tongue peak pressure measurement may be utilized in screening, oral motor examination may be applied to the diagnostic process to pinpoint the underlying physiological abnormality. However, these suggestions are preliminary and no other previous literature has supported these hypotheses. More investigations are suggested to obtain more data for confirmation.

**Additional implication on the treatment of oropharyngeal dysphagia.** The result of the current study not only shed light on the screening methods, but may also give insight about the importance of tongue strengthening exercise in the treatment of dysphagia. First, the results showed a strong correlation between tongue peak pressure and the swallowing
rating. In other words, when tongue strength decreased, the severity of oropharyngeal dysphagia increased. This result further supported the notion that the reduction in maximum isometric pressure (i.e. tongue peak pressure) in elderly might be coupled with increased risk of dysphagia due to the unchanged demand in swallowing pressure across age (Robbins, Levine, Wood, Roecker, & Luschei, 1995). All these research postulated the role of tongue strengthening exercise in the treatment of dysphagia, for which improvement in deglutition has been supported by previous study (Robbins et al., 2007).

Secondly, despite of the fact that different lingual movements were involved in the measurement of tongue peak pressure and the subjective evaluation of the strength of the tongue, there was a strong correlation between the two measurements. While the tongue peak pressure was related to the elevation of the tongue blade, the subjective evaluation examined the strength in lateralization and protrusion by asking the participant to push against a tongue depressor with the tongue. The elevation of tongue blade is mainly related to genioglossus muscles, and lateralization and protrusion are mainly related longitudinal muscles (Seikel, King, & Drumright, 2005). Thus, the strong correlation might imply the co-occurrence of weakness in various lingual muscles rather than in single lingual muscles. But, again, the explanation is rudimentary and needs further evidence from research before application to treatment of dysphagia.
Limitation and Further Investigation

The current study had some limitation related to the subject pool and the extent of exploration in the use of IOPI. Further investigations compensating these limitations are suggested. First, concerning the subject pool, the sample size in this study was small and thus was not representative enough. In addition, samples were collected only from two nursing homes, and there might be selection bias affecting the validity of the result. Moreover, the samples were not balanced in terms of the severity of dysphagia and gender. Therefore, further validation of the measurement of tongue peak pressure could be done with a greater sample (>30 for each group) with a more balanced gender proportion which is collected from different settings.

In addition, this study only explored the use of measurement in tongue peak pressure in the screening of oropharyngeal dysphagia. However, IOPI has been equipped with a lights mode as a feedback for tongue strengthening exercise. Therefore, IOPI has a great potential in training the tongue strength of elderly with dysphagia. Further investigation on its treatment outcome is suggested, particularly for the population of dysphagic elderly.

Conclusion

Oropharyngeal dysphagia is an impairment which could lead to fatal consequences in elderly if early identification and treatment are not done. However, the validity and reliability of the existing screening methods have been criticized. As invalid screening tools may lead to a delay in identification, the measurement of tongue peak pressure with the use of IOPI was
investigated as a potential method for supplementing the present screening procedures.

The results reflected that the measurement of tongue peak pressure was a reliable method to differentiate out elderly with oropharyngeal dysphagia. It was also proved to be an objective correlate with the subjective rating in the oral motor examination. The finding of this study, with the portable and non-invasive feature of IOPI, poses important implications on the screening, the early identification and thus early management of oropharyngeal dysphagia.

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