Decreased swallowing function in the sarcopenic elderly, without clinical dysphagia: a case-control study

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Abstract

Background

Sarcopenia and dysphagia have both become pivotal issues due to the increased number of elderly people. However, it’s still in question that whether sarcopenia, defined by the reduced handgrip strength and/or reduced gait speed, would necessarily results in pathological effects on swallowing function. Studies that focus on the subclinical changes of swallowing function of the sarcopenic elderly are lacking. In this study, we aimed to evaluate the swallowing function of the sarcopenic elderly without dysphagia.

Methods

This was a case-control study and subjects were recruited from the community. 94 individuals aged 65 and older without dysphagia were divided into sarcopenia and non-sarcopenia group. Assessment of swallowing consisted of tongue pressure measurement, hyoid displacement and movement velocity measurement with submental ultrasonography, 100 ml water swallow test, and the 10-item Eating Assessment Tool (EAT-10).

Results

The average tongue pressure was $47.0 \pm 13.7$ kPa in sarcopenia group and $48.6 \pm 11.5$ kPa in non-sarcopenia group ($p = 0.55$). The average hyoid displacement during swallowing was $15.3 \pm 4.4$ mm in sarcopenia group and $13.0 \pm 4.2$ mm in non-sarcopenia group ($p < 0.05$). The average hyoid movement velocity during swallowing was $22.0 \pm 9.1$ mm/s in sarcopenia group and $17.4 \pm 7.4$ mm/s in non-sarcopenia group ($p < 0.05$). The time needed to consume 100 ml of water was $14.7 \pm 10.5$ seconds in sarcopenia group and $7.0 \pm 3.9$ seconds in non-sarcopenia group ($p < 0.05$). The average score of EAT-10 was $0.5 \pm 0.6$ in sarcopenia group and $0.1 \pm 0.3$ in non-sarcopenia group ($p < 0.05$).

Conclusions

Swallowing function was significantly diminished in elderly individuals with sarcopenia, before clinical symptoms became evident. However, tongue muscles seemed resistant to sarcopenia at an early stage. Compensative strategies, such as reduced swallowing speed and increased hyoid bone movement, were observed in the sarcopenic subjects.
Background
Skeletal muscle mass declines with advancing age, which may lead to decreased strength and functionality. In 1989, Irwin Rosenberg proposed the term 'sarcopenia' to describe this age-related decrease of muscle mass (1). Although a large number of research groups exist worldwide, and their definitions and diagnostic criteria for sarcopenia vary, it is generally agreed that sarcopenia should be defined through a combined approach of muscle mass and muscle quality (2, 3). According to the diagnostic criteria provided by Asian Working Group for Sarcopenia (AWGS), sarcopenia should be described as low muscle mass plus low muscle strength (reduced handgrip strength) and/or low physical performance (reduced gait speed) (3).

Histologically, the swallowing muscles are considered to be striated muscles, but their embryological characteristics are different from those of somatic muscles, which compose the skeletal muscles of the extremities (4). Furthermore, many suprathyroid, infrahyoid, pharyngeal and laryngeal muscles receive constant input stimulation from the respiratory center, and their activities are potentially synchronized with the contraction and relaxation of the diaphragm (5). Therefore, sarcopenia, defined by the reduced handgrip strength and/or reduced gait speed (3), does not necessarily result in pathological effects on swallowing function.

The prevalence of dysphagia due to sarcopenia is unknown (4). Recently, there has been an increase in studies showing sarcopenia might reduce not only body strength, but also the strength of muscles involved in swallowing, which could cause the decline of swallowing function (6-10). Most studies enrolled hospitalized and facility-dwelling patients (6-9). Further studies are required among various settings, especially the community setting. It may be beneficial to discover the characteristics useful for predicting the decline of swallowing function in the sarcopenic elderly without dysphagia, and provide appropriate interventions before dysphagia becomes evident.

Tongue muscle pressure has already been used frequently as a measure of swallowing muscle strength (9, 11-14). Hyoid movement is required for adequate opening of upper esophageal sphincter (UES) and is readily measured by submental ultrasonography (15, 16). 100-ml water swallowing test (WST) is a sensitive indicator for identifying patients at risk for swallowing dysfunction. The sensitivity
of swallowing speed in detecting swallowing dysfunction was 85.5%, and the specificity was 50% (17). The 10-item Eating Assessment Tool (EAT-10) is a self-administered, symptom-specific outcome instrument for dysphagia. It has displayed excellent internal consistency, test-retest reproducibility, and criterion-based validity (18). In this study, we use tongue pressure measurement, submental ultrasonography, 100-ml WST, and the EAT-10 to evaluate the swallowing function of the sarcopenic elderly without dysphagia.

Methods
A total of 94 community-dwelling older individuals (ages above 65) were enrolled in this study. They were all living independently and fully cooperative. All the participants preserved the ability to eat orally at the time of referral, and people who scored 3 points or higher on the 10-item Eating Assessment Tool (EAT-10) (18) were excluded. People with history of a neurological disorder including cerebrovascular diseases, Parkinson’s disease (PD), motor neuron disease, multiple sclerosis (MS), myopathy, or head-and-neck cancers were also excluded. Participants were assigned to sarcopenia or non-sarcopenia group (47 individuals in each) according to a definition used by the Asian Working Group for Sarcopenia (AWGS) (3). According to AWGS, sarcopenia should be described as low muscle mass plus low muscle strength and/or low physical performance.

Iowa Oral Performance Instrument (IOPI) was used to measure the maximal pressure generated by contact between the tongue and palate. The IOPI is a portable, handheld device that uses an air-filled pliable plastic tongue bulb connected via a clear plastic tube to measure peak pressure exerted on the tongue bulb. It is one of the most commonly used measurement techniques to objectively measure tongue strength and endurance in practice (12, 19), with good inter- and intra-rater reliability (14, 20). Submental ultrasonography was used to measure the hyoid movement during swallowing. The protocol was described in detail in previous works (15, 21). Each participant swallowed 3 mL of clear water. Hyoid bone movement during swallowing was recorded and later analyzed. Time interval from the onset of swallow-related hyoid motion to the first moment of maximal displacement in the forward movement trajectory was also measured. The speed of hyoid movement was calculated as the maximal hyoid bone displacement divided by the time interval. 100-
ml water swallowing test (WST) was performed as we asked the participants to drink a glass of 100 ml of water as quickly as possible. Participants who choked during swallowing were asked to stop drinking immediately regardless of whether they had finished the water. The protocol was elaborated in previous work (17). Swallowing speed, defined as the amount of drunken water divided by elapsed time on the stopwatch, was also calculated. The 10-item Eating Assessment Tool (EAT-10) was used to assess the swallowing function. The content was described in detail in Appendix A.

Statistical tests were conducted using IBM SPSS software (SPSS Statistics 20.0; SPSS Inc., Chicago, IL, USA). The sarcopenia group was compared with non-sarcopenia group using the Mann-Whitney U test. The level of significance was chosen as 0.05.

Results

Participant characteristics are shown in Table 1. Among the 94 subjects, the mean age was 75.1 ± 5.8 years, and 26 (27.7 %) were men. 47 of the 94 participants were in sarcopenia group. No significant difference in age or sex was found between the two groups.

Table 2 summarizes the swallowing factors of sarcopenia and non-sarcopenia groups. The 10-item Eating Assessment Tool score was significantly lower in non-sarcopenia group. Swallowing time obtained in the 100-ml water swallowing test was significantly longer in sarcopenia group. The hyoid bone displacement and velocity during swallowing were significantly greater in sarcopenia group. No significant difference was found in maximal tongue pressure between the two groups.

Table 1. Characteristics of the study population

|                | Sarcopenia group | non-Sarcopenia group |
|----------------|------------------|----------------------|
|                | (n = 47)         | (n = 47)             |
| Gender         |                  |                      |
| Male           | 13               | 13                   |
| Female         | 34               | 34                   |
| Age (years)    | 75.2 ± 6.3       | 75.1 ± 5.4           |
Mann-Whitney U test *p < 0.05

Table 2. Sarcopenia group and non-sarcopenia group outcomes

|                     | Sarcopenia group | non-Sarcopenia group |
|---------------------|------------------|----------------------|
|                     | (n = 47)         | (n = 47)             |
| MTP (kPa)           | 47.0 ± 13.7      | 48.6 ± 11.5          |
| HD (mm)             | 15.3 ± 4.4       | 13.0 ± 4.2*          |
| HV (mm/s)           | 22.0 ± 9.1       | 17.4 ± 7.4*          |
| EAT-10              | 0.5 ± 0.6        | 0.1 ± 0.3*           |
| WST (second)        | 14.7 ± 10.5      | 7.0 ± 3.9*           |

MTP maximal pressure generated by contact between the tongue and palate, HD hyoid displacement during swallowing, HV hyoid velocity during swallowing, EAT-10 the 10-item Eating Assessment Tool score, WST swallowing time obtained in the 100-ml water swallowing test

Mann-Whitney U test *p < 0.05

Discussion
In the present study, we evaluated the swallowing function of the sarcopenic elderly without dysphagia. The average score of EAT-10 was significantly greater in sarcopenia group. This might be an evidence of the reduced swallowing function in sarcopenia group although all the participants still preserved the ability to eat orally at the time of referral, since higher scores on the EAT-10 indicate patients’ perception of more severe swallowing problems (18, 22). A previous study showed the EAT-10 score is associated with nutritional status and activities of daily living (ADL) in elderly individuals requiring long-term care (23). Also, serial administration of the EAT-10 has been shown efficacious in documenting initial symptom severity and in monitoring treatment efficacy (18, 24).

The time needed to consume 100 ml of water was significantly longer in sarcopenia group. This might
be another evidence of the reduced swallowing function in sarcopenia group. Nathadwarawala et al. first used objective swallowing speed to assess swallowing function and found that swallowing speed was significantly reduced in subjects with swallowing problems (25). Furthermore, a swallowing speed of below 10 ml/s was proposed as the cutoff point for defining swallowing dysfunction (26). This phenomenon probably reflects the compensated or adapted mechanics used by many individuals before an overt clinical problem develops (25, 27). Individuals with swallowing dysfunction may reduce the size of the swallowed bolus to reduce the risk of aspiration, thus slowing their swallowing speed (27).

The sarcopenia group represented greater hyoid bone displacement in swallow of 3 mL water. To our knowledge, our study is the first to investigate the relationship between hyoid bone movement and sarcopenia. There was only one case report about a patient with sarcopenic dysphagia. It showed that the maximum amounts of displacements and maximum moving velocities of the hyoid bone during swallowing were improved after rehabilitation (28). Previous research showed that in an older population with dysphagia, the hyoid bone elevated farther than normal for small bolus sizes, but the patients were unable to maintain this strategy in larger bolus swallows, and the distance of hyoid elevation diminished to normal or below normal levels (29). It is hypothesized that greater displacement reflects compensation for insufficient upper esophageal sphincter opening, and this compensation may break down with larger boluses in patients with dysphagia (29). If so, one implication of our finding would be the clinical application of restricted bolus volume in sarcopenic patients with or without dysphagia. In the meanwhile, strategies and therapies designed to improve the distance of hyoid elevation may be helpful (28).

Our results showed that there was no significant difference between the sarcopenia group and healthy counterpart regarding the tongue pressure. A study conducted in 2015 showed that decreased tongue pressure is associated with sarcopenia elderly (9). However, 42.3% of their subjects had dysphagia, and all their subjects were hospitalized when enrolled. Also, they only included very elderly (age 75 or older) subjects. Another study conducted in Japan showed that sarcopenia is one of the independent explanatory factors for decreased maximum tongue pressure (9). Their study also
enrolled hospitalized patients and some of them had dysphagia. Ours only enrolled community dwelling elderly without dysphagia. Histologically, the swallowing muscles are of different embryological origin from somatic muscles, and receive constant input stimulation from the respiratory center (5). Although the swallowing muscles are striated, their characteristics are different from those of skeletal muscles. Features common to sarcopenic appendicular muscle, i.e., a shift to slower myosin heavy chain isoforms, type II muscle fiber atrophy and neuromuscular junction dysmorphology, are absent or minimal in rat tongue muscles (30, 31). In particular, the styloglossus muscle has been shown to exhibit resistance against sarcopenia both molecularly and immunohistochemically (32). It was reported that normal and effortful swallow pressures do not decline with age (13) and by some measures tongue functional reserve is maintained with age (33). Those results suggested tongue muscles may be resistant to sarcopenia at an early stage, and that age-related decline in tongue motor performance may be non-myogenic in origin.

This study had a few limitations. First, we did not evaluate the muscle mass related to swallowing. Second, we were not able to stratify the sarcopenic patients according to their severity. Third, this study was carried out in a single region, and included only community-dwelling elderly without dysphagia within that location. A follow-up study including an expanded target area and sarcopenic patients with dysphagia is required in the future.

Conclusions
Swallowing function is significantly diminished in elderly individuals with sarcopenia, before clinical symptoms become evident. However, tongue muscles seem to be resistant to sarcopenia at an early stage. Compensative strategies, such as reduced swallowing speed and increased hyoid bone movement, were observed in our sarcopenic subjects.

Abbreviations
EAT-10: the 10-item Eating Assessment Tool; AWGS: Asian Working Group for Sarcopenia; WST: 100-ml water swallowing test.

Declarations
Ethics approval and consent to participate

This study was approved by the ethics committee of National Taiwan University Hospital. Written
informed consent was obtained from each participant.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

All authors declare that they have no competing interests.

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Authors' contributions

Yen-Chih Chen participated in the data analysis and drafting the manuscript. Der-Sheng Han participated in the data collection. Pei-Yun Chen and Yu-Chen Wang participated in the statistical analysis. Thanks to Tyng-Guey Wang for revising the manuscript critically for important intellectual content.

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Appendix A
The EAT-10 was self-administered by participants as follow:

To what extent are the following scenarios problematic for you? Each item is scored from 0 to 4 according to the severity of the problem.

0 = No problem, 4 = Severe problem

1. My swallowing problem has caused me to lose weight.
2. My swallowing problem interferes with my ability to go out for meals.
3. Swallowing liquids takes extra effort.
4. Swallowing solids takes extra effort.
5. Swallowing pills takes extra effort.
6. Swallowing is painful.
7. The pleasure of eating is affected by my swallowing.
8. When I swallow food, it sticks in my throat.
9. I cough when I eat.
10. Swallowing is stressful.