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Research article

# Appropriate volumes of water for non-invasive swallowing assessments of nursing home residents: A descriptive correlational study

Meng Rung Tsai [a], Wann Yun Shieh [b], Hsiu Hsin Tsai [c,d,*], Yea Ing Lotus Shyu [c], Kuo Hsuan Chang [e,f], Fur Hsing Wen [g], Chia Yih Liu [d,f]

[a] Department of Nursing, Meiho University, Neipu, Pingtung, Taiwan
[b] Department of Computer Science and Information Engineering, Chang Gung University, Taoyuan, Taiwan
[c] School of Nursing, College of Medicine, Chang Gung University, Taoyuan City, Taiwan
[d] Department of Psychiatry, Chang Gung Memorial Hospital at Linkou, Taoyuan City, Taiwan
[e] Department of Neurology, Chang Gung Memorial Hospital at Linkou, Taoyuan City, Taiwan
[f] College of Medicine, Chang Gung University, Taoyuan City, Taiwan
[g] Department of International Business, Soochow University, Taipei City, Taiwan

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ABSTRACT

*Background:* The volume of water that can be swallowed without risk of choking or aspiration is a common way to assess swallowing function in patients with dysphagia in institutional settings. However, no evidence-based study has established what volumes of water are safest and most effective for testing.

*Objective:* A validated portable non-invasive device for swallowing and respiration (NIDSAR) was employed to determine safe swallowing volumes for nursing home residents with different levels of dysphagia.

*Methods:* Participants (N = 94) were grouped by the absence or presence of a nasogastric (NG)-tube: those without an NG-tube (n = 60) and those with an NG-tube (n = 34).

Swallowing 1 ml, 3 ml, and 5 ml of water was assessed with the Functional Oral Intake Scale (FOIS) and compared with measures with objective scores from the portable NIDSAR. In addition, swallowing measures were compared between groups, as well as relationships with participant-reported choking frequency.

*Results:* Participants without an NG-tube had significant different scores for swallowing during the respiration phase and pharyngeal stage for both 3 ml ($t = 3.894$ to 4.277, $p < .001$) and 5 ml ($t = 1.999$ to 2.944, $p < .05$ to $p < .01$) compared with participants with an NG-tube.

*Discussion:* Our research revealed that participants with frequent episodes of choking required more time to swallow 1 ml compared with 3 ml or 5 ml which might be a function of piecemeal swallowing.

*Conclusions:* NIDSAR measures with 3 ml and 5 ml boluses of water are effective volumes for safely assessing swallowing ability of nursing home residents with dysphagia without risk of choking or aspiration.

* Corresponding author. School of Nursing, Chang Gung University, No. 259, Wenhua 1st Rd., Guishan Dist., Taoyuan City, 333, Taiwan.
*E-mail address:* kitty@mail.cgu.edu.tw (H.H. Tsai).

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## 1. Introduction

Mealtimes are recognized as the 'highlight of the day' for many older people in residential nursing homes, especially in Chinese culture where mealtime plays an important social role in making friends and enhancing family relationships [1]. The presence of impaired swallowing (dysphagia) can negatively impact mealtimes. Dysphagia among residents of nursing homes is a frequent problem, which ranges from 50 % to 75 % [2–4], and is associated with aspiration pneumonia, hospital admissions, and even death [5]. Thus, although assessing swallowing function in nursing home residents is important, these assessments are a challenge for nursing home staff.

There are many ways to measure dysphagia. Jung et al. demonstrated a videofluoroscopic swallowing study (VFSS), which is considered the gold standard for assessing swallowing function, provides accurate and objective measures for swallowing different volumes of barium or food [6]. However, a VFSS is invasive, expensive [7], increases the risk of pneumonia, and is inconvenient for nursing home residents because the test is conducted in a hospital setting [6]. The COVID-19 pandemic added an additional challenge to procedures that require hospital access. Ultrasound has been evaluated as a non-invasive method of assessing swallowing function and parameters are being tested to determine if measurements are reliable [8]. However, the size of the ultrasound machine makes it impractical for use at residential care facilities, though there is pocket-sized system that has been developed but is undergoing additional validation studies [9]. Fiber-optic Endoscopic Evaluation of Swallowing (FEES) is another method commonly used for dysphagia assessment, but the procedure is invasive and can have adverse effects, such as mucosal perforation or laryngospasm [10]. Furthermore, assessments with VFSS, ultrasound devises, and FEES require a trained technician to perform the test and a physician specialist to read the data and provide a diagnosis, which makes these devices unsuitable for use in nursing homes and long-term care facilities [9,10].

An instrument that is easy to use and a reliable tool for assessing swallowing function is essential for tailoring food intake for nursing home residents with dysphagia. Self-report bed-side assessment instruments are often used in institutional settings because they are inexpensive and convenient to use [11]. However, these assessments often employ large volumes of water (20–60 ml) or large quantities of food, and for individuals requiring a nasogastric (NG)-tube, determining suitable or safe amounts that can be swallowed is not practical, because they require such large boluses of water [11]. Severe dysphagia is more prevalent in Taiwan than in other countries [12], thus ease of assessing swallowing function accurately in the nursing home setting is important because the presence of physicians is limited.

A validated non-invasive device for measuring swallowing and respiration (NIDSAR) has been used for patients with dysphagia associated with aging, stroke, obstructive sleep apnea, and Parkinson's disease [13–16]. Therefore, this study aimed to employ the validated NIDSAR to evaluate what volume of water nursing home residents with dysphagia can safely swallow without risk of choking or aspiration when assessing swallowing ability. Measurements included the NIDSAR (with 1-, 3-, and 5 ml boluses of water, the Functional Oral Intake Scale (FOIS) for swallowing, and self-reported frequency of choking. NIDSAR scores were compared for participants without and with an NG-tube, mild or severe dysphagia (based on scores on the FOIS), and frequency of choking. Correlations between NIDSAR scores (for all participants and without and with an NG-tube) and scores on the FOIS were also examined.

## 2. Materials and methods

This descriptive correlational study was approved by Chang Gung Medical Foundation Institutional Review Board (201900847B0C601). The authors then sought permission from individual nursing home directors to participate in the study prior to data collection. Cluster sampling was used to select nursing home residents that were representative of nursing home settings in Northern Taiwan. Nursing homes located in northern Taiwan were used as the unit for randomization to prevent dilution of the effect and were purposively selected based on three criteria: size >65 beds, accessibility to the researchers, and registered with the Taiwan Association of Long-term Care. Among 24 medium-large nursing homes that met the recruitment criteria, 16 declined to participate in our study. A total of eight nursing homes were included in our study.

### 2.1. Sample

The following criteria were required for nursing home residents to participate in the study: 1) able to communicate in either Mandarin or Taiwanese; 2) had no significant hearing impairment; 3) a score >10 on the Chinese Mini-Mental State Examination; 4) ability to respond to verbal questions and follow verbal instructions; and 5) consent to participate.

The first author explained the study purposes and procedures to eligible nursing home residents of the participating nursing homes and their family members. They were informed that residents could withdraw from the study at any time and/or refuse to answer any questions and were assured of the confidentiality of their data. Past research indicated an NG-tube was prevalent in roughly 30%–35 % of nursing home residents in Taiwan [12,17,18], therefore, a ratio of 1:2 was selected for participants with and without an NG-tube, respectively. Nursing home residents were excluded if pronounced neck wrinkles were determined to prevent the force-sensing resistor to detect swallowing signals, which could result in unreliable data. All residents needing an NG-tube for decompression purposes were excluded because of safety concerns.

A total of 130 nursing home residents agreed to participate and signed informed consent. However, 36 residents were subsequently excluded for reasons that would interfere with recordings: unable to retain the bolus of water (n = 14), unable to remain seated for the entire procedure (n = 11), head shaking (n = 7), or pronounced neck wrinkles (n = 4). The remaining participants (N = 94) were

grouped by absence of an NG-tube (–NG-tube, n = 60) or presence of an NG-tube (+NG-tube, n = 34). The flow diagram of study participants as shown in Fig. 1.

### 2.2. Measures of dysphagia and choking frequency

Although the presence of an NG-tube can indicate severe dysphagia, there are other reasons for placement of an NG-tube. Therefore, we evaluated the level of swallowing difficulty for all participants and assigned them to one of two levels based on the Chinese version of the Functional Oral Intake Scale (FOIS), which was developed by Crary et al. to assess the level of dysphagia in patients with stroke [19]. The FOIS is a seven-point self-report instrument designed to measure swallowing function, which was demonstrated to be a reliable measure and sensitive to changes in functional oral intake [19]. The FOIS has been used to assess changes in swallowing for patients in the US and Taiwan with acute stroke following rehabilitation [20,21]. Scores ≤3 indicate significant difficulty in swallowing; scores ≥4 indicate swallowing ability is independent of an NG-tube. We divided participants into two levels of swallowing ability: normal (≥4) or poor (≤3). The Chinese FOIS (C-FOIS) has been used for older adults in Taiwan [22].

Choking is the second highest cause of preventable death in older adults cared for in nursing home facilities [23] and coughing or gagging is a sign of choking which may lead to aspiration in dysphagia [24]. Therefore, choking frequency was assessed by asking participants, "Do you ever experience symptoms of choking, such as coughing or gagging, when eating or swallowing?" Responses were scored from 1 to 3: 1 = no/rarely; 2 = sometimes (once a month); or 3 = frequently (≥ once a week).

### 2.3. Non-invasive objective measure of swallowing

This study adopted a non-invasive device for measuring swallowing and respiration (NIDSAR) validated for patients with dysphagia due to aging, stroke, obstructive sleep apnea, and Parkinson's disease [13–16]. NIDSAR measurements are obtained using a force-sensing resistor, which detects the motion of the thyroid cartilage in the pharyngeal swallowing phase, and a nasal cannula, to detect nasal airflow, while individuals drink varying volumes of water [13]. Placement of the force-sensing resistor and the nasal cannula is shown in Fig. 2A. Respiratory signals are detected by a nasal airflow transducer in the nasal cannula, which detects respiratory pauses during sequential water swallowing. Swallowing and respiration signals are simultaneously recorded, and the voltage signal is transformed into seconds (duration).

Representative recordings (Fig. 2, Right) demonstrate the four phases of swallowing used for data collection from the NISDAR: T1 (respiration), which is indicated by a short period of apnea (N1 to N2); T2 and T3, which involve movement of the thyroid cartilage (C) from C1 to C2 to block the trachea and C2 to C3 to reopen the trachea, respectively; and T4, which indicates the total pharyngeal stage of swallowing. The FSR graph (Fig. 2, bottom right) shows a W-shaped waveform, which represent two phases of thyroid cartilage movement: phase 1 (T2) involves the thyroid cartilage moving upward and forward to block the trachea; phase 2 (T3) ensures that water passes smoothly through the pharynx to the esophagus. The thyroid cartilage then returns to its original position. The total time from C1 to C3 is termed the total excursion time (T4). Details have been reported previously [13–16,25].

### 2.4. Procedure

After participants signed informed consent, the authors contacted homecare nurses in charge of tube changes for nursing home residents in the +NG-tube group and appointments were scheduled to assist the nursing home residents during testing. Participants completed the FOIS and choking questionnaires on the day of the nurse's appointment (questionnaire included as supplemental content). After completion of the subjective assessments, the nurse removed the NG-tube, and the first author quantitatively assessed swallowing function with the NIDSAR. A nasal airflow cannula (Salter Labs De Mexico, Chihuahua, Mexico) was placed in front of the

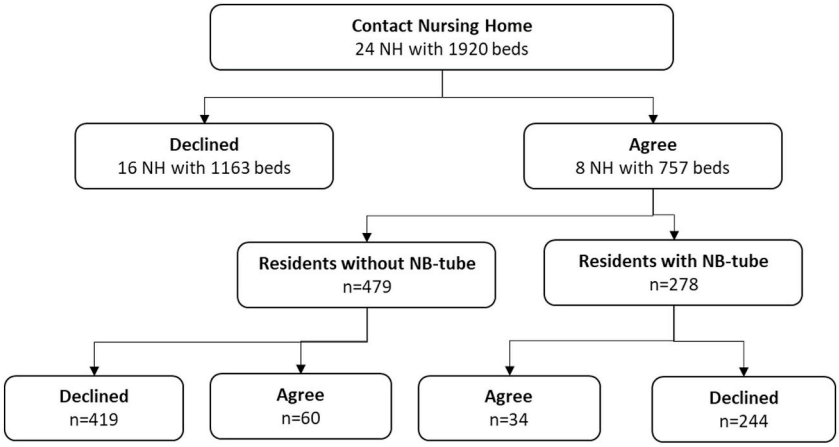


**Fig. 1.** Flow diagram for study participants.

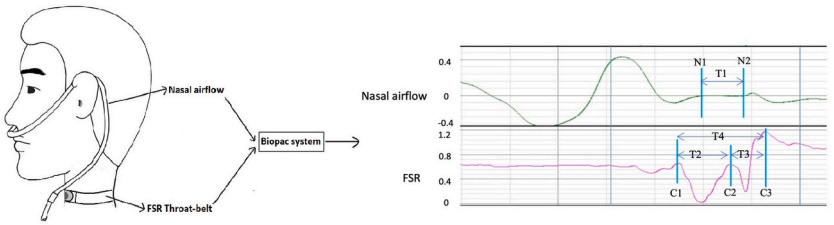


**Fig. 2.** The non-invasive device for swallowing and respiration (NIDSAR). (Left) Schematic showing location of placement for sensor components of the BIOPAC MP100: force-sensing resistor (FSR), which contained in an air-filled bulb attached to a throat belt; and the nasal airflow sensor contained in the nasal canula. (Right) Graphs of representative sensor recordings demonstrating the coordination between respiration (top) detected by the nasal airflow sensor (N1-N2 = T1) and swallowing (bottom), detected by the FSR (T2 + T3 = T4).

nasal cavity to detect respiration, which comprises inhalation, exhalation, or apnea. The cannula was connected to a pressure transducer (Pro-Tech Services, Murrysville, PA, USA) that converts airflow pressure into digital signals. The nasal airflow waveform (T1) indicates a short period of apnea, which is regarded as a protective phenomenon that enables safe swallowing without aspiration. Participants were instructed to swallow 1 ml, 3 ml, and 5 ml boluses of water at room temperature, which involved holding each bolus in the mouth and then swallowing naturally. Each bolus was drawn using a 20 ml syringe without a needle and was delivered at the side of the patient's lips. The patients were to hold the water in their mouth and then swallow it all at once when the measurement began. Each volume was repeated three times with a 3-min break between swallows. The volumes were chosen because a pilot test revealed only one of nine participants with NG-tube was able to swallow 10 ml of water. The total time for the assessment of swallowing with NIDSAR (three boluses three times each) ranged from 50 to 60 min, which allowed for rest periods between each measurement to prevent fatigue and reduce the risk of choking for participants with compromised swallowing abilities, thus ensuring their safety during the test. Testing stopped immediately if there were signs of choking, to ensure participants' safety. Subjective and quantitative assessments of swallowing for nursing home residents without an NG-tube only differed in the absence of tube removal prior to the non-invasive procedure. A trained research assistant collected data and documented the conditions of the measurement

**Table 1**
Demographic and clinical characteristics for participants and differences between residents without and with a Nasogastric Tube (-NG tube and +NG tube, respectively).

| Characteristic | All participants (N = 94) | –NG-tube (n = 60) | +NG-tube (n = 34) | $t/\chi^2$ | p |
|---|---|---|---|---|---|
| Gender, (n, %) | | | | 3.09 | 0.079 |
| Female | 50 (53.2) | 36 (60.0) | 14 (41.2) | | |
| Male | 44 (46.8) | 24 (40.0) | 20 (58.8) | | |
| Age, years (Mean ± SD) | 71.7 ± 14.9 | 73.4 ± 15.4 | 68.6 ± 13.7 | 1.50 | 0.136 |
| Age group (n, %) | | | | 3.14 | 0.209 |
| < 65 years | 28 (29.8) | 16 (26.7) | 12 (35.3) | | |
| 65–79 years | 33 (35.1) | 19 (31.7) | 14 (41.2) | | |
| ≥ 80 years | 33 (35.1) | 25 (41.7) | 8 (23.5) | | |
| Education level (n, %) | | | | 1.72 | 0.189 |
| ≤ Junior high | 64 (68.1) | 38 (63.3) | 26 (76.5) | | |
| ≥ High school | 30 (31.9) | 22 (37.7) | 8 (23.5) | | |
| Duration of NH stay, (Mean ± SD) | 1095.7 ± 1005.8 | 1001.6 ± 1008.2 | 1261.7 ± 994.6 | −1.21 | 0.230 |
| Disease status (n, %) | | | | | |
| Hypertension | 61 (64.9) | 38 (63.3) | 23 (67.6) | 0.18 | 0.674 |
| Respiratory diseases | 17 (18.1) | 8 (13.3) | 9 (26.5) | 2.53 | 0.112 |
| Diabetes | 37 (39.4) | 21 (35.0) | 16 (47.1) | 1.32 | 0.250 |
| Stroke | 33 (35.1) | 16 (26.7) | 17 (50.0) | 5.18 | **.023** |
| Dementia | 20 (21.3) | 11 (18.3) | 9 (26.5) | 0.86 | 0.354 |
| Eating method | | | | 94.01 | **< .001** |
| Mouth only | 60 (63.8) | 60 (100.0) | 0 (0.0) | | |
| NG-tube only | 13 (13.8) | 0 (0.0) | 13 (38.2) | | |
| Mouth and NG-tube | 21 (22.3) | 0 (0.0) | 21 (61.8) | | |
| Subjective swallowing scores | | | | | |
| FOIS score (Mean ± SD) | 5.38 ± 1.86 | 6.47 ± 0.83 | 3.47 ± 1.60 | 10.17 | **< .001** |
| Swallowing ability (n, %) | | | | 36.62 | **< .001** |
| Normal (FOIS ≥4) | 77 (81.9) | 60 (100) | 17 (50.0) | | |
| Poor (FOIS ≤3) | 17 (18.1) | 0 (0.0) | 17 (50.0) | | |
| Choking frequency (n, %) | | | | 51.61 | **< .001** |
| No/Rarely | 57 (60.6) | 52 (86.7) | 5 (14.7) | | |
| Sometimes (once a month) | 18 (19.1) | 7 (11.7) | 11 (32.4) | | |
| Frequently (≥ once a week) | 19 (20.2) | 1 (1.7) | 18 (52.9) | | |

Abbreviations:*NG,* Nasogastric; *SD*, Standard deviation; *FOIS*, Functional Oral Intake Scale, *NH*, nursing home.

process to ensure accuracy. Recorded data were stored using AcqKnowledge software (version 3.9.1a; BIOPAC Systems). Off-line parameters for swallowing analyses were established for the duration between onset and offset times of the force-sensing resistor sensors at T2-T4 and nasal airflow signals at T1 based on voltage levels (seconds) [25]. NIDSAR measures were determined from T1 to T4 for all participants.

### 2.5. Statistical analysis

Data were analyzed using SPSS, version 22 (IBM Corporation, NY). Descriptive statistics examined participants' characteristics using mean and standard deviation (SD) for continuous variables of age, duration of nursing home stay, and FOIS scores; categorical variables were described with numbers and frequencies. Comparisons of NIDSAR measures for participants without and with an NG-tube while swallowing 1-, 3-, and 5-ml boluses of water and differences in NIDSAR measures between scores on the FOIS $\geq$4 and $\leq$ 3 (normal and poor, respectively) were compared for all participants and participants with an NG-tube were analyzed by t-tests. Participants without an NG-tube were excluded from analyses of NIDSAR and FOIS Participants without an NG-tube were excluded from analysis because all 60 participants had normal scores on the FOIS. NIDSAR measures for all participants and participants with an NG-tube among the three levels of choking frequency were analyzed by one-way analysis of variance (ANOVA). Participants without an NG-tube were excluded from analyses because most (87 %) reported they rarely choked and only one reported frequent choking, making ANOVA impractical due to the small sample size. Associations between the NIDSAR for the three boluses of water from phase T1-T4 and scores on the FOIS were analyzed with Pearson's correlation coefficient (r).

## 3. Results

### 3.1. Demographic and clinical characteristics of participants

Demographic and clinical characteristics of the 94 participants and differences between nursing home residents without and with an NG-tube are shown in Table 1. The mean age of all participants was 71.7 years (SD = 14.9). There were no differences in any of the demographic characteristics for the +NG-tube group and –NG-tube group. However, the percentage of participants with a comorbidity of stroke was higher in the +NG-tube group (50.0 %) compared with the –NG-tube group (26.7 %) ($X^2 = 5.18$, $p = 0.02$).

The method of eating was statistically significantly different ($X^2 = 94.00$, $p < .001$), with only 63.8 % of the +NG-tube participants able to eat by mouth compared with 100 % of the –NG-tube group. The mean FOIS score for all participants was 5.38 (SD = 1.86); most had a score $\geq$4 (81.9 %), while 18.1 % (n = 17) had a score $\leq$3, indicating the presence of dysphagia. Mean FOIS scores for participants without an NG-tube were statistically significantly higher than scores for participants with an NG-tube ($X^2 = 10.17$, $p < .001$).

Frequency of choking was 19.1 % and 20.2 % for sometimes and frequently, respectively for all participants compared with only 11.7 % (sometimes) and 1.7 % (frequently) for participants without an NG-tube. When choking frequency was examined for participants with an NG-tube compared to those without an NG-tube, most participants in the +NG-tube group reported choking sometimes or frequently (32.4 % and 52.9 %, respectively), which was statistically significantly higher compared with the -NG tube group ($X^2 = 51.61$, $p < .001$).

### 3.2. NIDSAR scores for participants with different levels of dysphagia

Mean NIDSAR scores for participants without and with an NG-tube swallowing three different boluses of water and comparison between the two groups are shown in Table 2. No significant differences were seen between groups when swallowing 1 ml. Participants

**Table 2**
NIDSAR scores (seconds) for respiration (T1) and swallowing (*T2, T3, & T4* for participants without and with a nasogastric (NG) tube and differences between groups for three boluses of water. Student's t-test, two-tailed.

| | | Without NG tube (n = 60) | | With NG Tube (n = 34) | | t | p |
|---|---|---|---|---|---|---|---|
| **Bolus** | **Phase** | **Mean** | **SD** | **Mean** | **SD** | | |
| 1 ml | T1 | 0.90 | 0.41 | 0.84 | 0.54 | 0.548 | 0.585 |
| | T2 | 0.83 | 0.35 | 0.71 | 0.45 | 1.413 | 0.161 |
| | T3 | 0.86 | 0.46 | 0.77 | 0.43 | 0.901 | 0.370 |
| | T4 | 1.69 | 0.73 | 1.48 | 0.85 | 1.236 | 0.220 |
| 3 ml | T1 | 1.11 | 0.64 | 0.73 | 0.28 | 3.894 | **< 0.001** |
| | T2 | 0.90 | 0.39 | 0.63 | 0.28 | 3.916 | **< 0.001** |
| | T3 | 1.06 | 0.42 | 0.73 | 0.29 | 4.388 | **< 0.001** |
| | T4 | 1.96 | 0.70 | 1.36 | 0.51 | 4.277 | **< 0.001** |
| 5 ml | T1 | 1.04 | 0.51 | 0.82 | 0.37 | 1.999 | **0.049** |
| | T2 | 0.93 | 0.42 | 0.66 | 0.33 | 2.925 | **0.004** |
| | T3 | 1.05 | 0.45 | 0.82 | 0.38 | 2.396 | **0.019** |
| | T4 | 1.97 | 0.77 | 1.48 | 0.65 | 2.944 | **0.004** |

Abbreviations: NIDSAR, non-invasive device for swallowing and respiration; *NG,* Nasogastric; *SD*, Standard deviation.

without an NG-tube had significant different scores for swallowing at T1, T2, T3 and T4 for both 3 ml ($t = 3.894$ to 4.277, $p < .001$) and 5 ml ($t = 1.999$ to 2.944, $p < .05$ to $p < .01$) compared with participants with an NG-tube. In the other words, these two groups were significantly different for swallowing during the respiration phase (T1) and pharyngeal stage (T2-T4) for both 3 ml and 5 ml of water.

NIDSAR measures in different amounts of water for participants with scores ≥4 were compared with participants with scores ≤3 on the self-report FOIS (Table 3). We only compared NIDSAR measures with the FOIS for all participants and participants with an NG-tube because the FOIS for participants without an NG-tube were all normal (Table 1). Student's t-test showed all participants with scores ≥4 (normal) also had significant scores for swallowing 1 ml at T2 and T4 ($t = 2.32$ and 2.27, respectively, $p < .05$) compared with residents with scores ≤3 (poor). Scores also differed for swallowing at T2 and T4 when drinking 3 ml and 5 ml of water. When NIDSAR measures for participants in the +NG-tube group were compared between those with scores ≥4 those with scores ≤3, measures were only significantly higher for participants with scores ≥4 at T3 ($t = 4.80$, $p < .001$) and T4 ($t = 3.25$, $p < .01$) swallowing 5 ml of water.

When all participants were grouped by the three choking frequencies (Table 4), the time needed to swallow 3 ml at phases T1, T2, T3 and T4 (all $p < .01$) and the time for swallowing 5 ml at phase T3 and T4 (both $p < .05$) was significantly different among the three frequencies of choking. Those who rarely choked had longer swallowing times than those who sometimes or frequently choked. In the +NG-tube group, all three groups had low measures on the NIDSAR, and the only significant differences among the three choking frequencies were seen with at phase T1 for 1 ml ($F = 3.52$, $p = 0.04$) and 3 ml ($F = 6.5$, $p < 0.01$).

For all participants, NIDSAR measures for phases T2 to T4 were correlated with FOIS scores for swallowing 3 ml ($r = 0.32$–$0.38$, $p < .01$) and 5 ml ($r = 0.30$–$0.36$, $p < .01$). For participants with an NG-tube, there was a statistically significant correlation between NIDSAR scores and FOIS scores when swallowing 5 mL at phase T3 ($r = 0.74$, $p < .01$) and T4 ($r = 0.60$, $p < .01$).

## 4. Discussion

This is the first study to evaluate swallowing in nursing home residents with a non-invasive assessment device and to demonstrate how drinking different of volume of water affects the swallowing function in nursing home residents with different levels of dysphagia. We used 1 ml, 3 ml and 5 ml volumes for the different boluses of water based on the results of a pilot study. Therefore, the bolus volumes of water in our study were smaller than the multiple studies by Wang and colleagues, which also included 10 ml and 20 ml volumes in a hospital setting; however, they were evaluating swallowing in populations that did not included individuals with an NG-tube [13–16,25]. Our findings indicate the importance of small volumes of water when assessing dysphagia for nursing home residents, especially when severe dysphagia might put residents at risk of choking.

Our research also revealed that participants with frequent episodes of choking required more time to swallow 1 ml compared with 3 ml or 5 ml. The results are similar with Shieh et al. study [25]. This might be a function of piecemeal swallowing, which serves as a protective mechanism by dividing a bolus of liquid into two or three swallows, rather than one swallow [26,27]. The presence of

**Table 3**
Mean NIDSAR scores (in seconds) for respiration phase (T1) and swallowing phase (*T2, T3, & T4*) with scores ≥4 and ≤3 on the Functional Oral Intake Scale (FOIS) (normal and poor, respectively) for all participants and those with a nasogastric tube (+NG). All 60 participants without an NG-tube had normal scores on the FOIS (≥4) and therefore were not analyzed as a separate group. Student's t-test, two tailed.

| Participants[a] | Bolus | Phase | FOIS | NIDSAR | | FOIS | NIDSAR | | t | p |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | ≥4 | Mean | SD | ≤3 | Mean | SD | | |
| Total (N = 94) | 1 ml | T1 | n = 77 | 0.91 | 0.45 | n = 17 | 0.73 | 0.48 | 1.40 | 0.165 |
| | | T2 | | 0.83 | 0.40 | | 0.59 | 0.32 | 2.32 | **.023** |
| | | T3 | | 0.87 | 0.46 | | 0.64 | 0.36 | 1.88 | 0.063 |
| | | T4 | | 1.70 | 0.78 | | 1.22 | 0.64 | 2.27 | **.026** |
| | 3 ml | T1 | | 1.04 | 0.60 | | 0.68 | 0.24 | 2.46 | **.016** |
| | | T2 | | 0.86 | 0.38 | | 0.58 | 0.24 | 2.90 | **.005** |
| | | T3 | | 1.01 | 0.41 | | 0.66 | 0.21 | 3.37 | **.001** |
| | | T4 | | 1.87 | 0.70 | | 1.24 | 0.41 | 3.56 | **.001** |
| | 5 ml | T1 | | 1.03 | 0.48 | | 0.61 | 0.23 | 3.00 | **.004** |
| | | T2 | | 0.89 | 0.42 | | 0.57 | 0.25 | 2.66 | **.009** |
| | | T3 | | 1.05 | 0.42 | | 0.54 | 0.23 | 4.28 | **< .001** |
| | | T4 | | 1.93 | 0.74 | | 1.11 | 0.44 | 3.89 | **< .001** |
| +NG (n = 34) | 1 ml | T1 | n = 17 | 0.95 | 0.59 | n = 17 | 0.73 | 0.48 | 1.15 | 0.260 |
| | | T2 | | 0.83 | 0.53 | | 0.59 | 0.32 | 1.57 | 0.126 |
| | | T3 | | 0.90 | 0.45 | | 0.64 | 0.36 | 1.81 | 0.079 |
| | | T4 | | 1.72 | 0.97 | | 1.22 | 0.64 | 1.74 | 0.092 |
| | 3 ml | T1 | | 0.79 | 0.33 | | 0.68 | 0.24 | 1.13 | 0.266 |
| | | T2 | | 0.69 | 0.31 | | 0.58 | 0.24 | 1.10 | 0.280 |
| | | T3 | | 0.81 | 0.34 | | 0.66 | 0.21 | 1.54 | 0.135 |
| | | T4 | | 1.50 | 0.59 | | 1.24 | 0.41 | 1.45 | 0.157 |
| | 5 ml | T1 | | 0.99 | 0.38 | | 0.61 | 0.23 | 3.15 | **.004** |
| | | T2 | | 0.74 | 0.38 | | 0.57 | 0.25 | 1.41 | 0.169 |
| | | T3 | | 1.05 | 0.32 | | 0.54 | 0.23 | 4.80 | **< .001** |
| | | T4 | | 1.79 | 0.64 | | 1.11 | 0.44 | 3.25 | **.003** |

Abbreviations: *FOIS*, Functional Oral Intake Scale, *NIDSAR, non-invasive device for swallowing and respiration; SD*, Standard deviation.
[a]Most participants without an NG-tube either never or rarely choked (86.7 %) and therefore were not analyzed as a separate group.

**Table 4**
Comparison of self-reported choking frequency with mean scores for the non-invasive device for swallowing and respiration (NIDSAR) (in seconds) for respiration phase (T1) and swallowing phase (*T2, T3, & T4*) among all participants and those with a nasogastric (+NG) tube). Differences in NISDAR measures among the three groups were determined with one-way analysis of variance (ANOVA).

| | | Frequency of Choking | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Bolus** | **Phase** | **Total[a] N = 94** | **Never/Rarely (n = 57) Mean** | **SD** | **Sometimes (n = 18)** | **Mean** | **Frequently (n = 19) SD** | **Mean** | **SD** | **F** | **p** |
| 1 ml | T1 | | 0.84 | 0.39 | | 1.09 | 0.53 | 0.79 | 0.56 | 2.57 | 0.082 |
| | T2 | | 0.79 | 0.35 | | 0.88 | 0.40 | 0.69 | 0.50 | 1.06 | 0.350 |
| | T3 | | 0.82 | 0.47 | | 0.88 | 0.36 | 0.78 | 0.49 | 0.22 | 0.803 |
| | T4 | | 1.61 | 0.75 | | 1.76 | 0.66 | 1.47 | 0.97 | 0.62 | 0.541 |
| 3 ml | T1 | | 1.09 | 0.64 | | 0.99 | 0.39 | 0.61 | 0.20 | 5.37 | **.006** |
| | T2 | | 0.89 | 0.40 | | 0.79 | 0.30 | 0.58 | 0.23 | 4.87 | **.010** |
| | T3 | | 1.04 | 0.42 | | 0.91 | 0.38 | 0.66 | 0.21 | 7.09 | **.001** |
| | T4 | | 1.93 | 0.73 | | 1.70 | 0.58 | 1.24 | 0.38 | 7.68 | **.001** |
| 5 ml | T1 | | 1.02 | 0.48 | | 1.03 | 0.54 | 0.72 | 0.32 | 2.79 | 0.067 |
| | T2 | | 0.91 | 0.41 | | 0.79 | 0.44 | 0.64 | 0.35 | 2.92 | 0.060 |
| | T3 | | 1.05 | 0.44 | | 0.98 | 0.45 | 0.71 | 0.30 | 3.99 | **.022** |
| | T4 | | 1.95 | 0.75 | | 1.77 | 0.82 | 1.35 | 0.59 | 4.17 | **.019** |
| | | **+NG-tube n = 34** | **Never/Rarely (n = 5)** | | | **Sometimes (n = 11)** | | **Frequently (n = 18)** | | **F** | **p** |
| 1 ml | T1 | | 0.59 | 0.33 | | 1.16 | 0.62 | 0.71 | 0.45 | 3.52 | **.042** |
| | T2 | | 0.55 | 0.29 | | 0.84 | 0.40 | 0.67 | 0.52 | 0.77 | 0.473 |
| | T3 | | 0.61 | 0.32 | | 0.89 | 0.38 | 0.74 | 0.47 | 0.83 | 0.445 |
| | T4 | | 1.16 | 0.60 | | 1.73 | 0.74 | 1.42 | 0.97 | 0.85 | 0.439 |
| 3 ml | T1 | | 0.69 | 0.35 | | 0.96 | 0.24 | 0.61 | 0.21 | 6.50 | **.005** |
| | T2 | | 0.51 | 0.35 | | 0.79 | 0.26 | 0.57 | 0.23 | 2.65 | 0.087 |
| | T3 | | 0.71 | 0.44 | | 0.86 | 0.30 | 0.66 | 0.21 | 1.71 | 0.199 |
| | T4 | | 1.23 | 0.75 | | 1.65 | 0.51 | 1.23 | 0.39 | 2.51 | 0.099 |
| 5 ml | T1 | | 1.10 | 0.33 | | 0.89 | 0.42 | 0.72 | 0.32 | 2.10 | 0.143 |
| | T2 | | 0.75 | 0.16 | | 0.66 | 0.39 | 0.64 | 0.35 | 0.16 | 0.854 |
| | T3 | | 1.04 | 0.13 | | 0.91 | 0.52 | 0.71 | 0.30 | 1.76 | 0.192 |
| | T4 | | 1.80 | 0.21 | | 1.58 | 0.85 | 1.35 | 0.59 | 0.88 | 0.427 |

Abbreviations: NG, Nasogastric; SD, Standard deviation.
[a]Most partcipants without an NG-tube either never or rarely choked (86.7 %) and therefore were not analyzed as a separate group.

physical dysfunction of the hyoid and larynx can prevent either upward movement or forward movement that facilitates the transfer of water from the pharynx into the esophagus. Nursing home residents who reported frequent choking might use piecemeal swallowing when drinking of water to prevent choking, which would result in longer swallowing times in 1 ml than larger volumes of 3 ml and 5 ml.

When participants with an NG-tube were grouped by choking frequency, analysis of NIDSAR measures showed significant differences among the three groups for the time required to swallow 3 mL for all four phases (T1-T4) and 5 mL for T3 and T4. This finding suggests that a 1 mL bolus of water is inadequate for predicting swallowing difficulties based on choking frequency. We suggest additional studies be conducted to strengthen our findings that 3 ml and 5 ml of water can be used with the NISDAR to determine the minimum volume of water that nursing home residents can swallow without risk of choking. Whereas the time required to swallow 1 ml and 3 ml showed a significant difference at T1 (respiratory time), with the longest time for those who sometimes choked being higher than those who choked rarely or frequently. This may be due to participants with an NG-tube who have severe dysphagia may require a larger force and a lengthier amount of time to swallow a small volume of water.

The mean score for the FOIS for all participants in our study (5.38, SD = 1.86) was higher than the score of 4.8 (SD = 1.8) by Hollaar et al. [28]. The higher score for the FOIS for our participants is most likely explained by the difference between inclusion criteria for the two studies; nursing home residents in the study by Hollaar et al. were ≥65 years of age and physically disabled [28]. However, when participants with scores on the FOIS ≥4 were compared with those scoring ≤3, there were statistically significant differences between groups for 3 ml and 5 ml at T4. The positive association between assessments of swallowing with the NIDSAR and scores on the FOIS suggest the NIDSAR would be an effective approach for quantitative assessments of swallowing function among nursing home residents.

Our findings showed 39.4 % of all participants experienced some degree of choking, which is higher than the 20 % reported in a study of 639 nursing home residents [29]. These differences in choking frequencies might be a reflection of the presence of an NG-tube in 30 % of participants, which is similar to the prevalence of NG-tubes across all nursing home residents in Taiwan. In addition, 85.3 % of participants in the +NG-tube group experienced choking, which may be one reason these participants required an NG-tube. Therefore, whether an NG-tube reduces incidences of choking is worth further study [30]. The mean age of all participants was 71.7 years, which is younger than the mean age of nursing home residents in European countries such as Belgium [31] and the state of Delaware in the US (85.4 years and 82.5 years, respectively) [32], however this is similar to the age of nursing home residents in other studies conducted in Taiwan [33,34]. One explanation may be that families in Taiwan tend to care for older relatives at home unless

they have physical difficulties, such as dysphagia, which may result in the placement of older relatives in nursing home facilities at a younger age.

### 4.1. Limitations

Despite the strengths of our findings, our study had some limitations. First, the swallowing process includes three-phases: oral, pharyngeal, and esophageal. The NIDSAR only assesses the pharyngeal phase of swallowing of water, therefore it is suggested textures be added to incorporate measures of the oral phase, which could provide a broader picture of swallowing deficits. Second, because we did not include the oral phase of swallowing, we did not assess the presence of dry mouth, which should be considered in future studies. Finally, the W-shaped FSR waveform response at T4 (Fig. 2, Right) indicated the thyroid cartilage moved in two phases. However, we did not investigate the mechanisms behind this response, which might provide more details of swallowing difficulties associated with dysphagia. We suggest future studies include this variable in outcome assessments.

## 5. Conclusion

Our results showed that participants without an NG-tube had better scores for swallowing both 3 ml and 5 ml volumes of water than those with an NG-tube, in terms of respiration and total pharyngeal stage time during swallowing movements. Participants who choked frequently took longer to swallow 1 ml than 3 ml or 5 ml. Thus, we suggest that both 3 ml and 5 ml are effective amounts of water for safely assessing swallowing ability in nursing home residents with dysphagia.

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## Data availability statement

All data used in the generation of the results presented in this manuscript will be made available upon reasonable request from the corresponding author.

## Ethics and consent

This study was approved by the Chang Gung Medical Foundation Institutional Review Board (201900847B0C601) on November 5, 2019. The authors then sought permission from individual nursing home directors to participate in the study prior to data collection. Each participant was informed and consented to the study and its procedures. Participants also provided explicit consent to publish the findings.

## CRediT authorship contribution statement

**Meng Rung Tsai:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Wann Yun Shieh:** Writing – original draft, Visualization, Validation, Resources, Methodology, Formal analysis, Data curation, Conceptualization. **Hsiu Hsin Tsai:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Yea Ing Lotus Shyu:** Writing – review & editing, Validation, Methodology, Formal analysis, Conceptualization. **Kuo Hsuan Chang:** Writing – original draft, Validation, Methodology, Formal analysis, Conceptualization. **Fur Hsing Wen:** Software, Formal analysis, Conceptualization. **Chia Yih Liu:** Writing – review & editing, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e37340.

## List of abbreviations

| | |
|---|---|
| ANOVA | analysis of variance |
| C-FOIS | Chinese FOIS |
| FEES | Fiber-optic Endoscopic Evaluation of Swallowing |
| FOIS | Functional Oral Intake Scale |
| NG | nasogastric |
| NIDSAR | non-invasive device for swallowing and respiration |
| VFSS | videofluoroscopic swallowing study |

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