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Tongue Adiposity and Strength in Healthy Older Adults

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Abstract

Objectives/Hypothesis—To identify treatable risk factors for aspiration in older adults—particularly those associated with sarcopenia – we examined tongue composition. We hypothesized that 1) isometric and swallowing posterior tongue strength would positively correlate with posterior tongue adiposity, and 2) healthy older adults who aspirate would have greater tongue adiposity than healthy older adults who did not aspirate.

Study Design—Prospective

Methods—Participants were 40 healthy adults, comprised of 20 aspirators (*Mean age* = 78 years) and 20 non-aspirators (*Mean age* = 81 years), as identified via flexible endoscopic evaluation of swallowing. Measures of maximal isometric posterior tongue strength and posterior swallowing tongue strength were acquired via tongue manometry. An index of posterior tongue adiposity was acquired via computed tomography for a 1 cm region of interest.

Result(s)—Posterior tongue adiposity was correlated with posterior tongue isometric ($r = .32$, $p = 0.05$) but not swallowing pressures ($p > 0.05$) as examined with separate partial correlation analyses. Tongue adiposity did not significantly differ as a function of age, gender, or aspiration status ($p > 0.05$).

Conclusion(s)—Lower posterior isometric tongue strength was associated with greater posterior tongue adiposity. However, aspiration in healthy older adults was not affected by posterior tongue adiposity. This finding offers insight into the roles of tongue composition and strength in healthy older adults.

Keywords

Tongue; Adiposity; Fat; Swallowing; Older Adults; Computed Tomography

Introduction

The tongue has received much attention in research, specifically with regards to strength changes in aging. In 1995, Robbins and colleagues reported that isometric tongue strength was significantly reduced in older healthy adults¹. Shortly thereafter, Crow and Shipp²

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Conflict of Interest: None

reported healthy adults over the age of 79 years showed statistically significantly decreased tongue strength compared to young adults. Over the years, this finding has been repeatedly confirmed¹⁻⁶

We have previously reported that approximately 30% of healthy older adults periodically aspirated liquids⁷⁻¹⁰. We recently found that healthy older adult aspirators had significantly less tongue¹¹ and pharyngeal strength¹² compared to healthy older adult non-aspirators. Thus, tongue strength appears to be related to aspiration in older adults. Similarly, the relationship between tongue strength and dysphagia has also been studied. Yoshida and colleagues (2006) were the first to link reduced tongue strength to swallowing dysfunction, albeit with subjective criteria for dysphagia. They found an association between reduced tongue strength and dysphagia (not specifically aspiration) in 145 patients in nursing homes¹³. Multiple researchers have now demonstrated reduced isometric tongue strength in older adults¹⁻⁶ and a few have linked dysphagia and/or aspiration to reduced tongue strength^{11,13}. There is, however, a paucity of literature establishing mechanisms (e.g., tongue muscle/fat ratio) associated with reduced tongue strength.

Identifying mechanisms associated with reduced tongue strength is critical because they may provide treatable mechanisms that can be targeted in swallowing rehabilitation programs to reverse dysphagia and/or aspiration. Associations exist between lower muscle attenuation values on CT and decreased muscle strength¹⁴, as well as high percentage body fat and increased disability^{15,16} in other parts of the body. It is probable that tongue muscle/fat composition may also be linked to decreased strength and disability (i.e., aspiration).

To date, only Humbert and colleagues¹⁷ have assessed both total tongue volume and tongue fat composition in healthy adults. They utilized a magnetic resonance imaging (MRI) method called iterative decomposition of water and fat with echo asymmetry and least squares estimation (IDEAL-FSE). Ten healthy adults, nine of whom were 37 years of age or younger, participated. The average fat composition across participants was 26.5% (range = 21-31.5%). The oldest participant, who was 64 years of age, had the highest tongue fat percentage. Thus, it is plausible that tongue fat composition is greater in older adults and may be associated with reduced tongue strength and aspiration status.

The effects of gender on tongue strength and adiposity have been equivocal. Some studies report that men have greater isometric tongue strength^{2,5} and women have greater swallowing tongue strength^{3,11}, but other studies reported no gender differences in tongue isometric^{3,4} or swallowing strength^{4,5}. It is plausible that gender differences in lingual adiposity may explain some gender differences in tongue strength. In an autopsy study, Nashi and colleagues¹⁸ found that tongue weight was significantly greater in men than women, and posterior tongue adiposity correlated with body mass index (BMI). Given that the BMI for males and females were similar in their cohort (i.e., 28 vs. 27), gender differences in adiposity percentage may not be expected. Likewise, in a cohort with obstructive sleep apnea, women had greater posterior tongue adiposity than men, as well as a higher BMI¹⁹. In summary, very little information is known on tongue adiposity in healthy older adults relative to age, gender, tongue strength, and swallowing function.

Accordingly, we examined tongue strength, tongue adiposity, BMI, and swallowing ability as a function of advanced age and gender. Specifically, measures of maximal isometric posterior tongue strength, posterior swallowing tongue strength, posterior tongue adiposity, and BMI were acquired. We hypothesized lower muscle attenuation values (i.e., higher tongue fat composition) would be associated with reduced maximal isometric tongue strength, reduced posterior swallowing tongue strength, aspiration, advanced age, and

female gender in healthy adults. In addition, we hypothesized lower tongue strength and greater tongue adiposity would be associated with higher BMI.

Materials and Methods

Participants

We enrolled 40 healthy older adults between 65 and 90 years of age, comprised of 20 aspirators (*Mean age* = 78 yrs) and 20 non-aspirators (*Mean age* = 81 yrs) randomly identified (within their aspiration status) from a cohort of 73 older adults who had previously undergone a flexible endoscopic evaluation of swallowing (FEES) and tongue isometric and swallowing pressures^{7,11}. Fifteen women were in the aspirator group and 9 women were in the non-aspirator groups. Participants reported no history of swallowing, speech, and voice problems; no known neurologic or otolaryngologic disorders; and reported they were in good health. Participants were recruited by bulletins approved by the Wake Forest University Health Sciences Institutional Review Board. Informed consent was obtained.

Procedure

Aspiration status, tongue strength, and swallowing strength measures were acquired 6 to 10 months before the x-ray computed tomography (CT) procedure. Detailed procedures of FEES (with classification of aspiration status), maximal isometric posterior tongue strength, and posterior swallowing tongue strength measures are described elsewhere^{7,11}. Briefly, participants underwent FEES while sitting in the upright position. A 3.1 mm digital flexible endoscope was lubricated with Surgilube® (Altana Inc., Melville, NY) and passed transnasally, typically on the floor of the nose, by the first author to obtain a superior view of the hypopharynx.

Four liquid boluses (i.e., water, skim milk, two percent milk, and whole milk) with four volumes (i.e., 5, 10, 15, and 20 ml) were administered with two delivery methods (i.e., straw vs. cup). Approximately 0.3 ml of green food coloring was added per 118 ml liquid. The boluses were randomly presented to each participant in one data collection session of approximately 15 minutes. Swallows were reviewed in real-time, slow motion, and frame-by-frame. If a participant aspirated (liquid material passed below the vocal folds into the trachea with or without a cough reflex) on a minimum of one swallow, then s/he was categorized as an aspirator.

Immediately following the FEES, participants underwent isometric and tongue strength measures. Lingual pressure was measured from three small air-filled bulbs (KayPENTAX Inc., Lincoln Park, NJ) similar to previously described techniques²⁰. The examiner positioned the bulb strip anteriorly to posteriorly along the midline of the hard palate of each participant. For the isometric tongue strength task, participants were instructed to “press your entire tongue against the roof of your mouth as hard as you possibly can when I say go.” Once, the examiner instructed the participant to “go,” the examiner immediately coached the participant, “press, press, press, okay and rest.” After a 30-second rest period, the sequence was repeated two additional times for a total of three trials. For the swallowing tongue strength task, participants were instructed to swallow with the bulb array on their tongue when they were ready. Three trials were obtained with a one-minute time lapse between the previous swallow and the cue to swallow for the next trial. Peak pressures (mmHg) as a function of time for the posterior bulbs were measured off-line.

A GE Lightspeed® Pro 16 CT scanner was used to conduct the posterior tongue adiposity measurements. Participants removed head and neck jewelry and removable dental work. Participants were positioned in the supine position on the CT table using a padded head

cradle and extended their chin slightly toward the ceiling. A scanogram at 0 and 90 degrees was performed identifying a superior landmark of the mid-maxillary sinuses and an inferior border of C7. The scanogram was used to plot a helical scan. Participants were instructed to not swallow or use their tongue while the CT scan was being obtained. CT scan parameters were 120 KV, 280 mA, .8 seconds helical rotation time, 1.25 mm slice thickness, 6.25 speed, .625 pitch, small focal spot (SFOV), and DFOV 18 cm.

To estimate posterior tongue adiposity, the muscle attenuation values of the posterior tongue were measured by Hounsfield units (HUs) ¹⁹ off-line in the axial plane with a 1-cm elliptical region of interest (ROI). The Hounsfield scale is a quantitative measure of radiodensity that ranges from -1,000 for air to +400 for bone with distilled water defined as zero. Adipose tissue is approximately -120 HUs, with the more negative HU representing greater adiposity relative to muscle ^{21,22}. The posterior tongue was selected to acquire the HU measurements, because it is considered the most important in swallowing and is least likely to be affected by dental-work artifact ¹⁹. The ROI on the posterior tongue was selected between the tip of the epiglottis and tip of the uvula and was identified via consensus by the first and second authors (Figure 1).

Data Analysis

An analysis of variance (ANOVA) was used to examine differences in posterior tongue adiposity as a function of age, gender and aspiration status. Pearson correlation coefficients were calculated between posterior tongue adiposity and posterior isometric and swallowing tongue strength, respectively. Pearson partial correlations were further performed to adjust for age, gender and aspiration status. Significance level was set at 0.05 for all analyses. All analyses were performed using SAS 9.2 (Cary, NC).

Results

Mean posterior tongue attenuation/composition as a function of age, gender, and aspiration status are summarized in Table 1. There were no significant differences in tongue adiposity as a function of age, gender, or aspiration status ($p > 0.05$). Interactions were not significant ($p > 0.05$).

Posterior tongue adiposity ($Mean = 24 \pm 13$ HU) was correlated with posterior isometric ($Mean = 336 \pm 178$ mmHg; $r = .32$, $p = 0.05$) but not swallowing tongue strength ($Mean = 230 \pm 100$ mmHg; $r = 0.10$, $p > 0.05$) (Figure 2). This association was slightly elevated after adjusting for age, gender and aspiration status ($r = 0.31$, $p = 0.07$). BMI was correlated with posterior isometric tongue strength ($r = 0.32$, $p = 0.05$) but not swallowing tongue strength ($r = 0.17$, $p > 0.05$) or posterior tongue adiposity ($r = 0.03$, $p = 0.83$).

Discussion

Non-adjusted posterior tongue adiposity was correlated with isometric but not swallowing tongue strength. That is, greater posterior tongue adiposity was correlated with lower isometric tongue strength. Contrary to our hypothesis, tongue adiposity did not differ as a function of age, gender, or aspiration status.

This is the first study to demonstrate that lower isometric tongue strength is associated with greater tongue adiposity in healthy older adults. This is an important finding, since high levels of adiposity have been linked to decreased physical performance and disability. For example, in the Cardiovascular Health Study, Visser and colleagues reported that high body fat was associated with mobility-related disability and concluded that "high body fatness in old age should be avoided to decrease the risk of disability (p. 584) ¹⁶." Certainly, increased

weight may explain decreased mobility, yet changes in muscle/fat composition ratios may also explain decreased strength and related performance.

Our study demonstrated that higher tongue adiposity was associated with lower isometric tongue strength but not disability (i.e., aspiration status). However, the size of our cohort may have masked possible associations with tongue adiposity and disability/aspiration. Further, the 20 aspirators were healthy adults with intermittent and trace aspiration of liquids only ⁷. In patients with dysphagia, tongue adiposity may be correlated with aspiration.

The finding that posterior tongue adiposity was correlated with posterior isometric but not swallowing tongue strength is logical when reviewing the literature on isometric versus swallowing pressures in young vs. older healthy adults. Both Youmans ³ and Nicosia ⁴ found that *isometric* tongue pressure was significantly lower in older versus young adults; but *swallowing* tongue pressure was similar between young and older adults. Thus, given swallowing is a sub-maximal strength task, it is reasonable that we did not observe a correlation between tongue adiposity and swallowing tongue strength. However, we previously found, in a larger cohort, that anterior and posterior tongue strength was associated with aspiration status in healthy older adults ¹¹. Thus, a larger cohort may reveal an association between swallowing tongue pressures and tongue adiposity.

Another possibility is that the ROI used to acquire the posterior tongue pressures coincided with that region of the tongue most heavily recruited to perform the isometric task but not swallowing. Perhaps a different ROI of the tongue may be more closely associated with swallowing pressures and could be evaluated in future investigations.

The finding that tongue adiposity did not vary by gender is somewhat surprising. Barkdull and colleagues found higher tongue adiposity in women compared to men ¹⁹, although unlike our cohort, most of their participants had obstructive sleep apnea. Another likely explanation for a lack of gender effect is that the BMI of our male and female participants were almost identical. An earlier study using autopsy samples found that the percent of posterior tongue fat correlated with BMI in both men and women ¹⁸. Thus, gender, perhaps in association with BMI, may predict tongue fat composition. In the present study, we found no correlation between BMI and tongue fat composition. Earlier, we found no difference in aspiration status relative to BMI ¹¹. There does appear to be a relationship between isometric and swallowing tongue strength and aspiration status ¹¹, as well as posterior isometric tongue strength and lingual adiposity. Future duplication of these findings in larger cohorts is needed.

This is the first study to use HUs as acquired via CT scans to assess tongue adiposity as a function of tongue strength and swallowing function. HUs offer a relatively easy way to acquire tongue measures of radiodensity and thus muscle/fat composition, and a previous study demonstrated the use of HUs in tongue adiposity measurements relative to sleep apnea scores ²¹. One drawback to this approach is the radiation exposure from the CT scan. Others have used MRI to acquire tongue volume measurements ^{17,23-26}, and most recently, a method called iterative decomposition of water and fat with echo symmetry and least squares estimation (IDEAL-FSE) to quantify tongue adiposity ¹⁷. It remains to be seen whether HUs via CT scans or IDEAL-FSE methods are the most effective way to measure tongue adiposity. Both are vulnerable to possible interferences from dental artifact; however, CT scans may be most clinically generalizable given their widespread use as part of standard patient care.

Assessing tongue adiposity may provide important insight into the mechanisms of tongue rehabilitation. The tongue is amenable to strength training ^{23,27-29}, and one study reported increases in tongue volume in a sub-group of four patients following an 8-week tongue

exercise program ²³. However, whether the increases in tongue volume were the result of a change in muscle/fat composition is unknown. Further investigation via CT scans would help to identify if change in muscle/fat composition occurs relative to increases in tongue strength.

A possible limitation of this study is that although the identification of aspiration status and tongue strength measures were acquired during the same testing session, there was an approximate six-ten month lapse before the acquisition of the CT scans. However, our previous investigation found that aspiration status in healthy older adults (i.e., aspirator, N=9 and non-aspirator, N=9) remained stable over a one-year period (manuscript in preparation).

Conclusion

Posterior tongue adiposity was correlated with posterior isometric but not swallowing tongue strength. In addition, posterior tongue strength but not adiposity was correlated with BMI. These findings advance our understanding of an underlying and likely treatable mechanism associated with lower tongue strength. Although increased tongue adiposity did not explain aspiration status in this healthy older cohort, it deserves further investigation in larger cohorts and patients with dysphagia.

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Figure 1. Representative CT scan, axial plane, demonstrating region of interest at posterior tongue selected for HU measurements.

Figure 2.

Bivariate scatterplot for isometric posterior tongue strength (mmHg) as a function of posterior tongue adiposity (HU).

Table 1

Mean Posterior Tongue Composition Measured via CT Hounsfield Units (HU) as a Function of Age, Gender, and Aspiration Status.

	Number of Participants	Hounsfield Units (mean $\pm$ SD)
Age		
61-70 Yrs	9	24.82 (19.90)
71-80 Yrs	17	26.39 (10.19)
81-90 Yrs	14	20.15 (10.43)
Gender		
Male	24	21.83 (11.50)
Female	16	26.89 (14.76)
Aspiration Status		
Aspirator	20	23.52 (13.21)
Nonaspirator	20	24.19 (13.05)