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Sarcopenic Dysphagia as a New Concept

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Additional information is available at the end of the chapter

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Abstract

Dysphagia (swallowing difficulties) is a serious problem associated with malnutrition, dehydration, aspiration pneumonia, and death. Its well-known causes include stroke, neuromuscular disease, and head and neck cancer, and these affect muscles and sensation during deglutition. In recent years, dysphagia due to sarcopenia (i.e. “sarcopenic dysphagia”) has been reported as a new concept. Sarcopenic dysphagia results from low swallowing and general skeletal muscle mass and strength. The characteristic changes in swallowing muscles occur primarily in oral and pharyngeal muscles along with other associated factors. With a rapidly aging population, the number of older adults with sarcopenic dysphagia is expected to increase. Therefore, it is necessary to investigate the pathophysiology and treatment strategies for sarcopenic dysphagia. In this chapter, we summarize previous studies related to sarcopenic dysphagia.

Keywords: sarcopenia, deglutition disorders, rehabilitation

1. Introduction

The term “sarcopenia” was first proposed by Rosenberg [1] to describe age-related decrease in muscle mass. In 2010, the European Working Group on Sarcopenia in Older People (EWG-SOP) proposed the sarcopenia consensus on definition and diagnostic criteria. The EWG-SOP defined sarcopenia as a geriatric syndrome characterized by progressive and generalized loss of muscle mass and strength. In addition, they proposed diagnostic criteria for sarcopenia [2]. Subsequently, the International Working Group on Sarcopenia (IWGS) proposed similar definitions [3]. In 2014, the Asian Working Group for Sarcopenia (AWGS) proposed diagnostic criteria based on data on Asian populations [4]. In 2016, sarcopenia was recognized as an independent condition by an ICD-10-CM code [5]. Currently, sarcopenia is recognized worldwide.

Since sarcopenia is characterized by generalized loss of muscle mass and function, it can involve a concomitant reduction in swallowing muscles mass and function. Swallowing is defined as “the function of clearing food and drink through the oral cavity, pharynx, and esophagus into the stomach at an appropriate rate and speed” by the International Classification of Functioning, Disability and Health [6]. According to medical terminology, “dysphagia” is the symptom (not a disease) characterized by swallowing problems. Dysphagia has been proposed as a geriatric syndrome such as sarcopenia [7]. In 1992, Veldee and Peth indicated that malnutrition affects swallowing muscles; however, the term “sarcopenia” was not coined [8]. In 2005, Robbins et al. used the term “dysphagia due to sarcopenia” in their study [9]. Since then, studies on dysphagia related to sarcopenia have increased drastically. The term “sarcopenic dysphagia” was first used by Kuroda in 2012 [10]. Since then, the term “sarcopenic dysphagia” has been used by mainly Japanese researchers [11]. However, this is not a standard medical term. In 2015, Clave and Shaker, worldwide leading researchers in dysphagia, used the term “sarcopenic dysphagia” in a review article [12], wherein sarcopenic dysphagia was introduced as a new concept of dysphagia. To our knowledge, that was the first article that described the term “sarcopenic dysphagia,” except those from Japan.

Dysphagia results in serious complications such as aspiration pneumonia, choking, dehydration, malnutrition, and lower quality of life, all of which are potentially lethal. A meta-analysis on aspiration pneumonia in frail older people revealed that dysphagia is a significant risk factor for aspiration pneumonia [13]. Furthermore, dysphagia negatively affects the nationwide cost of medication because of these complications, readmissions, higher drug intake, and prolonged hospitalization [14, 15]. Therefore, dysphagia is a serious problem that should be prevented and treated.

Many studies have been reported on dysphagia due to neurological diseases such as stroke, Parkinson’s disease and other forms of dementia, amyotrophic lateral sclerosis, head and neck cancer, and esophageal cancer. However, articles on sarcopenic dysphagia are few because it is a new concept of dysphagia. We described the number of articles about dysphagia based on years of publication in **Table 1**. We used “aging” or “frail” or “sarcopenia” and “dysphagia”

	Total	2016	2015	2014
Stroke	1416	159	145	134
Head and neck cancer	1019	139	141	120
Parkinson’s disease	472	50	53	46
Aging	305	31	31	30
Frail	75	8	6	8
Sarcopenia	38	13	11	6

We set the keywords related to sarcopenia (aging, frail, or sarcopenia) and major causes of dysphagia (stroke, head and neck cancer, or Parkinson’s disease) for comparison of research interests. We described the number of articles overall and their years of publication in the last three years. Compared to stroke, Parkinson’s disease, and head and neck cancer, articles related to sarcopenic dysphagia are less. The articles were accessed on January 7, 2017.

Table 1. Number of articles retrieved for the terms “dysphagia” or “swallowing” and each keyword on PubMed.

or “swallowing” as keywords for retrieving in PubMed. In addition, stroke or Parkinson’s disease or head and neck cancer were used as keywords to compare these with the number of articles on dysphagia related to sarcopenia. Since sarcopenia is a geriatric syndrome [2], the number of older adults with sarcopenia would increase with a rapidly aging worldwide population. Similarly, the number of older adults with sarcopenic dysphagia would increase. Thus, it is important to investigate the clinical conditions and treatment strategies for sarcopenic dysphagia. In this chapter, we summarize dysphagia related to sarcopenia based on previous studies on mainly healthy or frail subjects or those with sarcopenia.

2. Epidemiology of sarcopenic dysphagia

2.1. Definition and prevalence

The current definition of sarcopenic dysphagia is “difficulty swallowing due to sarcopenia of general skeletal and swallowing muscles” [7, 12]. Although the diagnostic criteria for sarcopenia are defined by the cutoff value of muscle mass and physical function or muscle strength [2, 16], the diagnostic criteria for sarcopenic dysphagia have not been standardized. However, a few studies have attempted to investigate the prevalence of sarcopenic dysphagia; these included subjects without diseases directly affecting swallowing function, such as stroke, Parkinson’s disease, and head and neck cancer. Maeda and Akagi [17, 18] reported its prevalence as 42.3 and 30%, respectively, in acute older inpatients at admission. In addition, in their prospective observational study [19], 26% of acute older inpatients developed sarcopenic dysphagia within 60 days of admission. Their studies mainly included older inpatients with acute internal diseases. For older inpatients, it is easy to develop sarcopenic dysphagia during hospitalization because of rest in bed and anorexia by illness. In our study subjects, from acute hospitals to a rehabilitation hospital [11], 32.2% of older inpatients had sarcopenic dysphagia on admission. Our study included many older inpatients with orthopedic disorders. These findings suggest that the prevalence of sarcopenic dysphagia is approximately 30–40% in older inpatients. In community-dwelling older adults, the review article reported that approximately 15% of them had dysphagia [20]. The risk factors of dysphagia included age, history of clinical disease, and physical frailty, including reduced activities of daily living. However, this review did not have sarcopenic dysphagia as an endpoint. Older inpatients are at a higher risk of sarcopenic dysphagia than community-dwelling older adults. The prevention, assessment, and intervention for sarcopenic dysphagia are important, especially in older inpatients.

2.2. Etiology

Several pathophysiological mechanisms are known for sarcopenia in general skeletal muscles. Sarcopenia is categorized as primary and/or secondary sarcopenia based on etiology [2]. The most prominent cause of primary sarcopenia is aging, while those of secondary sarcopenia are inactivity (bed rest, sedentary lifestyle, deconditioning, or zero-gravity conditions), malnutrition (inadequate dietary intake), and disease (advanced organ failure such as heart, lung, liver, kidney, brain, inflammatory disease, malignancy, or endocrine disease).

Several studies have shown associations of aging, inactivity, malnutrition, and disease with dysphagia [21–23]. The characteristic change in the swallowing mechanism in healthy older adults, because of aging, is referred to as “presbyphagia” [24]. Anatomical and functional changes due to aging render older adults at risk of dysphagia [25, 26]. Though aging causes reduced swallowing function, it does not cause dysphagia. In relation to inactivity, physical inactivity can cause sarcopenic dysphagia [19]. In our study in a rehabilitation hospital [11], physical activity level was independently associated with the functional level of oral intake of food and liquid. In addition, the duration of tentative nil per os (NPO) without dysphagia assessment in patients with aspiration pneumonia resulted in reduced swallowing ability during treatment [27]. Inactivity of swallowing muscles itself can cause disuse of themselves and appendicular skeletal muscles. Aspiration pneumonia in older adults usually results in bedrest and NPO for treatment. Although aspiration pneumonia is known to be caused by dysphagia, it can also cause sarcopenic dysphagia because of inactivity and malnutrition with its treatment. In relation to nutritional status, mid-upper arm circumference was associated with swallowing function [10]. In addition, nutritional status was a factor of the prognosis of swallowing ability in older inpatients [19]. In other studies, malnutrition has been suggested to cause dysphagia [8, 28]. Veldee and Peth [8] postulated that swallowing muscles have moderate-to-high percentage of type II fibers because normal swallowing is characterized by rapid contraction of muscles. Furthermore, malnutrition can affect those swallowing muscles because type II fibers are reportedly affected by malnutrition more easily than type I fibers [29–32]. Malnutrition can be one of the main causes of sarcopenic dysphagia.

In relation to the disease, the prevalence of sarcopenia is high among chronically ill patients, ranging from 15 to 50% in patients with cancer and 30 to 45% in patients with liver failure [33]. In addition, cachexia is a metabolic syndrome characterized by loss of muscle mass with or without loss of fat mass, which can cause sarcopenia, and is prevalent in 50 to 80% of cases in several types of cancer [34]. Wakabayashi et al. [23] showed that loss of skeletal muscle mass was related to severe dysphagia in patients with cancer. Patients with chronic progressive diseases such as cancer can develop dysphagia more easily than those with other diseases, owing to sarcopenia. In older adults with Alzheimer’s disease, decreased skeletal muscle mass resulted in poor swallowing functions [35]. Dysphagia in neurodegenerative disease can be caused by sarcopenia. Decreased general skeletal muscle mass was considered a risk factor for sarcopenic dysphagia in acute older inpatients [19]. Although the detailed pathophysiological mechanism of sarcopenic dysphagia from decreased general skeletal muscle mass is largely unclear, sarcopenic dysphagia can develop during general sarcopenia.

A high prevalence of sarcopenic dysphagia in older inpatients may be because hospitalization causes further inactivity and/or decrease in nutritional status and leads to severe sarcopenia. Almost all these studies revealed the associations between dysphagia and sarcopenia; however, these are not causal relationships because of the cross-sectional design of these studies. Further studies are required to explore causal relationships. We described the possible pathophysiological mechanism of sarcopenic dysphagia in **Figure 1**.

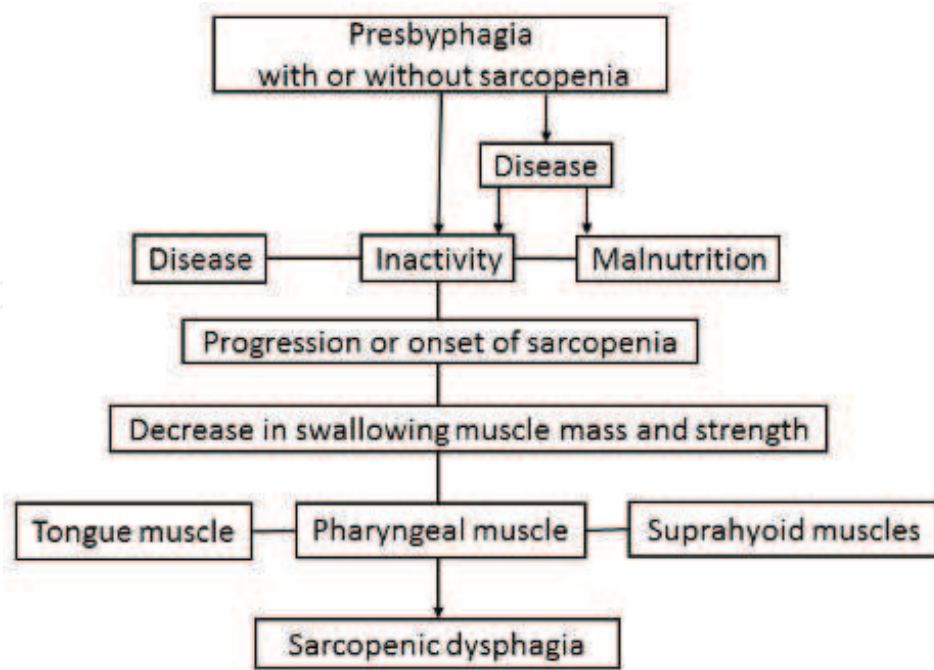


Figure 1. Possible mechanism of sarcopenic dysphagia. Older adults with presbyphagia can develop generalized sarcopenia due to disease, inactivity, or malnutrition. In the progress of generalized sarcopenia, sarcopenic dysphagia can develop due to decreased tongue, pharyngeal, and/or suprahyoid muscle function involved in swallowing.

3. Pathophysiology of sarcopenic dysphagia

3.1. Swallowing process

Swallowing is a complex process involving up to 30 striated muscles [12, 36], although swallowing is a continuous process generally conceptualized as occurring in several discrete phases. The first phase is the “preoral phase” wherein visual and olfactory qualities of food are recognized and they cause salivation, which is needed for bolus preparation [37]. The second phase is the “oral preparatory phase” wherein food is chewed and mixed with saliva to form a bolus that is easily transported to pharynx. The third phase is the “oral transit phase” wherein the tongue begins anterior-to-posterior propulsion of the bolus into pharynx. The fourth phase is the “pharyngeal phase” wherein numerous muscles function in a rapid sequence. The last phase is the “esophageal phase” wherein the bolus enters the esophagus and is transported toward the stomach by peristaltic contractions of the esophagus. Through swallowing, appropriate temporal coordination of feeding and breathing is needed to provide proper nutrition and to prevent aspiration because the pathways for food and air communicate in the pharynx [38].

3.2. Preoral phase to oral transit phase

In the preoral phase, cognitive function is related to dysphagia. In patients with congestive heart failure, cognitive dysfunction is a predictor of dysphagia [39]. In addition, sarcopenia

has been independently associated with cognitive impairment in meta-analysis [40]. Thus, cognitive impairment can contribute to development of sarcopenic dysphagia. On transitioning from the oral preparatory phase to the pharyngeal phase, several muscles are involved in swallowing, of which the tongue is a major muscle. The previous studies [9, 41] have found that individuals who aspirate have lower tongue strength than those who do not. Thus, tongue strength is a very important factor for swallowing. To our knowledge, Robbins et al. [42] are the first to indicate that tongue strength is affected by sarcopenia. In their study on healthy men, maximal isometric pressures were significantly greater at the tongue blade site in younger subjects, whereas peak swallow pressures remained similar across both young and older subjects. Nicosia et al. [43] also showed the same results in both healthy men and women. However, Robbins and colleagues [44] showed that both maximal isometric pressures and swallow pressures reduced with aging, and differences between maximal isometric pressures and swallow pressures were greater in younger adults than in older ones. Their studies have suggested diminished reserve of tongue strength in older adults. Buehring et al. [45] showed that both anterior and posterior maximum tongue pressure negatively correlated with age among community-dwelling individuals aged ≥ 70 years. Furthermore, Utanohara et al. [46] showed that men aged 20–40 years had higher anterior tongue pressure than the women, and anterior tongue pressure started to decrease from the age of 60 years in men and 70 years in women among healthy older adults. Their study indicated that tongue strength in men reduced with age at a faster rate than it did in women. Collectively, anterior and posterior tongue strength can decrease differently owing to age-related sarcopenia among men and women. Although a standard value of tongue strength in healthy older adults has not been established yet, Robbins et al. [41] considered tongue strength of <40 kPa as low, and Utanohara et al. [46] showed average tongue strength at 60 years of age was 37.6 ± 8.8 and 31.9 ± 8.9 kPa at 70 years of age. These values can be useful references in the clinical settings and in research. However, in our subjects aged ≥ 65 years [11], malnutrition was independently associated with low anterior tongue strength but not with age. Thus, decreased tongue strength in older adults can occur easily owing to malnutrition than because of aging.

The association between tongue strength and grip strength that represents whole body strength has been reported in several studies. Mendes et al. [47] showed that tongue and grip strength were reduced with increasing age. This study indicated that tongue strength was decreased owing to reduction in general muscle strength. Anterior tongue strength was significantly correlated with grip strength [11, 45, 47, 48]. However, Butler et al. [49] reported that posterior tongue strength, not anterior, was correlated with grip strength. The association between general muscle strength and tongue strength, whether anterior or posterior tongue, is under discussion. In addition to the difference of magnitude of tongue strength, Nicosia et al. [43] showed the difference of timing of tongue pressure generation between older and younger healthy adults. Time taken to reach maximal isometric pressure and swallowing pressure for liquids was longer in the older group than in the younger one. The timing of tongue strength generation may be also important in sarcopenic dysphagia.

Regarding tongue composition, a few studies have reported the distribution of tongue adipose tissue. Miller et al. [50] reported greater muscle tissue and correspondingly less adipose tissue in the posterior tongue than in the anterior tongue, whereas Nashi et al. [51] reported greater

adipose tissue in the posterior tongue than in the anterior tongue on autopsy. As tongue muscle composition changed, amyloid deposits were found to be higher in older adults [52]. Owing to few studies on the tongue composition change by sarcopenia, further studies are required.

Regarding the association with appendicular skeletal muscle mass and tongue strength, Buehring et al. [45] showed that tongue strength was not significantly different in individuals who did or did not meet skeletal muscle mass criteria for sarcopenia. However, studies in older inpatients [11, 17] found a significant association between appendicular skeletal muscle mass and tongue strength in correlation analyses. In any case, the association between tongue strength and grip strength as one of sarcopenia indices is evident, and decreased tongue strength can be a symptom of sarcopenia and lead to sarcopenic dysphagia. Not only tongue strength but also tongue thickness was related to general muscle mass. Tamura et al. [53] showed that tongue thickness was significantly associated with mid-arm muscle area. Not only appendicular skeletal muscle mass but also tongue muscle mass can be affected by sarcopenia.

3.3. Pharyngeal phase

In the pharyngeal phase of swallowing, decreased pharyngeal strength has been shown to be related to aspiration status [54]. The suprahyoid muscles are important muscles responsible for pharyngeal strength required for swallowing. Feng and colleagues [55] examined the geniohyoid muscle—one of the suprahyoid muscles—using 80 computed tomography scans of the head and neck from healthy older and younger adults and revealed that the geniohyoid muscle atrophies with age in both the midsagittal and anterior coronal planes in men as well as women. In addition, atrophy of the geniohyoid muscle in the midsagittal plane was related to aspiration in men.

The movement of the hyoid bone, which is pulled upward and forward by the suprahyoid muscles, is assessed as an indicator of suprahyoid muscle function in videofluoroscopic swallowing studies (VFSS). VFSS is considered the gold standard examination for assessment of swallowing function because it is the only objective examination that evaluates the oral, palatal, pharyngeal, and pharyngoesophageal components of deglutition, comprehensively. Decreased range of motion and velocity of movement of the hyoid bone is observed more frequently in healthy older men than in younger men [56, 57]. In another study, the elevation of the hyoid was found to be greater in older adults both with and without dysphagia than in younger adults; however, in contrast to older adults without dysphagia, those with dysphagia were unable to use this strategy during deglutition of larger boluses [58]. In another study, the range of motion of the hyoid bone during swallowing was not significantly different between older and younger adults among both men and women. In contrast, the hyoid-larynx distance at rest was greater in both older men and women than in younger ones, and the change between the hyoid-larynx distance at rest and at the maximum approximation during swallowing was greater in older adults than in younger adults (men: mean 1.25 cm in younger men and 1.54 cm in older men; women: 1.07 cm in younger women and 1.19 cm in older women) [59]. The duration of supraglottic closure in VFSS was longer in older healthy adults than in younger healthy adults [60]. In addition, frail older adults showed slower laryngeal

closure and upper esophageal sphincter opening and delayed maximal vertical hyoid motion (healthy, 0.310 ± 0.048 s; frail, 0.480 ± 0.055 s) than healthy adults. Tongue bolus propulsion strength measured by means of Newton's second law of motion in the pharyngeal phase in VFSS was 22.16 ± 2.54 mN in healthy older adults; frail older adults exhibited weaker tongue propulsion strength (8.99 ± 1.09 mN), leading to low bolus velocity and less kinetic energy [60]. There have been few studies on kinematic change related to sarcopenic dysphagia based on imaging findings; therefore, further research is warranted to investigate this issue.

In the assessment of dysphagia, jaw-opening strength was proposed as an indicator of suprahyoid muscle strength [61]. Based on measurement of jaw-opening strength in healthy adults, Iida et al. [62] suggested that suprahyoid muscle strength decreases with aging in both men and women. Machida et al. [63] demonstrated that low jaw-opening strength was associated with sarcopenia in older men. Suprahyoid muscle strength may decrease with aging and is further decreased in older men with sarcopenia. Hiramatsu et al. [64] demonstrated that the initiation of saliva swallowing was delayed and the number of saliva swallowings per 30 s decreased after meals in older adults but not in young adults (premeal, mean 7.61 and postmeal 7.30 in younger adults [no significant difference]; premeal, mean 5.35 and postmeal, mean 4.65 in older adults [significant difference, $p < 0.05$]). Their study indicated low endurance of swallowing muscles, including the suprahyoid muscles, in older adults. Low swallowing endurance can be an important component of sarcopenic dysphagia. Compared to studies on tongue muscles related to sarcopenia, fewer studies have been conducted on the suprahyoid muscles in relation to sarcopenia.

Kendall and Leonard [65] demonstrated that elderly patients with dysphagia of unknown etiology had delayed and incomplete pharyngeal constriction compared with both younger and age-matched controls without dysphagia. Leonard et al. [59] investigated spatial displacement variables in adults with no history of dysphagia and swallowing complaints. In their study, older adults with dysphagia exhibited poorer maximal pharyngeal constriction during swallowing as compared to healthy young controls. Dysfunction of pharyngeal constriction can be an important symptom of sarcopenic dysphagia. Based on the MRI scans of the neck in 60 women, Molfenter et al. [66] demonstrated that pharyngeal muscle thickness decreases and the size of the pharyngeal lumen increases with age. Such a structural change in the pharynx can result in incomplete pharyngeal constriction.

As for the sensory impairment associated with dysphagia, silent aspiration is a serious problem. Silent aspiration refers to aspiration before, during, or after swallowing in the absence of cough or visible signs of choking and distress. In a previous study, 32.5% of frail older adults with impaired safety swallow exhibited silent aspiration [60]. In a study on 76 healthy older adults [67], 83% (63/76) and 28% (21/76) exhibited penetration and silent aspiration, respectively. In addition, 85 and 61% of the subjects who exhibited penetration and aspiration, respectively, did not elicit a sensorimotor response. In another study with 56 healthy subjects [68], older adults showed a progressive decline in pharyngeal and supraglottic sensitivity measured using air pulse stimulation; sensory discrimination was 2.07 ± 0.20 mmHg in subjects aged 20–40 years and 2.68 ± 0.63 mmHg in subjects aged 61–90 years. Sarcopenia can lead to sensory decline in the pharynx and larynx and cause silent aspiration.

With regard to the changes in muscle tissue, sarcopenia or fatty degeneration after atrophy of striated muscles was observed to be accompanied by accumulation of macrophages [69, 70]. The numbers of macrophages per striated muscle fiber were 5–6 times greater in the larynx and pharynx than in other parts of the body (e.g. tongue, shoulder, and anus) in old men [71]. This kind of change in muscle tissue can lead to dysfunction of swallowing muscles with age.

3.4. Esophageal phase

Dysphagia caused by problems associated with the esophageal phase of swallowing is termed “esophageal dysphagia”. Esophageal dysphagia can occur due to achalasia, diffuse esophageal spasm, nonspecific motor disorders, obstructive lesions such as stenosis or neoplasm, or gastroesophageal reflux disease [72]. Esophageal motility disorder with aging is termed “presbyesophagus” [73]. Neuromuscular dysfunction, decreased resting upper esophageal sphincter (UES) pressure, and delayed relaxation of the UES after swallowing are some age-related changes in swallowing [74, 75]. Sarcopenia can also alter esophageal functions. Sarcopenic esophageal dysphagia may be also important in addition to sarcopenic oropharyngeal dysphagia.

3.5. The coordination of swallowing with respiration

Disturbed respiration can cause aspiration in older adults [76]. The expiration-swallow-expiration (EX/EX) pattern is essential to prevent aspiration [77]. However, the probability of the non-EX/EX respiratory phase pattern has been found to be higher in the middle- and old-age groups than in the young-age group [78]. In addition, older adults had a longer swallowing apnea duration than younger adults for preventing aspiration [78]. Though the coordination of respiration and swallowing is regulated by the central pattern generator center in the brainstem, it can be altered in case of advanced age or disease [79]. This mechanism seems to be related to respiratory function change with age or disease. A few studies showed that respiratory muscle strength was related to sarcopenia [80, 81]. Sarcopenia can affect the safety swallowing respiratory pattern. The relationship between sarcopenic dysphagia and respiratory function should be investigated.

4. Treatment for sarcopenic dysphagia

A systematic review suggested that interventions such as resistance training, compound exercises (a mix of aerobic, flexibility, and/or balance training), and nutritional interventions (protein supplementation, essential amino acid [EAA, mainly leucine] supplementation, β -hydroxy β -methylbutyric acid [HMB; a bioactive metabolite of leucine] supplementation with arginine or alone or fatty acid supplementation) were effective for improvement of generalized muscle mass and strength or functions [82]. Among these interventions, supervised resistance exercise or composite exercise programs for at least 3 months and preferably longer, EAA (with leucine), and HMB were indicated to be more beneficial for improving muscle-related parameters in sarcopenia. In another review, Morley [83] suggested that resistance

exercise is the most promising candidate for attenuating sarcopenia. In addition, supplementation with essential amino acids, creatine, vitamin D, or testosterone was also indicated to be effective.

With respect to treatment of dysphagia in relation to sarcopenia, the effectiveness of resistance training intervention to improve tongue muscle function has been demonstrated. Robbins et al. [9] used the Iowa Oral Performance Instrument to examine the effect of an 8-week progressive tongue resistance exercise program consisting of compressing an air-filled bulb between the tongue and hard palate in 10 healthy older adults aged 70–89 years. The frequency of exercise was 30 times in a single session, three times a day, and 3 days a week. The exercise intensity level in that study was 60% of the maximum pressure in the first week and 80% of the maximum pressure in the remaining 7 weeks. In this study, isometric tongue strength (baseline: mean 41 kPa; week 2: 44 kPa [nonsignificant difference]; week 4: 47 kPa [$p = 0.02$ compared to baseline]; week 6: 49 kPa [$p = 0.01$ compared to baseline]), tongue volume (change rate ranges from 2.16 to 10.68% upward), and peak swallowing pressure increased after the intervention. Tongue strength and thickness are decreased in sarcopenia but can have possible reversibility. The method used for measurement of tongue strength is described in **Figure 2**.

The effectiveness of the Shaker Exercise for strengthening the suprahyoid muscles is well-known in the field of dysphagia rehabilitation. The Shaker Exercise consists of an isometric component comprising three head lifts for 60 s each with a 60-s rest period between two consecutive head lifts and an isokinetic component comprising 30 consecutive head lifts at constant velocity (**Figure 3**). Shaker et al. [84] and Easterling [85] examined the effect of this

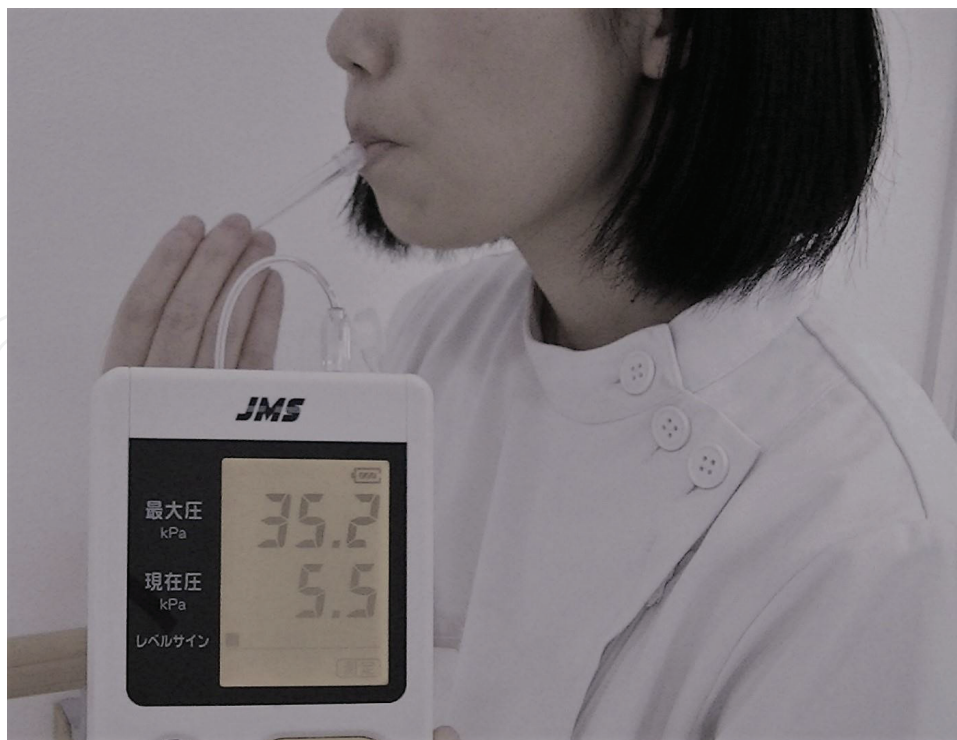


Figure 2. Tongue strength measurement. Compressing an air-filled bulb between the tongue and the hard palate and displaying the maximum tongue strength at the upper row (JMS, Hiroshima, Japan).



Figure 3. Shaker exercise. Lying on a bed and raising the head without lifting the shoulder, while looking at the toes.

exercise in healthy older adults. They showed that the anterior hyoid and larynx as well as the deglutitive anteroposterior UES opening diameter increased after this exercise was performed three times daily for 6 weeks. Wakabayashi et al. [86] demonstrated that dysphagia with aspiration was independently associated with both malnutrition and low head lifting strength. They suggested head lifting strength as an indicator of the severity of dysphagia in frail older adults. Strengthening the head lifting muscles can be an effective treatment for sarcopenic dysphagia. In recent years, a new method to strengthen the suprahyoid muscles—the Chin Tuck against Resistance (CTAR) exercise—has been developed [87]. This exercise involves squeezing a rubber ball placed between the chin and the manubrium sterni (**Figure 4**). The maximum activation level of the suprahyoid muscles measured using sEMG was significantly greater after this exercise than after both the isometric and isokinetic tasks in the Shaker Exercise; in addition, the CTAR exercise was less strenuous. CTAR was suggested to also be more specific in targeting the suprahyoid muscles than the Shaker exercise [88]. Instead of the rubber ball, a training device named ISO Swallowing Exercise Device (Alternative Speech and Swallowing Solutions, Inc.) was developed in America recently. The CTAR may be more feasible and efficient to improve swallowing function in older adults with sarcopenic dysphagia. The jaw-opening Exercise was developed as another training regimen for improving suprahyoid muscle strength [89]. This exercise is performed by opening the jaw to the maximum extent and maintaining this position for 10 s while feeling a sensation of stretching. This exercise is repeated 5 times with 10 s of rest as 1 set. Two sets of this exercise are needed to be performed daily. After this exercise, the upward movement of the hyoid bone and the opening of the UES significantly increased in all subjects. In addition, the time for pharynx passage also significantly decreased. In this study, among eight subjects with chronic dysphagia, four had dysphagia due to cerebrovascular disease and the remaining four had dysphagia due to possible sarcopenia. Further studies on interventions for people with sarcopenic dysphagia are warranted in the future.

For the treatment of dysphagia and prevention of aspiration pneumonia, compensatory strategies are important [7]. Particularly, modification of the consistency of ingested liquids is commonly used as a compensatory strategy. Rofes et al. [60] demonstrated that the prevalence of penetration and aspiration decreased by increasing the viscosity of ingested liquids

CTAR using ball



Figure 4. Chin tuck against resistance exercise. Squeezing a rubber ball placed between the chin and the manubrium sterni. Source: <http://www.speechtherapyworks.com.sg/blog/new-dysphagia-exercise-chin-tuck-against-resistance-alternative-to-shaker-exercise/>.

(liquid, nectar, and pudding viscosity) in frail older patients. In contrast, they also found that the prevalence of oral and pharyngeal residue increased with increase in viscosity. Thus, altering the consistency of ingested liquids can be effective for increasing the safety but not the efficiency of swallowing. The appropriate viscosity level should be determined by objective examination in older adults with sarcopenic dysphagia.

As treatments for sarcopenic dysphagia, nutritional and physical interventions have been indicated to be effective. Maeda and Akagi [90] describes the case of an 80-year-old woman who recovered from sarcopenic dysphagia with aggressive nutritional management and physical therapy in addition to dysphagia therapy. In their nutritional management, the total energy intake increased from 1200 to 1830 kcal/day, and the amount of protein intake increased from 0.84 ideal body weight (IBW)/day to 1.42 g/kg IBW/day. As a result, the oral intake level [91] improved from “nothing by mouth” level to “total oral diet with multiple consistencies, but requiring special preparation or compensations” level. Wakabayashi and Uwano [92] also described the case of a 71-year-old man who recovered from sarcopenic dysphagia with aggressive nutritional management and physical therapy in addition to dysphagia therapy. His energy intake was 986 kcal/day at the time of referral to the department of rehabilitation medicine and was increased to 2200 kcal/day. The oral intake level in this case improved from “nothing by mouth” level to “total oral diet with no restriction” level. In both the cases, physical function and nutritional status also improved with improvement in oral intake level. These cases indicate that nutritional management and physical rehabilitation

in addition to dysphagia rehabilitation can be effective in the treatment of sarcopenic dysphagia. Our study [11] investigated the association between tongue strength, grip strength, and nutritional status, suggesting the effectiveness of physical rehabilitation and nutritional therapy in improving tongue strength. Yoshimura et al. [93] demonstrated that nutritional intervention added to resistance training improved muscle mass and activities of daily living more than resistance training alone in older inpatients in a rehabilitation hospital. Therefore, the combination of nutritional intervention and resistance training can also be effective in the treatment of sarcopenic dysphagia. Wakabayashi and Sakuma [94] have proposed that nutritional rehabilitation is useful for the treatment of sarcopenic dysphagia. In this concept, nutrition management, to increase muscle mass and strength, is proposed to be indispensable for rehabilitation. On the other hand, the effectiveness of nutritional intervention in sarcopenic dysphagia is unclear because of the lack of intervention studies and hence, such studies are warranted in future.

In adults aged 60 years or older, with atrophy of the vocal cords or sulcus vocalis with aging, self-controlled vocal exercise in the sitting position that consists of counting out loud from 1 to 10 while pulling up firmly on both sides of the seat reduced the frequency of hospitalization for aspiration pneumonia (2/199 in the intervention group and 18/216 in the control group) [95]. Subjects in the intervention group exercised for a total of two sets, both in the morning and in the evening for 6 months. The intrinsic laryngeal muscles commonly cause glottal closure insufficiency with aging [96–98]; therefore, sarcopenia can cause atrophy of the vocal cords. Because insufficient glottal closure increases the risk of aspiration [99], atrophy of the vocal cords can lead to aspiration pneumonia in older adults. The vocal exercise mentioned above can be an effective treatment for sarcopenic dysphagia.

As decrease in pharyngeal and supraglottic sensitivity was indicated in older adults with sarcopenic dysphagia, sensory stimulation may be an effective treatment. Ortega et al. [100] demonstrated the effectiveness of two sensory stimulation techniques. One was the chemical sensory stimulation with a natural TRPV1 agonist solution (natural capsaicinoids 1×10^{-5} M). In this study, capsaicin solution was obtained from an alimentary sauce containing 185.5 $\mu\text{g/g}$ of capsaicinoid. Subjects consumed 10 mL of tomato juice mixed with the capsaicinoid sauce three times per day before each meal, 5 days per week for 2 weeks. The other technique was electrical stimulation in the thyrohyoid position using the Intelect VitalStim device (Chattanooga Group, Hixson, TN, USA), consisting of the application, at rest, of 80 Hz of transcutaneous electrical stimulus (biphasic, 700 μs). Subjects received this therapy for 1 h per day, 5 days a week for 2 weeks. Aspiration was significantly reduced in the group that received a natural TRPV1 agonist solution (TRPV1 group; 38.46% vs. TSES group; 0%) and the prevalence of penetration decreased significantly in the group receiving electrical stimulation (TSES group; 87.5 vs. TRPV1 group; 25%). In addition, the time for laryngeal vestibule closure was significantly shortened in responder patients in the group receiving electrical stimulation (TSES group; 480 ± 167 ms vs. TRPV1 group; 295 ± 189.9 ms). Because the cause of dysphagia in the subjects in this study was aging (39.5%), or a combination of aging with previous stroke or neurodegenerative diseases, the effectiveness of these techniques for older adults with sarcopenic dysphagia should be examined.

In rehabilitation for sarcopenic dysphagia, risk management for aspiration pneumonia is also important. Frail older patients with oropharyngeal dysphagia have poorer oral health, higher oral bacterial load, and a higher prevalence of oral colonization by respiratory pathogens than healthy older adults [101]. Since these can be potential risk factors of aspiration pneumonia, oral care is important as a risk management strategy in the treatment of sarcopenic dysphagia.

The Dysphagia Working Group from the European Society for Swallowing Disorders and the European Union Geriatric Medicine Society has proposed that oropharyngeal dysphagia is a multifactorial geriatric syndrome [7] and is treatable only with a multidimensional approach. Further research is required to identify the components of this multidimensional approach.

5. Conclusions

Sarcopenic dysphagia is a swallowing disorder caused by sarcopenia of the swallowing muscles, including the general skeletal muscle. Its prevalence seems to be high, particularly in older adults after acute disease. Because sarcopenic dysphagia is caused mainly by inactivity and malnutrition, it is preventable and treatable in most cases. Among published articles on dysphagia, there have been few studies on sarcopenic dysphagia. With an increasing aging population, sarcopenic dysphagia has become an important public health issue. For adequate prevention, diagnosis, and treatment, further studies on the pathophysiology of and intervention for sarcopenic dysphagia are warranted in future.

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References

- [1] Rosenberg IH. Sarcopenia: Origins and clinical relevance. *The Journal of Nutrition*. 1997;127:990-991
- [2] Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, Martin FC, Michel JP, Rolland Y, Schneider SM, Topinkova E, Vandewoude M, Zamboni M. Sarcopenia:

European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. *Age and Ageing*. 2010;**39**:412-423

- [3] Fielding RA, Vellas B, Evans WJ, Bhasin S, Morley JE, Newman AB, Abellan van Kan G, Andrieu S, Bauer J, Breuille D, Cederholm T, Chandler J, De Meynard C, Donini L, Harris T, Kannt A, Keime Guibert F, Onder G, Papanicolaou D, Rolland Y, Rooks D, Sieber C, Souhami E, Verlaan S, Zamboni M. Sarcopenia: An undiagnosed condition in older adults. Current consensus definition: Prevalence, etiology, and consequences. International Working Group on Sarcopenia. *Journal of the American Medical Directors Association*. 2011;**12**:249-256
- [4] Chen LK, Liu LK, Woo J, Assantachai P, Auyeung TW, Bahyah KS, Chou MY, Chen LY, Hsu PS, Krairit O, Lee JS, Lee WJ, Lee Y, Liang CK, Limpawattana P, Lin CS, Peng LN, Satake S, Suzuki T, Won CW, Wu CH, Wu SN, Zhang T, Zeng P, Akishita M, Arai H. Sarcopenia in Asia: Consensus report of the Asian Working Group for Sarcopenia. *Journal of the American Medical Directors Association*. 2014;**15**:95-101
- [5] Anker SD, Morley JE, Haehling SV. Welcome to the ICD-10 code for sarcopenia. *Journal of Cachexia, Sarcopenia and Muscle*. 2016;**7**:512-514
- [6] WHO. International classification of functioning, disability and health [online]. 2016; **20**:22-27 <http://www.who.int/classifications/icf/en/>
- [7] Baijens LWJ, Clavé P, Cras P, Ekberg O, Forster A, Kolb G, Leners JC, Masiero S, Mateos del Nozal J, Ortega O, Smithard DG, Speyer R, Walshe M. European Society for swallowing disorders—European Union geriatric medicine society white paper: Oropharyngeal dysphagia as a geriatric syndrome. *Clinical Interventions in Aging*. 2016;**11**:1403-1428
- [8] Veldee MS, Peth LD. Can protein-calorie malnutrition cause dysphagia? *Dysphagia*. 1992;**7**:86-101
- [9] Robbins J, Gangnon RE, Theis SM, Kays SA, Hewitt AL, Hind JA. The effects of lingual exercise on swallowing in older adults. *Journal of the American Geriatrics Society*. 2005;**53**:1483-1489
- [10] Kuroda Y, Kuroda R. Relationship between thinness and swallowing function in Japanese older adults: Implications for sarcopenic dysphagia. *Journal of the American Geriatrics Society*. 2012;**60**:1785-1786
- [11] Sakai K, Nakayama E, Tohara H, Maeda T, Sugimoto M, Takehisa T, Takehisa Y, Ueda K. Tongue strength is associated with grip strength and nutritional status in older adult inpatients of a rehabilitation hospital. *Dysphagia*. 2016. [Epub ahead of print]
- [12] Clave P, Shaker R. Dysphagia: Current reality and scope of the problem. *Nature Reviews of Gastroenterology and Hepatology*. 2015;**12**:259-270
- [13] van der Maarel-Wierink CD, Vanobbergen JN, Bronkhorst EM, Schols JM, de Baat C. Meta-analysis of dysphagia and aspiration pneumonia in frail elders. *Journal of Dental Research*. 2011;**90**:1398-1404
- [14] Bonilha HS, Simpson AN, Ellis C, Mauldin P, Martin-Harris B, Simpson K. The one-year attributable cost of post-stroke dysphagia. *Dysphagia*. 2014;**29**:545-552

- [15] Altman KW, Yu GP, Schaefer SD. Consequence of dysphagia in the hospitalized patient: Impact on prognosis and hospital resources. *Archives of Otolaryngology—Head & Neck Surgery*. 2010;**136**:784-789
- [16] Chen LK, Lee WJ, Peng LN, Liu LK, Arai H, Akishita M. Recent advances in sarcopenia research in Asia: 2016 update from the Asian Working Group for Sarcopenia. *Journal of the American Medical Directors Association*. 2016;**17**:767.e1-767.e7
- [17] Maeda K, Akagi J. Decreased tongue pressure is associated with sarcopenia and sarcopenic dysphagia in the elderly. *Dysphagia*. 2015;**30**:80-87
- [18] Maeda K, Akagi J. Sarcopenia is an independent risk factor of dysphagia in hospitalized older people. *Geriatrics & Gerontology International*. 2015;**4**:515-21
- [19] Maeda K, Takaki M, Akagi J. Decreased skeletal muscle mass and risk factors of sarcopenic dysphagia: A prospective observational cohort study. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences*. 2016. [Epub ahead of print]
- [20] Madhavan A, LaGorio LA, Crary MA, Dahl WJ, Carnaby GD. Prevalence of and risk factors for dysphagia in the community dwelling elderly: A systematic review. *The Journal of Nutrition, Health & Aging*. 2016;**20**:806-815
- [21] Wakabayashi H, Matsushima M. Dysphagia assessed by the 10-item eating assessment tool is associated with nutritional status and activities of daily living in elderly individuals requiring long-term care. *The Journal of Nutrition, Health & Aging*. 2016; **20**:22-27
- [22] Aslam M, Vaezi MF. Dysphagia in the elderly. *Gastroenterology & Hepatology*. 2013; **9**:784-795
- [23] Wakabayashi H, Matsushima M, Uwano R, Watanabe N, Oritsu H, Shimizu Y. Skeletal muscle mass is associated with severe dysphagia in cancer patients. *Journal of Cachexia, Sarcopenia and Muscle*. 2015;**6**:351-357
- [24] Robbins J, Hamilton JW, Lof GL, Kempster GB. Oropharyngeal swallowing in normal adults of different ages. *Gastroenterology*. 1992;**103**:823-829
- [25] Humbert IA, Robbins J. Dysphagia in the elderly. *Physical Medicine and Rehabilitation Clinics of North America*. 2008;**19**:853-866
- [26] Ney DM, Weiss JM, Kind AJ, Robbins J. Senescent swallowing: Impact, strategies, and interventions. *Nutrition in Clinical Practice: Official Publication of the American Society for Parenteral and Enteral Nutrition*. 2009;**24**:395-413
- [27] Maeda K, Koga T, Akagi J. Tentative nil per os leads to poor outcomes in older adults with aspiration pneumonia. *Clinical Nutrition (Edinburgh, Scotland)*. 2016;**35**:1147-1152
- [28] Hudson HM, Daubert CR, Mills RH. The interdependency of protein-energy malnutrition, aging, and dysphagia. *Dysphagia*. 2000;**15**:31-38
- [29] Lewis MI, Sieck GC. Effect of acute nutritional deprivation on diaphragm structure and function. *Journal of Applied Physiology*. 1990;**68**:1938-1944

- [30] Sieck GC, Lewis MI, Blanco CE. Effects of undernutrition on diaphragm fiber size, SDH activity, and fatigue resistance. *Journal of Applied Physiology*. 1989;**66**:2196-2205
- [31] Drew JS, Farkas GA, Pearson RD, Rochester DF. Effects of a chronic wasting infection on skeletal muscle size and contractile properties. *Journal of Applied Physiology*. 1988;**64**:460-465
- [32] Lewis MI, Li H, Huang Z-S, Biring MS, Cercek B, Fournier M. Influence of varying degrees of malnutrition on IGF-I expression in the rat diaphragm. *Journal of Applied Physiology*. 2003;**95**:555-562
- [33] Peterson SJ, Braunschweig CA. Prevalence of sarcopenia and associated outcomes in the clinical setting. *Nutrition in Clinical Practice: Official Publication of the American Society for Parenteral and Enteral Nutrition*. 2016;**31**:40-48
- [34] von Haehling S, Anker SD. Prevalence, incidence and clinical impact of cachexia: Facts and numbers-update 2014. *Journal of Cachexia, Sarcopenia and Muscle*. 2014;**5**:261-263
- [35] Takagi D, Hirano H, Watanabe Y, Edahiro A, Ohara Y, Yoshida H, Kim H, Murakami K, Hironaka S. Relationship between skeletal muscle mass and swallowing function in patients with Alzheimer's disease. *Geriatrics & Gerontology International*. 2016. [Epub ahead of print]
- [36] Matsuo K, Palmer JB. Anatomy and physiology of feeding and swallowing: Normal and abnormal. *Physical medicine and Rehabilitation Clinics of North America*. 2008;**19**:691-707
- [37] Leopold NA, Kagel MC. Dysphagia – ingestion or deglutition? A proposed paradigm. *Dysphagia*. 1997;**12**:202-206
- [38] Matsuo K, Palmer JB. Coordination of mastication, swallowing and breathing. *The Japanese Dental Science Review*. 2009;**45**:31-40
- [39] Yokota J, Ogawa Y, Yamanaka S, Takahashi Y, Fujita H, Yamaguchi N, Onoue N, Ishizuka T, Shinozaki T, Kohzuki M. Cognitive dysfunction and malnutrition are independent predictors of dysphagia in patients with acute exacerbation of congestive heart failure. *PloS One*. 2016;**11**:e0167326
- [40] Chang K-V, Hsu T-H, Wu W-T, Huang K-C, Han D-S. Association between sarcopenia and cognitive impairment: A systematic review and meta-analysis. *Journal of the American Medical Directors Association*. 2016;**12**:1164.e7-1164.e15
- [41] Robbins J, Kays SA, Gangnon RE, Hind JA, Hewitt AL, Gentry LR, Taylor AJ. The effects of lingual exercise in stroke patients with dysphagia. *Archives of Physical Medicine and Rehabilitation*. 2007;**88**:150-158
- [42] Robbins J, Levine R, Wood J, Roecker EB, Luschei E. Age effects on lingual pressure generation as a risk factor for dysphagia. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences*. 1995;**50**:M257-M262

- [43] Nicosia MA, Hind JA, Roecker EB, Carnes M, Doyle J, Dengel GA, Robbins J. Age effects on the temporal evolution of isometric and swallowing pressure. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences*. 2000;**55**:M634-M640
- [44] Robbins J, Humpal NS, Banaszynski K, Hind J, Rogus-Pulia N. Age-related differences in pressures generated during isometric presses and swallows by healthy adults. *Dysphagia*. 2016;**31**:90-96
- [45] Buehring B, Hind J, Fidler E, Krueger D, Binkley N, Robbins J. Tongue strength is associated with jumping mechanography performance and handgrip strength but not with classic functional tests in older adults. *Journal of the American Geriatrics Society*. 2013;**61**:418-422
- [46] Utanohara Y, Hayashi R, Yoshikawa M, Yoshida M, Tsuga K, Akagawa Y. Standard values of maximum tongue pressure taken using newly developed disposable tongue pressure measurement device. *Dysphagia*. 2008;**23**:286-290
- [47] Mendes AE, Nascimento L, Mansur LL, Callegaro D, Jacob Filho W. Tongue forces and handgrip strength in normal individuals: Association with swallowing. *Clinics (Sao Paulo, Brazil)*. 2015;**70**:41-45
- [48] Crow HC, Ship JA. Tongue strength and endurance in different aged individuals. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences*. 1996;**51**:M247-M250
- [49] Butler SG, Stuart A, Leng X, Wilhelm E, Rees C, Williamson J, Kritchevsky SB. The relationship of aspiration status with tongue and handgrip strength in healthy older adults. *The Journals of Gerontology Series A, Biological Sciences and Medical sciences*. 2011;**66**:452-458
- [50] Miller JL, Watkin KL, Chen MF. Muscle, adipose, and connective tissue variations in intrinsic musculature of the adult human tongue. *Journal of Speech, Language, and Hearing Research*. 2002;**45**:51-65
- [51] Nashi N, Kang S, Barkdull GC, Lucas J, Davidson TM. Lingual fat at autopsy. *The Laryngoscope*. 2007;**117**:1467-1473
- [52] Yamaguchi A, Nasu M, Esaki Y, Shimada H, Yoshiki S. Amyloid deposits in the aged tongue: A postmortem study of 107 individuals over 60 years of age. *Journal of Oral Pathology*. 1982;**11**:237-244
- [53] Tamura F, Kikutani T, Tohara T, Yoshida M, Yaegaki K. Tongue thickness relates to nutritional status in the elderly. *Dysphagia*. 2012;**27**:556-561
- [54] Butler SG, Stuart A, Wilhelm E, Rees C, Williamson J, Kritchevsky S. The effects of aspiration status, liquid type, and bolus volume on pharyngeal peak pressure in healthy older adults. *Dysphagia*. 2011;**26**:225-231
- [55] Feng X, Todd T, Lintzenich CR, Ding J, Carr JJ, Ge Y, Browne JD, Kritchevsky SB, Butler SG. Aging-related geniohyoid muscle atrophy is related to aspiration status in healthy

older adults. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences*. 2013;**68**:853-860

- [56] Logemann JA, Pauloski BR, Rademaker AW, Colangelo LA, Kahrilas PJ, Smith CH. Temporal and biomechanical characteristics of oropharyngeal swallow in younger and older men. *Journal of Speech, Language, and Hearing Research*. 2000;**43**:1264-1274
- [57] Kang BS, Oh BM, Kim IS, Chung SG, Kim SJ, Han TR. Influence of aging on movement of the hyoid bone and epiglottis during normal swallowing: A motion analysis. *Gerontology*. 2010;**56**:474-482
- [58] Kendall KA, Leonard RJ. Hyoid movement during swallowing in older patients with dysphagia. *Archives of Otolaryngology—Head & Neck Surgery*. 2001;**127**:1224-1229
- [59] Leonard R, Kendall KA, McKenzie S. Structural displacements affecting pharyngeal constriction in nondysphagic elderly and nonelderly adults. *Dysphagia*. 2004;**19**:133-141
- [60] Rofes L, Arreola V, Romea M, Palomera E, Almirall J, Cabre M, Serra-Prat M, Clave P. Pathophysiology of oropharyngeal dysphagia in the frail elderly. *Neurogastroenterology and Motility: The Official Journal of the European Gastrointestinal Motility Society*. 2010;**22**:851-858, e230
- [61] Hara K, Tohara H, Wada S, Iida T, Ueda K, Ansai T. Jaw-opening force test to screen for dysphagia: Preliminary results. *Archives of Physical Medicine and Rehabilitation*. 2014;**95**:867-874
- [62] Iida T, Tohara H, Wada S, Nakane A, Sanpei R, Ueda K. Aging decreases the strength of suprahyoid muscles involved in swallowing movements. *The Tohoku Journal of Experimental Medicine*. 2013;**231**:223-228
- [63] Machida N, Tohara H, Hara K, Kumakura A, Wakasugi Y, Nakane A, Minakuchi S. Effects of aging and sarcopenia on tongue pressure and jaw-opening force. *Geriatrics & Gerontology International*. 2017;**17**:295-301
- [64] Hiramatsu T, Kataoka H, Osaki M, Hagino H. Effect of aging on oral and swallowing function after meal consumption. *Clinical Interventions in Aging*. 2015;**10**:229-235
- [65] Kendall KA, Leonard RJ. Pharyngeal constriction in elderly dysphagic patients compared with young and elderly nondysphagic controls. *Dysphagia*. 2001;**16**:272-278
- [66] Molfenter SM, Amin MR, Branski RC, Brumm JD, Hagiwara M, Roof SA, Lazarus CL. Age-related changes in pharyngeal lumen size: A retrospective MRI analysis. *Dysphagia*. 2015;**30**:321-327
- [67] Butler SG, Stuart A, Leng X, Rees C, Williamson J, Kritchevsky SB. Factors influencing aspiration during swallowing in healthy older adults. *The Laryngoscope*. 2010;**120**:2147-2152
- [68] Aviv JE, Martin JH, Jones ME, Wee TA, Diamond B, Keen MS, Blitzer A. Age-related changes in pharyngeal and supraglottic sensation. *The Annals of Otolaryngology, Rhinology, and Laryngology*. 1994;**103**:749-752

- [69] Gumucio J, Flood M, Harning J, Phan A, Roche S, Lynch E, Bedi A, Mendias C. T lymphocytes are not required for the development of fatty degeneration after rotator cuff tear. *Bone & Joint Research*. 2014;**3**:262-272
- [70] Siriett V, Salerno MS, Berry C, Nicholas G, Bower R, Kambadur R, Sharma M. Antagonism of myostatin enhances muscle regeneration during sarcopenia. *Molecular Therapy: The Journal of the American Society of Gene Therapy*. 2007;**15**:1463-1470
- [71] Rhee S, Yamamoto M, Kitamura K, Masaaki K, Katori Y, Murakami G, Abe SI. Macrophage density in pharyngeal and laryngeal muscles greatly exceeds that in other striated muscles: An immunohistochemical study using elderly human cadavers. *Anatomy & Cell Biology*. 2016;**49**:177-183
- [72] Greenslade J, Wyman A. Investigation of dysphagia. *Surgery (Oxford)*. 2006;**24**:89-92
- [73] DeVault KR. Presbyesophagus: A reappraisal. *Current Gastroenterology Reports*. 2002;**4**:193-199
- [74] Fulp SR, Dalton CB, Castell JA, Castell DO. Aging-related alterations in human upper esophageal sphincter function. *The American Journal of Gastroenterology*. 1990;**85**:1569-1572
- [75] van Herwaarden MA, Katz PO, Matthew Gideon R, Barrett J, Castell JA, Achem S, Castell DO. Are manometric parameters of the upper esophageal sphincter and pharynx affected by age and gender? *Dysphagia*. 2003;**18**:211-217
- [76] Nilsson H, Ekberg O, Bulow M, Hindfelt B. Assessment of respiration during video fluoroscopy of dysphagic patients. *Academic Radiology*. 1997;**4**:503-507
- [77] Preiksaitis HG, Mills CA. Coordination of breathing and swallowing: Effects of bolus consistency and presentation in normal adults. *Journal of Applied Physiology*. 1996;**81**:1707-1714
- [78] Wang CM, Chen JY, Chuang CC, Tseng WC, Wong AM, Pei YC. Aging-related changes in swallowing, and in the coordination of swallowing and respiration determined by novel non-invasive measurement techniques. *Geriatrics & Gerontology International*. 2015;**6**:736-744
- [79] Shaker R, Li Q, Ren J, Townsend WF, Dodds WJ, Martin BJ, Kern MK, Rynders A. Coordination of deglutition and phases of respiration: Effect of aging, tachypnea, bolus volume, and chronic obstructive pulmonary disease. *The American Journal of Physiology*. 1992;**263**:G750-G755
- [80] Izawa KP, Watanabe S, Oka K, Kasahara Y, Morio Y, Hiraki K, Hirano Y, Omori Y, Suzuki N, Kida K, Suzuki K, Akashi YJ. Respiratory muscle strength in relation to sarcopenia in elderly cardiac patients. *Aging Clinical and Experimental Research*. 2016;**28**:1143-1148
- [81] Elliott JE, Greising SM, Mantilla CB, Sieck GC. Functional impact of sarcopenia in respiratory muscles. *Respiratory Physiology & Neurobiology*. 2016;**226**:137-146

- [82] Cruz-Jentoft AJ, Landi F, Schneider SM, Zuniga C, Arai H, Boirie Y, Chen LK, Fielding RA, Martin FC, Michel JP, Sieber C, Stout JR, Studenski SA, Vellas B, Woo J, Zamboni M, Cederholm T. Prevalence of and interventions for sarcopenia in ageing adults: A systematic review. Report of the International Sarcopenia Initiative (EWGSOP and IWGS). *Age and Ageing*. 2014;**6**:748-759
- [83] Morley JE. Pharmacologic options for the treatment of sarcopenia. *Calcified Tissue International*. 2016;**98**:319-333
- [84] Shaker R, Kern M, Bardan E, Taylor A, Stewart ET, Hoffmann RG, Arndorfer RC, Hofmann C, Bonnevier J. Augmentation of deglutitive upper esophageal sphincter opening in the elderly by exercise. *The American Journal of Physiology*. 1997;**272**:G1518-G1522
- [85] Easterling C. Does an exercise aimed at improving swallow function have an effect on vocal function in the healthy elderly? *Dysphagia*. 2008;**23**:317-326
- [86] Wakabayashi H, Sashika H, Matsushima M. Head lifting strength is associated with dysphagia and malnutrition in frail older adults. *Geriatrics & Gerontology International*. 2015;**4**:410-416
- [87] Yoon WL, Khoo JKP, Rickard Liow SJ. Chin Tuck Against Resistance (CTAR): New Method for enhancing suprahyoid muscle activity using a Shaker-type exercise. *Dysphagia*. 2014;**29**:243-248
- [88] Sze WP, Yoon WL, Escoffier N, Rickard Liow SJ. Evaluating the training effects of two swallowing rehabilitation therapies using surface electromyography – Chin Tuck Against Resistance (CTAR) Exercise and the Shaker exercise. *Dysphagia*. 2016;**31**:195-205
- [89] Wada S, Tohara H, Iida T, Inoue M, Sato M, Ueda K. Jaw-opening exercise for insufficient opening of upper esophageal sphincter. *Archives of Physical Medicine and Rehabilitation*. 2012;**93**:1995-1999
- [90] Maeda K, Akagi J. Treatment of sarcopenic dysphagia with rehabilitation and nutritional support: A comprehensive approach. *Journal of the Academy of Nutrition and Dietetics*. 2016;**116**:573-577
- [91] Crary MA, Mann GD, Groher ME. Initial psychometric assessment of a functional oral intake scale for dysphagia in stroke patients. *Archives of Physical Medicine and Rehabilitation*. 2005;**86**:1516-1520
- [92] Wakabayashi H, Uwano R. Rehabilitation nutrition for possible sarcopenic dysphagia after lung cancer surgery: A case report. *American Journal of Physical Medicine & Rehabilitation/Association of Academic Physiatrists*. 2016;**95**:e84-e89
- [93] Yoshimura Y, Uchida K, Jeong S, Yamaga M. Effects of nutritional supplements on muscle mass and activities of daily living in elderly rehabilitation patients with decreased muscle mass: A randomized controlled trial. *The Journal of Nutrition, Health & Aging*. 2016; **20**:185-191

- [94] Wakabayashi H, Sakuma K. Rehabilitation nutrition for sarcopenia with disability: A combination of both rehabilitation and nutrition care management. *Journal of Cachexia, Sarcopenia and Muscle*. 2014;**5**:269-277
- [95] Fujimaki Y, Tsunoda K, Kobayashi R, Tonghyo C, Tanaka F, Kuroda H, Numata T, Ishii T, Kuroda R, Masuda S, Hashimoto S, Misawa H, Shindo N, Mori T, Mori H, Uchiyama N, Kamei Y, Tanaka M, Hamaya H, Funatsuki S, Usui S, Ito I, Hamada K, Shindo A, Tokumaru Y, Morita Y, Ueha R, Nito T, Kikuta S, Sekimoto S, Kondo K, Sakamoto T, Itoh K, Yamasoba T, Matsumoto S. Independent exercise for glottal incompetence to improve vocal problems and prevent aspiration pneumonia in the elderly: A randomized controlled trial. *Clinical Rehabilitation*. 2016. [Epub ahead of print]
- [96] Malmgren LT, Fisher PJ, Bookman LM, Uno T. Age-related changes in muscle fiber types in the human thyroarytenoid muscle: An immunohistochemical and stereological study using confocal laser scanning microscopy. *Otolaryngology – head and neck surgery. Official Journal of American Academy of Otolaryngology-Head and Neck Surgery*. 1999;**121**:441-451
- [97] Malmgren LT, Jones CE, Bookman LM. Muscle fiber and satellite cell apoptosis in the aging human thyroarytenoid muscle: A stereological study with confocal laser scanning microscopy. *Otolaryngology – head and neck surgery. Official Journal of American Academy of Otolaryngology-Head and Neck Surgery*. 2001;**125**:34-39
- [98] Martins RH, Benito Pessin AB, Nassib DJ, Branco A, Rodrigues SA, Matheus SM. Aging voice and the laryngeal muscle atrophy. *The Laryngoscope*. 2015;**125**:2518-2521
- [99] Giraldez-Rodriguez LA, Johns M, 3rd. Glottal insufficiency with aspiration risk in dysphagia. *Otolaryngologic Clinics of North America*. 2013;**46**:1113-1121
- [100] Ortega O, Rofes L, Martin A, Arreola V, Lopez I, Clave P. A Comparative study between two sensory stimulation strategies after two weeks treatment on older patients with oropharyngeal dysphagia. *Dysphagia*. 2016;**31**:706-716
- [101] Ortega O, Sakwinska O, Combremont S, Berger B, Sauser J, Parra C, Zarcero S, Nart J, Carrion S, Clave P. High prevalence of colonization of oral cavity by respiratory pathogens in frail older patients with oropharyngeal dysphagia. *Neurogastroenterology and Motility: The Official Journal of the European Gastrointestinal Motility Society*. 2015;**27**:1804-1816