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Tongue Strength and Endurance in Different Aged Individuals

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Background. It is generally accepted that age-related changes occur in voluntary muscle. Studies of hand grip strength and aging demonstrate a decrease in strength with age; however, there are little data regarding tongue function. The purpose of this study was to determine the relationship of increased age to tongue strength and endurance.

Methods. A pressure transducer, the Iowa Oral Performance Instrument, was used to measure maximal strength and endurance of both the hand and tongue. Ninety-nine healthy volunteers from the oral physiology component of the Baltimore Longitudinal Study of Aging were divided into four age groups, ranging from 21 to 96 years of age. A multivariate analysis of variance was used to determine differences in strength and endurance between age groups and genders. Regression analysis was done to determine the relationship of strength and endurance with age.

Results. Gender analysis indicated that both tongue and hand strength were greater in males; however, tongue and hand endurance demonstrated no gender differences. The strength in both the tongue and hand decreased with age. Individuals over the age of 79 years showed statistically decreased tongue strength, and individuals over the age of 59 years showed statistically decreased hand strength. There was no significant change in the tongue and hand endurance with age.

Conclusions. The results of this study suggest that tongue function is gender- and age-dependent and follows the same trends as hand function. Tongue strength is decreased in older individuals and females, while tongue endurance is gender- and age-independent.

THE tongue is composed of intrinsic and extrinsic musculature arranged to allow for the multiple configurations needed to accommodate the essential functions of speech, mastication, and swallowing. Proper motor control of the tongue is essential in the oral stage of swallowing, with the tongue responsible for bolus formation and transportation from the anterior mouth toward the pharynx to trigger the pharyngeal stage of swallowing (1). In addition, the tongue aids in maintaining upper airway patency during sleep and denture retention. The arrangement of fibers in the tongue is unique: the intrinsic muscle fibers are oriented in all three planes with no bony attachments, while the extrinsic muscles originate in bony attachments and insert in the body of the tongue.

In normal aging, and in the absence of any concurrent tongue or neurologic pathology, there appears to be no clinically evident decrease in swallowing or phonation (2–4). When motor deficits occur in the tongue (e.g., after surgery or stroke), the loss of function can be demonstrated by dysarthria, dysphagia, and difficulty in forming and positioning a bolus (2,5,6). It is generally accepted that normal aging is accompanied by decreases in strength and changes in skeletal muscle (7). Loss of skeletal muscle mass occurs after the age of 60 years because of muscle atrophy and motor neuron loss. While these changes may also occur in the tongue (8), there is no evidence that this causes any clinical deficits. One study showed an increase in altered tongue function with age in males (9); however, the actual deficits were not categorized. Although clinical deficits in tongue function are not generally seen in the healthy, older population, it is important to categorize natural aging trends to determine what loss, if any, occurs in the physiologic reserve of an aging individual.

While it is clear that certain tongue-related functions remain stable with aging (e.g., swallowing), it is not clear what happens to tongue strength and endurance with aging. There is no evidence that the tongue musculature is unique among other striated muscles regarding age-related changes, and therefore it could be predicted that muscle atrophy and decrease in strength occur with age. However, no studies have concurrently examined tongue and other skeletal muscle function in different aged adults, and quantified significant declines that could have clinical manifestations. Therefore, the purpose of this study was to determine if tongue strength and endurance are altered with age, and if these changes parallel age-related trends seen in other skeletal muscle.

METHODS

Subjects. — This study included 99 volunteers from the oral physiology component (10) of the Baltimore Longitudinal Study of Aging (BLSA), conducted by the National Institute on Aging (11). The subjects were community-dwelling, ambulatory, Caucasian, and of middle socioeconomic status. There were 52 males and 47 females ranging in age from 19 to 96 years. The population was divided into four groups consisting of individuals in approximate 20-year age intervals (Table 1). All subjects were generally healthy, and all examinations were conducted by one investigator (JAS) under identical conditions.

Table 1. Study Population

Age Group (yrs)	Males	Females	Total
19–39	7	9	16
40–59	14	13	27
60–79	25	18	43
80–96	6	7	13
Total	52	47	99

Equipment. — The Iowa Oral Performance Instrument (IOPI, 12–14) was used to determine both hand and tongue strength and endurance. A rubber bulb is attached to a pressure transducer, and pressure exerted against the bulb is measured and displayed in kilopascals (kPa). Visual feedback can be attained by utilizing a light-emitting diode (LED) display, where a maximal pressure can be set and the subject asked to press hard enough to keep a light on the LED lit at a given level. A hand pressure bulb is squeezed in the palm of the dominant hand to measure hand strength and endurance. A smaller tongue pressure bulb is placed against the anterior roof of the mouth, and the anterior portion of the tongue presses against it to measure tongue strength and endurance. Subjects with removable dental prostheses were asked to remove their appliances for the duration of the experiment.

Design. — Maximal pressure and endurance were measured following a previously published paradigm (13,14). Maximal pressure for the tongue and the hand was determined by recording three maximal force efforts, each of approximate one-second duration, with a one-minute rest period between trials. Endurance was measured by asking subjects to maintain 50% of their maximal pressure for as long as possible. The length of the endurance trial was measured in seconds (12–14). One endurance trial was completed for both the tongue and the hand.

Statistical analysis. — Analysis of variance (ANOVA) was used to determine if there was a difference between the three trials of maximal pressure. As no statistical difference was seen ($p = .92$ for tongue strength; $p = .80$ for hand strength), the three trials were averaged, and a mean pressure value was used in subsequent analyses. Correlation coefficients (r) and coefficients of determination (r^2) were obtained between maximal pressure or endurance with age for both hand and tongue strength. Separate correlation analyses were performed for males and females. A two-way ANOVA was used to determine differences in strength and endurance between age groups and genders. Data were analyzed using RS-1 statistical program (BBN Software Products). A criterion of $p < .05$ was accepted for significance in the tests of correlation and the ANOVA.

Results

Hand strength. — Regression analysis revealed a statistically significant relationship between hand pressure and age in both males and females (Figure 1), where hand pressure

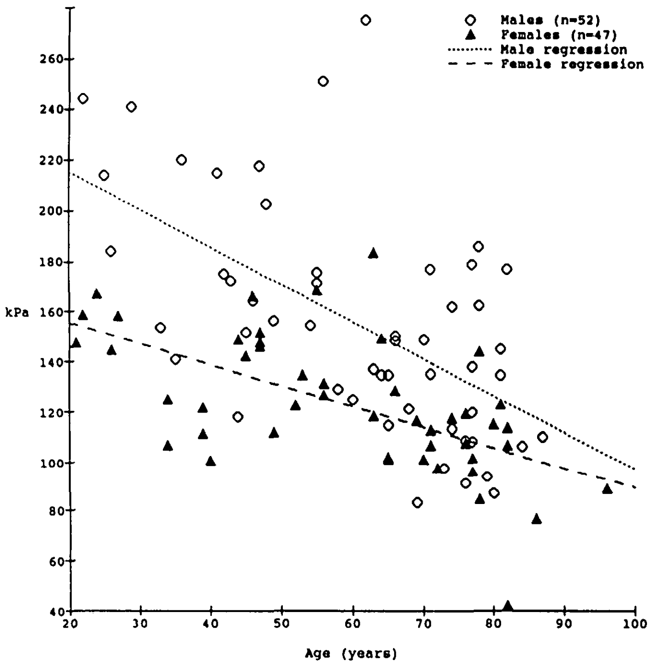

Figure 1. Average hand pressure in kilopascals (kPa) with age. The male regression (open circles, $r = -.58$, $r^2 = .34$) and the female regression (closed triangles, $r = -.59$, $r^2 = .35$) are significant ($p < .001$).

decreased with increasing age. The correlation coefficients for the male regression ($r = -.58$, $r^2 = .34$) and for the female regression ($r = -.59$, $r^2 = .35$) were both significant ($p < .001$). The two-way ANOVA demonstrated significant differences in hand strength between age groups and genders. There were statistically significant lower hand pressures in individuals aged 60 years and older compared to younger individuals (Table 2). The gender analysis revealed significantly ($p < .001$) lower hand pressures in females (123.6 ± 27.2 kPa, mean ± *SD*) compared to males (155.1 ± 44.6 kPa).

Hand endurance. — The regression analysis showed no significant relationship between hand endurance and age in either males ($r = -.13$, $r^2 = .02$; $p = .38$) or females ($r = .09$, $r^2 = .01$; $p = .56$). Likewise, there was no significant difference ($p = .41$) in hand endurance between individuals in the four age groups (Table 2). There was also no significant difference ($p = .08$) in hand endurance between males (74.2 ± 38.3 sec) and females (90.3 ± 49.8 sec).

Tongue strength. — Regression analysis revealed a statistically significant relationship between tongue pressure and age in males (Figure 2); however, the regression for females only approached significance. The correlation coefficient for the male regression ($r = -.38$, $r^2 = .14$) was significant ($p < .001$), but the correlation coefficient for the female regression ($r = -.27$, $r^2 = .07$) was not significant ($p = .07$). There were statistically significant lower tongue pressures in individuals aged 80 years and older compared to younger individuals (Table 3). The gender analysis revealed significantly ($p = .01$) lower tongue pressures in females (64.7 ± 19.6 kPa) compared to males (74.8 ± 18.9 kPa).

Table 2. Hand Strength and Endurance in Different Age Groups*

Age Group	*n*	Hand Strength† (kPa)	Hand Endurance† (sec)
19–39	16	165.0 ± 43.8	72.3 ± 44.3
40–59	27	157.7 ± 34.1	88.5 ± 39.6
60–79	43	129.0 ± 35.3	84.2 ± 46.6
80–96	13	110.0 ± 33.2	72.6 ± 50.5

*Significant difference in strength ($p < .001$) between individuals aged greater than 59 years and younger age groups.

†Data expressed as mean values ± *SD*.

Table 3. Tongue Strength and Endurance in Different Age Groups*

Age Group	*n*	Tongue Strength† (kPa)	Tongue Endurance† (sec)
19–39	16	75.7 ± 17.3	43.9 ± 21.3
40–59	27	75.2 ± 23.6	41.9 ± 24.3
60–79	43	69.5 ± 17.3	48.0 ± 40.8
80–96	13	53.7 ± 13.3	45.2 ± 25.5

*Significant difference in tongue strength ($p < .001$) between individuals aged greater than 79 years and younger age groups.

†Data expressed as mean values ± *SD*.

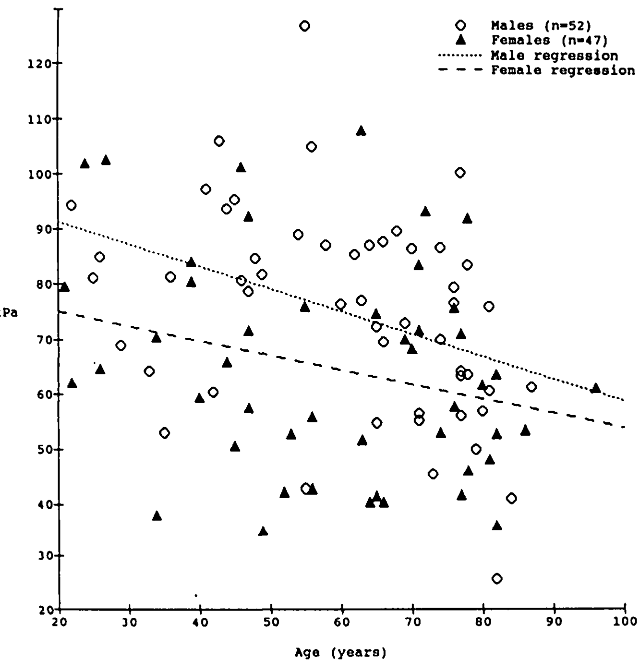

Figure 2. Average tongue pressure in kilopascals (kPa) with age. The male regression (open circles, $r = -.38$, $r^2 = .14$) is significant ($p < .001$), but the correlation coefficient for the female regression (closed triangles, $r = -.27$, $r^2 = .07$) is not significant ($p = .07$).

Tongue endurance. — The regression analysis showed no significant relationship between tongue endurance and age in either males ($r = -.07$, $r^2 = .01$; $p = .61$) or females ($r = .14$, $r^2 = .02$; $p = .33$). Likewise, there was no significant difference ($p = .67$) in tongue endurance between individuals in the four age groups (Table 3). There was also no significant difference in tongue endurance between males and females ($p = .11$).

Discussion

The results of this study demonstrated decreased strength in both hand and tongue pressures in older individuals compared to younger individuals, and females compared to males. There were no significant relationships between hand or tongue endurance and age between males or females, either using a regression analysis or evaluating endurance among different age groups.

Tongue strength appears to decrease with age and is lower in females. This follows the same age and gender trends seen in hand strength. Furthermore, the findings for hand strength correspond to previous reports on hand strength changes with age (15–17). In the present study, age-related decreases in tongue strength were not as pronounced as decreases in hand strength with age. In addition, only the oldest age group demonstrated significantly lower tongue strength with age. This could be due to multiple factors, such as a relatively constant level of tongue activity throughout life allowing for maintenance of strength through isotonic exercise. In addition, the tongue is made up of multiple muscles with various functions, and since this study primarily tested extrinsic tongue muscle strength, it is possible that there is a decrease in the strength of the intrinsic musculature or the motor function of the tongue as a whole, which was not measured.

There are little published data on tongue strength in the healthy older population. One study found a decrease in tongue strength in older dentate individuals compared to younger dentate individuals; however, there was an increase in tongue strength in a group of older edentulous individuals compared to the young or older dentate group (18). This study used a negative pressure, or sucking force, to measure tongue strength, and did not define the age groups involved, so it is difficult to compare results. In the present study, subjects with removable dentures kept their dentures out of their mouth for the duration of the measurements. When tongue strength was compared between individuals with or without dentures (fully dentate or with no removable appliances), there was no significant difference in tongue strength (males $p = .38$, females $p = .95$).

In the healthy aging individual, subclinical decreases in tongue strength appear to have no adverse effects on speech or swallowing. Normal aging changes in swallowing appear mostly in timing sequences, with increase in the duration of the total swallow (3). The oral phase of swallowing tends to be increased in the older population (3,4), as well as the duration of the pharyngeal transit (3). These delays, however, are not clinically evident in the normal aging population (5). The older individual also demonstrates decreases in rapid alternating movements of the tongue (19); however, this does not appear to affect clinical speech (2).

While in the generally healthy older individual a natural decrease in tongue strength may pose no clinical problems, this could potentiate oral dysfunction resulting from a pathological process. In post-laryngectomy patients, individuals who became proficient in esophageal speech did not demonstrate a decrease in tongue strength (20), while those who did not use esophageal speech (they utilized an electronic artificial larynx) had decreased tongue strength compared to controls (21). It was concluded that the esophageal speech patterns may promote strengthening of the tongue (20). In a study of tongue force in aging denture wearers, it was concluded that use of full dentures may promote strengthening of the tongue due to the increased use of the tongue in "paramasticatory" functions (18). These examples provide indications that it may be beneficial to devise and test exercises to promote tongue strength in individuals who have undergone surgical interventions that compromise tongue strength.

Tongue endurance may have less of a physiologic role in normal function (speaking, swallowing, mastication) than tongue strength. While mechanical fatigue of the tongue could have some physiologic ramifications in obstructive sleep disorders (22), endurance as tested in this study does not appear to change with age. Endurance is directly related to strength, with shorter endurance maintained with maximal strength output and longer endurance maintained with submaximal strength output (22). Since this study measured endurance at a constant percentage of an individual's submaximal strength, no gender differences in endurance were expected or demonstrated. As would be predicted, similar patterns of endurance with age are seen in both hand and tongue when examined using similar paradigms.

In summary, age-related patterns in tongue strength and endurance parallel hand strength and endurance findings. There is a reduction in strength of both the tongue and hand with age, and no changes in endurance with age. While this age-related change appears to have no clinical significance in normal aging, it could potentially cause a problem in association with other pathology.

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