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Age-related declines in the swallowing muscle strength of men and women aged 20–89 years: A cross-sectional study on tongue pressure and jaw-opening force in 980 subjects

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ABSTRACT

Swallowing muscle strength weakens with aging. Although numerous studies have investigated tongue pressure (TP) changes with age, studies on jaw-opening force (JOF), an indicator of suprahyoid muscle strength, are lacking. We investigated differences between age-related declines in TP and JOF in a cross-sectional study of 980 healthy and independent participants (379 men, 601 women) without dysphagia. Hand grip strength (HGS), TP, and JOF were compared among decade-based age groups in multiple comparison analyses with post-hoc tests and effect size calculated. Participants were divided into adult (20 s–50 s) and elderly groups (60 s–80 s); within each group, Pearson correlations between age and muscle strength indices were evaluated. TP started to significantly decline in the 60 s and 50 s for men and women ($p < .01$, medium effect size and $p < .05$, small effect size, respectively); HGS also declined at these ages (men: $p < .01$, women: $p < .01$, medium effect size). JOF started to significantly decline in men in their 80 s ($p < .01$, large effect size), but remained unchanged in women. In the elderly group, all measurements declined with age more sharply in men (HGS: $r = -0.56$, TP: $r = -0.63$, JOF: $r = -0.13$) than in women (HGS: $r = -0.38$, TP: $r = -0.49$, JOF: $r = -0.003$). TP declined more steeply than did JOF. Thus, the age related-decline in TP was similar to that of the HGS, but not the JOF. The results reveal that different patterns exist in the age-related decline in swallowing muscle strength, and suggest that maintenance of JOF might contribute to safe swallowing in healthy elderly individuals.

1. Introduction

Sarcopenia is defined as a progressive and systemic decrease in skeletal muscle mass and strength, accompanied by physical impairment, deterioration in patients' quality of life, and death (Cruz-Jentoft et al., 2010). The reduction in muscle mass and strength causes frailty and disability in elderly individuals (Xue, Bandeen-Roche, Varadhan, Zhou, & Fried, 2008). In general, muscle strength peaks in the fourth decade, then declines steadily with age (Lindle et al., 1997). In a study of 2468 Japanese individuals aged over 40 years, hand grip strength (HGS) began to decline in men in their sixties and in women in their fifties (Yoshimura et al., 2011). Thus, muscle strength deterioration and weakness already occur in middle age; however, it declines at a faster rate in old age.

In addition, sarcopenia reduces the strength of the muscles involved in swallowing, causing dysphagia in elderly individuals (Butler, Stuart, Leng et al., 2011; Butler, Stuart, Wilhelm et al., 2011; Iinuma et al., 2012; Machida et al., 2017). A relationship between tongue strength and aging has been reported (Butler, Stuart, Leng et al., 2011; Machida et al., 2017; Nicosia et al., 2000), as the tongue plays an important role not only in speech, but also in propelling the bolus into the pharynx and pushing it into the esophagus by contacting the pharyngeal muscles (Felton, Gaige, Reese, Wedeen, & Gilbert, 2007). Although maximal tongue strength decreases gradually with aging, tongue strength during swallowing does not (Nicosia et al., 2000). Furthermore, a study comparing maximum tongue pressure (TP) among age groups concluded that TP was greater in men than in women in the second to fourth decades of life (Utanohara et al., 2008). In addition, TP started to decline sooner in men than in women.

Suprahyoid muscle contraction plays an important role in elevating the hyoid bone, contributing to upper esophageal sphincter opening with cricopharyngeal muscle relaxation (Cook et al., 1989). Decreased

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suprahyoid muscle contraction results in decreased hyoid elevation, which can cause pharyngeal residue, leading to aspiration after swallowing (Eisenhuber et al., 2002). Recently, we developed a jaw-opening sthenometer to measure suprahyoid strength, as the suprahyoid muscle is a jaw-opening muscle, and showed that the jaw-opening force (JOF) is a useful screening measure for dysphagia (Hara et al., 2014). The JOF is associated with the cross-sectional area of the geniohyoid muscle, which is the one of the suprahyoid muscles (Kajisa et al., 2018). Therefore, the JOF can be used as an indicator of suprahyoid muscle strength. Furthermore, a previous study demonstrated that a low JOF leads to a lower position of the hyoid bone in the neck during resting, resulting in a compensatory larger displacement of the hyoid bone during swallowing (Shinozaki et al., 2017). In addition, we previously demonstrated that the JOF is significantly lower in men with sarcopenia than in men without sarcopenia (Machida et al., 2017). However, data regarding the deterioration of JOF among sex and age groups are lacking. Therefore, in the present study, we investigated the age at which different indices of muscle strength (HGS, TP, and JOF) decline and whether sex effects exist, comparing declines in TP and JOF to those of HGS, as a standard of skeletal muscle strength.

2. Methods

2.1. Participants

Data from 980 healthy participants (379 men, 601 women) who agreed to undergo the measurements listed below were collected from a database system in a Kobayashi dental clinic between April 2015 and March 2017. All participants were Japanese and citizens of Tokyo metropolis. Most of them live in Edogawa-ku, which is located in Tokyo metropolis, that has an estimated population of 682,418. The participants were able to consume regular food and did not complain of dysphagia. The participants visited the clinic due to minor dental complaints, such as dental cavities, gingivitis, or uncomfortable dentures. All participants had no record of diseases that caused swallowing impairments, such as cerebrovascular diseases, neuromuscular diseases, and other diseases causing dysphagia. Before the measurement, a nurse or dentists in the dental clinic interviewed the participants for any presence of muscle weakness and muscle pain as a side effect of the administered medication and a symptom of the chronic disease. However, none had any of these complaints. All participants had occlusal contact with either their own teeth or their dentures, had been treated for their dental problem, and were exants had no record of diseases that caused swallowing impairments, such as cerebrovascular diseases, neuromuscular diseases, and other diseases causing dysphagia. Before the measurement, a nurse or dentists in the dental clinic interviewed the participants for any presence of muscle weakness and muscle pain as a side effect of the administered medication and a symptom of the chronic disease. However, none had any of these complaints. All participants had occlusal contact with either their own teeth or their dentures, had been treated for their dental problem, and were examined for jaw stabilization by a dentist before starting this study. This study was approved by the ethics committee of the School of Tokyo Medical Dental University (D2014-047). Informed consent was obtained from all participants.

2.2. Procedures

HGS, TP, and JOF were measured by a dentist with experience in dysphagia evaluation and a medical technologist who had been well trained in these measurements. The HGS of the dominant hand was assessed using a hand-grip dynamometer (TTM, Inc., Tokyo, Japan), with the participant in a sitting position. The HGS was defined as the average of three measurements.

TP was assessed using a JMS TP device (JMS, Inc., Hiroshima, Japan). Participants were instructed to sit in a relaxed position. The evaluation probe consisted of a balloon and plastic catheter. Participants placed the balloon in their mouth and held the plastic catheter with their central incisors. Participants were then instructed to press the balloon to the hard palate for seven seconds, using their tongue with maximal pressure. The maximum TP was defined as the average of three measurements.

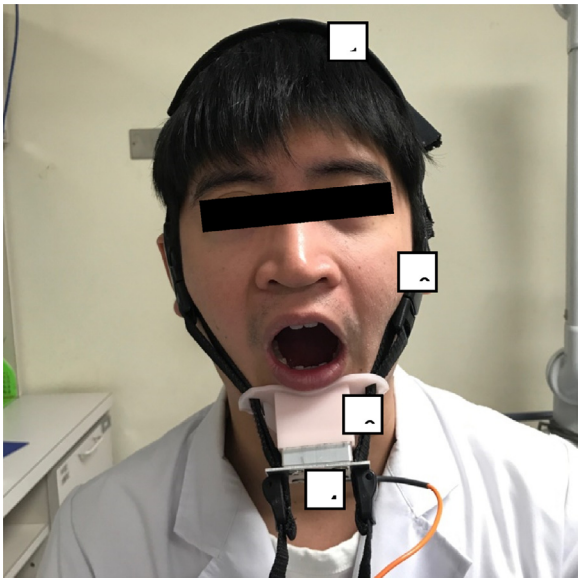

Fig. 1. Jaw-opening sthenometer.
1: Head-encircling belt
2: Two belts to secure the mandible to the head-encircling belt
3: Chin cap
4: Dynamometer to assess jaw-opening strength

The JOF was measured using a jaw-opening sthenometer (Livt, Inc., Tokyo, Japan; Fig. 1), which consisted of a head-encircling belt, two belts to secure the mandible to the head-encircling belt, a chin cap, and a dynamometer. The belts were placed around the top of the participant's head and under the jaw as tightly as possible to prevent the jaw from opening. The jaw-opening sthenometer was calibrated to zero before each measurement. The participants were then asked to open their jaws with as much strength as possible. Participants who complained of pain at the temporomandibular jaw joint during the assessment stopped performing the assessment and were excluded. The JOF was defined as the average of three measurements.

2.3. Statistical analysis

The participants were divided into 7 decade-based age groups: 20 s (65 men, 112 women, aged 20–29 years), 30 s (85 men, 93 women, aged 30–39 years), 40 s (65 men, 87 women, aged 40–49 years), 50 s (29 men, 67 women, aged 50–59 years), 60 s (46 men, 106 women, aged 60–69 years), 70 s (52 men, 89 women, aged 70–79 years), and 80 s (37 men, 47 women, aged 80–89 years). Equality of variance was confirmed using Levene's test. As appropriate, a one-way analysis of variance (ANOVA) or Kruskal-Wallis test was performed to compare HGS, TP, and JOF among age groups in both men and women; post-hoc tests were performed using Tukey's HSD or Games-Howell tests, respectively. In addition, the effect size and power of the results were calculated post-hoc using G*Power 3.1 software (Kiel University, Kiel, Germany). For ANOVAs, the effect size was evaluated using f, with $0.10 < f < 0.25$ considered a small effect, $0.25 < f < 0.40$ considered a medium effect and $f > 0.40$ considered a large effect. For Kruskal-Wallis tests, the effect size was evaluated using r, with $0.10 < r < 0.30$ considered a small effect, $0.30 < r < 0.50$ considered a medium effect, and $r > 0.5$ considered a large effect. In