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By: **Heather M. Clark** and Nancy Pearl Solomon

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Age and Sex Differences in Orofacial Strength

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ABSTRACT

This study explored age- and sex-related differences in orofacial strength. Healthy adult men (N = 88) and women (N = 83) participated in the study. Strength measures were obtained using the Iowa Oral Performance Instrument (IOPI). Anterior and posterior tongue elevation strength measures were obtained using a standard method. Tongue protrusion and lateralization, cheek compression, and lip compression measures utilized adaptors allowing the participant to exert pressure against the bulb in different orientations. Lip and cheek strength measures were greater for men than women, but tongue strength did not differ between sex groups. Strong correlations between age and strength were not observed. However, group comparisons revealed lower tongue protrusion and lateralization strength in the oldest participants. The oldest participants also exhibited lower anterior and posterior tongue elevation strength relative to the middle-age group. Cheek and lip compression strength demonstrated no age-related differences. The current study supplements and corroborates existing literature that shows that older adults demonstrate lower tongue strength than younger adults. Sex differences were noted such that men demonstrated greater lip and cheek strength but not tongue strength. These data add to the literature on normal orofacial strength, allowing for more informed interpretations of orofacial weakness in persons with dysphagia.

The tongue plays an extensive role in mastication and deglutition. The effort to understand how the tongue supports swallowing has led to the development of a significant literature documenting the range of normal tongue strength in healthy adults [1, 2], the impact of reduced tongue strength on swallowing function [3–6], and the benefit of tongue-strengthening exercises for improving swallowing function [7, 8]. Clinicians seeking to determine whether reduced tongue strength contributes to observed swallowing deficits must have access to normative data for tongue strength in men and women across the life span.

The range of normal performance for anterior tongue elevation strength is well-documented. In contrast, little is known about how strength of other tongue movements (e.g., lateralization) or of other orofacial muscle groups varies across sex and age. This in part reflects the relative lack of methods for quantifying orofacial strength apart from anterior tongue elevation. A recently developed adapter expands the use of a standard instrument for measuring tongue elevation strength to the assessment of tongue protrusion and lateralization and cheek compression [9–11]. Furthermore, a simple modification allows assessment of medial lip compression. The strength of these actions is potentially relevant to successful bolus containment and manipulation. The current report provides a compilation of data describing normal performance on these measures.

A number of previous studies have explored the effects of aging on tongue strength and the potential impact of age-related weakness on swallowing function. Although weak correlations between age and tongue elevation strength typically are observed [2, 12], group comparisons of participants in different age ranges often reveal that older participants produce lower tongue elevation pressures than younger participants [2, 5, 12]. Although studies are consistent in the finding that tongue strength is reduced in the oldest participants studied [2, 5, 12], reports disagree with respect to whether lingual swallowing pressures remain stable with age (interpreted as diminished reserve) [5], or if swallowing pressures in fact decrease proportionately to maximum strength [1, 2]. Tongue weakness associated with aging has been linked to sarcopenia, the loss of muscle mass observed in the aging process [7].

Examinations of sex differences in tongue elevation strength are mixed. Although several studies have reported no differences between men and women on this measure [2, 4, 6, 13], others have found that men exhibit greater tongue elevation strength than women [1, 3, 12, 14]. An interaction effect may exist between age and sex for tongue elevation strength; Utanohara et al. [15] reported greater sex differences in younger adults than in older adults.

The current study aimed to supplement the exploration of age- and sex-related differences in tongue elevation strength and to extend this line of research to include additional measures of orofacial strength. Included are assessments of the standard anterior tongue dorsum elevation, posterior tongue dorsum elevation, tongue protrusion, and tongue lateralization. In addition to tongue strength, the current study examined lip and cheek compression strength according to age and sex.

METHODS

Participants

One hundred seventy-one adult volunteers reporting negative histories for speech or swallowing impairment were recruited from two research sites: Appalachian State University and Walter Reed Army Medical Center. Individuals who reported a history of structural or neurologic impairment affecting swallowing or speech were excluded. Informed consent was obtained from all participants according to each institution's procedures and policies for human-subjects research. All participants exhibited grossly normal orofacial structure and function as judged by the examiner and adequate hearing and language capabilities for completing the assessment tasks. The participants included 88 men and 83 women ranging in age from 18 to 89 (mean age = 42.34, SD = 20.3). To address the question of age effects on orofacial strength, participants were subsequently placed in one of three age groups as described in Table 1. The groups were intended to reflect young, middle-age, and older adults. With the exception of 41 participants, the data reported here were collected as baseline measurements during experiments that examined the effects of orofacial strengthening [10, 16, 17] or as control data for studies that examined orofacial strength in individuals with dysarthria [9, 11]. One of the experiments, involving 24 participants, did not include the posterior tongue elevation or lip compression tasks. Table 2 details the number of participants contributing data for each of the reported measures.

Table 1 Number of participants in each group by age and sex

Age group (years)	**Mean age (SD)**	**Male (*N*)**	**Female (*N*)**
Young (18–29)	22.9 (3.5)	25	43
Middle (30–59)	44.7 (8.8)	35	25
Old (60–89)	70.8 (7.1)	28	15

Table 2 Number of participants contributing to specific measures by sex and age categories

Measure	**Male**			**Female**		
	Young	**Middle**[a]	**Old**[b]	**Young**	**Middle**	**Old**[b]
Anterior elevation	25	35	28	43	25	15
Posterior elevation[c]	25	28	23[d]	43	13	12
Protrusion	25	33	28	43	25	15
Lateralization	25	35	28	43	25	13
Cheek compression	25	35	28	43	25	13
Lip compression[c]	25	28	26	43	13	12

[a]Two participants in this group lacked adequate dentition to complete the tongue protrusion task

[b]Two participants in each of these groups lacked adequate dentition to complete the tongue lateralization and cheek compression tasks

[c]Nine men and 15 women participated in experiments that did not include these measures

[d]Three participants in this group could not tolerate posterior placement of the bulb

Instrumentation

Each of the orofacial strength measures was obtained using the Iowa Oral Performance Instrument (IOPI Medical LLC, Carnation, WA). The IOPI consists of a small hand-held or table-top component that contains pressure-sensing circuitry, a peak-hold function, and a timer. It has options for displaying pressure digitally (in kPa) or by a light array (in 10% increments). Thin flexible tubing connects the IOPI bulb with the main component. The bulb is pliable and air-filled, with an approximate internal volume of 2.8 ml. An optional bulb-holder adapter is composed of a plastic stick (approximately the size and shape of a popsicle stick), with one end configured with a smooth, firm, oblong plate (29 mm × 14 mm). A piece of double-sided surgical-grade adhesive tape is placed on the platform, to which the IOPI bulb is adhered. Pads of medical-grade silicone rubber (polyoxymethylene, Delrin® by DuPont) under the plate on either side of the stick serve as bite cushions; the user's teeth rest on the pads to secure the placement of the bulb and holder (see Clark et al. [10] for images).

Procedures

For all strength assessments, participants were instructed to press against the bulb with maximum effort. All trials were motivated by the examiner cheering "Push, push, push!" or "Squeeze, squeeze, squeeze!" Peak pressure was recorded, and the maximum pressure (P max) generated across three trials was selected for each strength measure [18].

Tongue Elevation

Anterior tongue elevation strength was assessed using traditional IOPI procedures [19]. The bulb was positioned longitudinally along the hard palate just posterior to the alveolar ridge. Participants were instructed to elevate the tongue against the bulb with maximum effort. Posterior tongue elevation strength was obtained with the bulb positioned longitudinally along the hard palate, with the distal end of the bulb at the posterior border of the hard palate. Three participants who could not tolerate the posterior position because of a gag response did not complete this task. A bite-block was not used [20], although participants were encouraged to rest their incisors gently on the tubing of the IOPI bulb.

Tongue Lateralization and Protrusion

For the tongue lateralization and protrusion measures, the IOPI bulb was attached to the bulb-holder adapter. For tongue lateralization, the holder was positioned between the upper and lower molars, with the tongue bulb facing intraorally. Participants were instructed to push the tongue to the side against the bulb with maximum effort. Separate measures for lateralization to the right and left were obtained. For tongue protrusion measures, the holder was positioned between the upper and lower incisors, again with the tongue bulb facing intraorally. Participants were instructed to protrude the tongue as hard as possible against the bulb, which was held firmly in place (via the adapter) by the teeth.

Cheek (buccodental) Compression

Measures of cheek strength were obtained with the bulb holder in the lateral position, with the modification that the bulb faced laterally toward the buccal surface. For this measure, participants were instructed to squeeze the cheek muscles against the bulb with maximum effort. Separate measures for compression on the right and left cheeks were obtained.

Lip (interlabial) Compression

Lip strength was assessed with the IOPI bulb sandwiched between two wooden tongue blades (Fig. 1). This configuration distributed the pressure exerted on the blades evenly across the entire surface of the tongue bulb to provide an accurate pressure reading. The blades were positioned between the lips at midline, with participants instructed to lightly place the teeth together and to separate and protrude the lips slightly as the blades were positioned; this prevented participants from using the jaw muscles to exert pressure on the wooden tongue blades and bulb. Participants were instructed to squeeze the lips together with maximum effort.

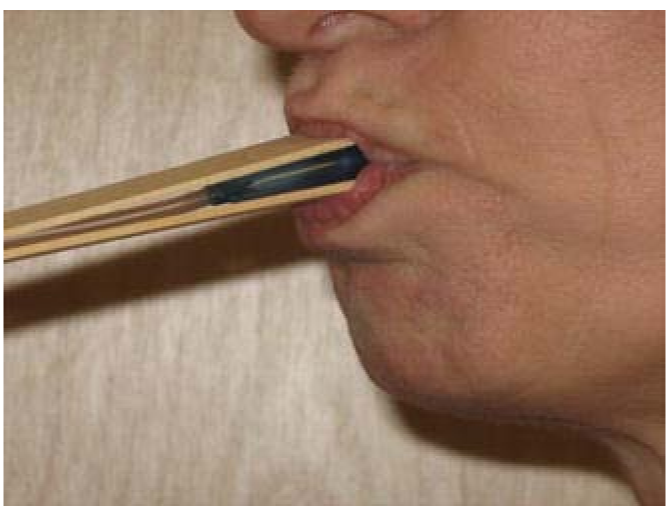

Fig. 1 IOPI tongue bulb positioned between two wooden tongue blades during lip compression assessment

DATA ANALYSES

A repeated-measures (RM) ANOVA was conducted with each orofacial strength (P max) measure as the within-subjects independent variable and age group and sex as the between-subjects variables. Although main effects of measure were not of interest to the current study, RM-ANOVA was conducted to identify significant interactions between measure and the between-subjects variables. Significant interactions were explored with appropriate ANOVA (age group interactions) or independent-samples t tests (sex interactions). When the sphericity assumption was not met, a Greenhouse-Geisser correction was used. To further examine the relationship between orofacial strength and age, Pearson's product-moment correlations were computed between age and each orofacial P max measure.

The initial omnibus test was conducted with an α level of 0.01. The next level of significance testing (i.e., follow-up tests of measure-by-sex and measure-by-age interactions) utilized an α level of 0.008 to correct for multiple tests. All follow-up comparisons proceeding from significant ANOVA utilized family-wise error rates with an α level of 0.01. Where indicated, one-tailed tests of significance were conducted, with the a priori prediction that men and younger adults would demonstrate greater orofacial strength.

RESULTS

Mean P max obtained from the right and left sides varied by less than 5% for both tongue lateralization (1.2 kPa, 2.2%) and cheek compression (1.5 kPa, 4.6%). Therefore, measures from the right and left sides were averaged to produce single measures of tongue lateralization and of cheek compression.

The RM-ANOVA revealed a significant main effect of measure [$F(3.6, 476.7) = 168.3$, $p = 0.000$]. The main effect of sex was significant [$F(1, 132) = 4.39$, $p = 0.038$], as was the interaction between measure and sex [$F(3.6, 476.7) = 5.06$, $p = 0.001$] (Fig. 2). To examine the nature of the interaction, separate independent t tests for the effect of sex were conducted for each strength measure. As summarized in Table 3, men had higher lip compression and cheek compression strength than women. None of the tongue strength measures differed significantly between men and women.

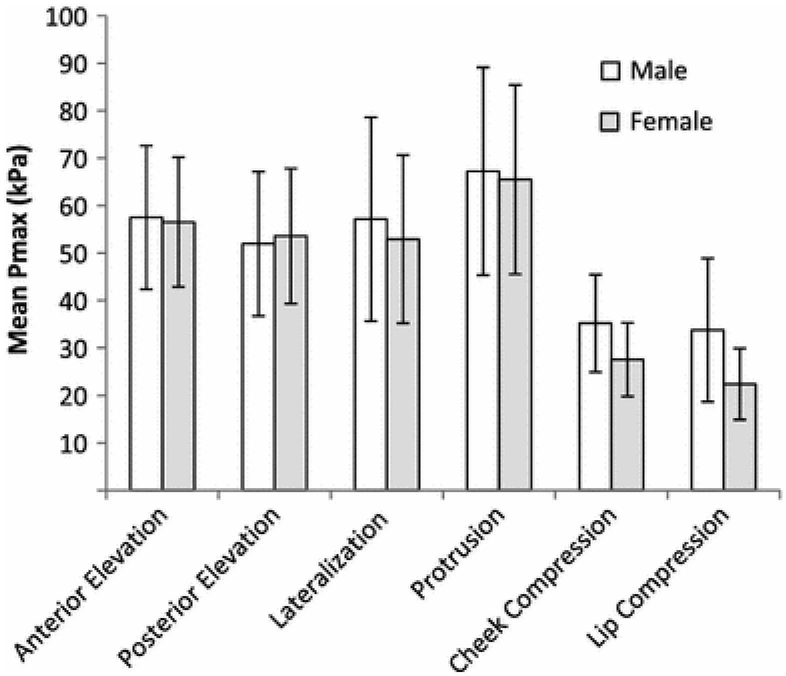

Fig. 2 Tongue and facial strength (maximum pressure in kPa) averaged across group for men and women. Error bars = ±1 SD

Table 3 Maximum pressure (P_{max}) (in kPa) generated for each measure according to sex

Measure	***P* max**		***t***	**df**	***p* (1-tailed)**
	Men	**Women**			
Anterior tongue elevation	57.5 (15.1)	56.5 (13.6)	0.445	169	0.329
Posterior tongue elevation	52.0 (15.2)	53.6 (14.2)	0.666	142	0.253
Tongue lateralization	57.1 (22.1)	52.9 (17.7)	1.38	165	0.085
Tongue protrusion	67.2 (21.9)	65.5 (20.0)	0.540	167	0.295
Cheek compression	35.2 (10.3)	27.5 (7.7)	5.47	167	0.000*
Lip compression	33.8 (15.1)	22.4 (7.5)	5.63	145	0.000*

Summary statistics (mean and SD) and independent *t* tests for sex differences

* $p \leq 0.008$

A significant main effect of age [F(2, 132) = 5.8, p = 0.004] was observed as well as a significant interaction of age and measure [F(7.21, 476.4) = 3.27, p = 0.002] (Fig. 3). To determine the nature of the interaction, separate ANOVAs were conducted for each of the strength measures. Significant main effects of age were identified for all of the tongue measures but not for cheek or lip compression (Table 4). Follow-up comparisons revealed that for anterior tongue elevation, the middle-age group mean was greater than the means for the other two groups, which did not differ from each other. For posterior elevation, the middle-age group mean was greater than that of the older group, with no other comparisons reaching significance. For tongue protrusion and lateralization, the older group mean was significantly lower than those of the other two groups, which did not differ from each other.

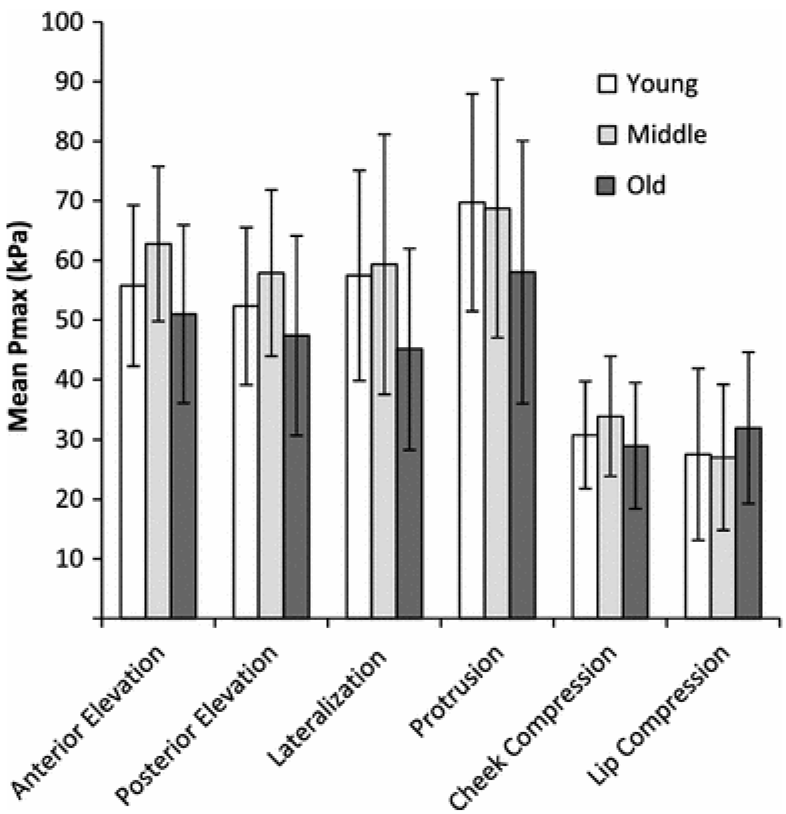

Fig. 3 Tongue and facial strength (maximum pressure in kPa) averaged for the three age groups. Error bars = ±1 SD

Table 4 Maximum pressure (P_{max}) (in kPa) generated for each measure according to age group

Measure	Age group			*F*	Within groups sum of squares df	*p*
	Young	Middle	Old			
Anterior tongue elevation	55.8[a] (13.5)	62.8[b] (13.0)	51.0[a] (15.0)	9.69	168	0.000*
Posterior tongue elevation	52.3 (13.2)	57.9[a] (14.0)	47.4[b] (16.7)	5.06	141	0.008*
Tongue lateralization	57.5[a] (17.6)	59.3[a] (21.8)	45.2[b] (16.8)	7.56	164	0.001*
Tongue protrusion	69.7[a] (18.3)	68.7[a] (21.7)	58.0[b] (22.0)	4.87	166	0.008*
Cheek compression	30.8 (8.9)	33.9 (10.0)	29.0 (10.5)	3.40	166	0.036
Lip compression	27.5 (14.4)	27.0 (12.1)	31.9 (12.7)	1.71	144	0.185

Summary (mean and SD) and inferential (ANOVA) statistical results for orofacial strength across age groups

[a, b]Results for each strength measure that differ significantly ($p < 0.01$) are denoted with unique alphabetic characters

* $p \leq .008$

The interaction between age and sex [F(2, 132) = 1.43, p = 0.241] and the three-way interaction between measure, age, and sex were not significant [F(7.2, 476.7) = 1.43, p = 0.081].

Correlations between age and P max were negative for all measures except lip compression, with statistical significance achieved for tongue lateralization and protrusion. Regardless of their direction or significance, the correlations were weak (Table 5). Figure 4 depicts scatterplots for each measure; these illustrate the variability and weak relationships between orofacial strength measures across age for these adults.

Table 5 Pearson's correlation coefficients (*r*) between age and each orofacial strength measure

	r	***p* (1-tailed)**
Anterior tongue elevation	−0.116	0.065
Posterior tongue elevation	−0.138	0.049
Tongue protrusion	−0.241	0.001*
Tongue lateralization	−0.219	0.002*
Cheek compression	−0.063	0.207
Lip compression	0.125	0.061

* $p \leq 0.008$

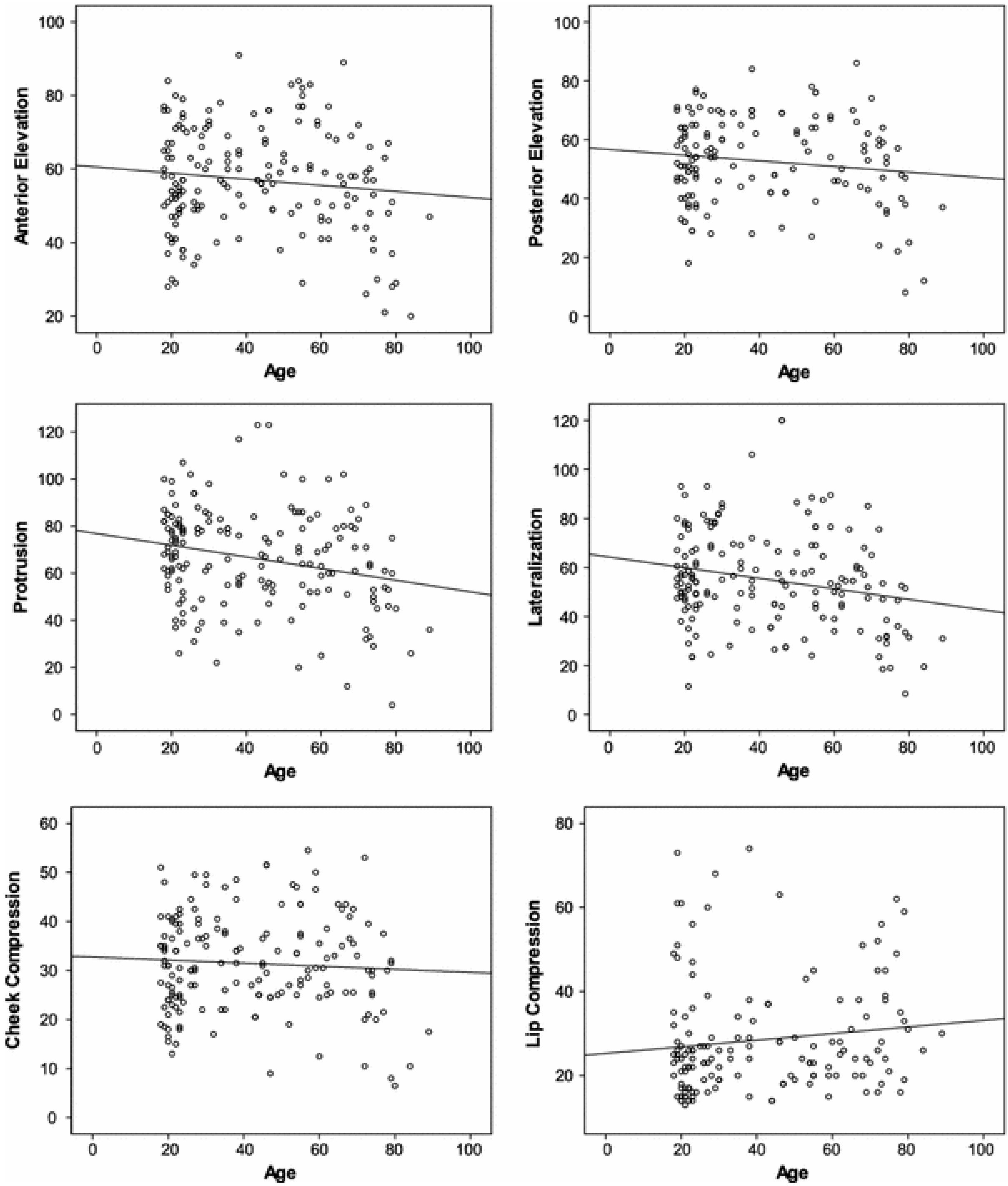

Fig. 4 Tongue and facial strength (maximum pressure in kPa) for individual participants as a function of age (in years); each plot includes linear regression line

DISCUSSION

This study presents orofacial strength measures from reportedly neurologically and structurally normal young, middle-age, and older adults. Data were examined for sex and age differences.

Sex-related Differences in Orofacial Strength

In the current study, tongue strength measures did not differ for men and women. Previous studies of tongue elevation strength have produced mixed results with respect to sex differences, but when differences are revealed, they always favor greater strength for male compared to female participants [1, 3, 12, 14]. The differences in tongue elevation strength between men and women in these previous studies ranged from 4 to 10 kPa. In the current study, mean tongue-strength differences between men and women ranged from 1.0 kPa (1.7%) for anterior tongue elevation to 4.2 kPa (7.3%) for tongue lateralization, with men demonstrating numerically higher mean strength for all but posterior tongue elevation. Taken together, the differences in mean tongue strength between men and women, regardless of the specific action tested, were quite small.

In contrast, men exhibited average cheek strength and lip strength that were 7.7 kPa (22%) and 11.4 kPa (33.7%), respectively, greater than those of women. There are no previous studies comparing maximum lip and cheek compression between men and women; yet we predicted a priori that sex differences in facial strength would follow the same pattern as that predicted for tongue strength. It is quite possible that facial muscles in men generate greater pressures in part because of their larger size. It is also possible that despite our instructions and vigilance to prevent participants from using their teeth to assist with lip compression, some participants, particularly men, may have done so.

Age-related Differences in Orofacial Strength

We predicted that older adults would demonstrate reduced orofacial strength relative to the younger groups. This prediction held true for tongue lateralization and protrusion compared to both younger groups, and for posterior-tongue elevation compared to the middle-age group. Anterior tongue elevation strength was lowest on average for the oldest group as well, but the difference was statistically significant only for the middle-age group. The unexpected finding that the middle-age group demonstrated the strongest tongue elevation results is difficult to explain and may simply be attributable to sampling differences. The overall finding of reduced tongue strength in older adults is consistent with previous reports incorporating age group comparisons of tongue elevation strength [2, 5, 12]. Across these studies, maximum anterior tongue elevation pressures of the oldest adults were, on average, 10–15 kPa lower than the younger adults, a difference that would likely be considered clinically significant. The current tongue strength measures averaged 5-14 kPa lower in the oldest participant group compared to the younger groups, with the greatest age differences observed for tongue lateralization and protrusion. Cheek and lip compression did not differ significantly with age, perhaps suggesting that the facial muscles may be less susceptible to the effects of sarcopenia than what has been documented for the tongue [5, 7].

Despite age group differences in tongue strength, tongue strength was only weakly correlated with age in the predicted direction; correlation coefficients ranged from −0.116 to −0.241. Other studies have also reported weak correlations across entire age ranges for tongue elevation strength [2, 12]. These results reveal substantial variability in tongue strength measures across participants and support the need for large enough sample sizes to reveal general relationships between tongue strength and age. Consistent with the group statistical results, cheek compression strength showed no association with age ($r = -0.063$), and lip compression was positively but weakly correlated with age ($r = -0.125$). Examination of the scatterplots in Fig. 4 reveals the large amount of variability for all measures. Notable, however, is the asymmetry of data around the regression line for lip compression. This suggests either that lip strength is exceptionally variable using the method reported here, or that some other mechanism occasionally assisted in generating the most extreme values. As mentioned previously, if the teeth inadvertently assisted with lip pressure generation, results would be spuriously high. This is impossible to confirm with the present method, but future examiners are warned to watch participants closely during this particular assessment.

Orofacial Strength and Swallowing Function

The majority of studies that examined the relationship between orofacial strength and swallowing function have measured tongue strength using the IOPI during anterior tongue elevation [1–5, 7, 8, 21] as well as elevation of the tongue blade and dorsum [5]. The role of tongue elevation in creating pressures to strip the bolus from the hard palate and propel it posteriorly during the oral transit phase justifies the extensive study of this movement. However, given that the tongue moves in directions other than elevation during bolus preparation, it is not surprising that Clark et al. [4] reported that ratings of tongue strength obtained during elevation, protrusion, and lateralization better predicted the presence of oral-phase swallowing impairment than measures obtained during elevation only. Reddy et al. [22] also found that tongue protrusion strength was reduced in participants with dysphagia. That study further reported that dysphagic participants exhibited lower lip-closure strength compared to nondysphagic participants.

Collectively, these studies highlight the need for normative data on tongue strength that clinicians can consult to determine whether weakness may be contributing to a patient’s swallowing impairment. The current study provides data from healthy participants that add to accumulating evidence indicating that older adults demonstrate weaker tongues than younger adults, especially for protrusion and lateralization. Taken together with previous findings of a significant association between protrusion and lateralization strength and oral-phase swallowing function [4], we speculate that the protrusion and lateralization measures described here will be good predictors of oral-phase swallowing impairment. Furthermore, lip and cheek strength as assessed here would be expected to be associated with oral containment and manipulation effectiveness.

CONCLUSIONS

The contribution of tongue function, including adequate strength, to successful mastication and deglutition is well established. The current study expands the data set describing age- and sex-related differences in strength measures obtained from the orofacial muscles by using a variety of tasks in a relatively large group of nondysphagic men and women. Future studies will explore how these measures relate to specific aspects of swallowing function.

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