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Janice W. Bennett (*St. Joseph's Health Centre, Toronto Ontario*)
Pascal HHM van Lieshout
Catriona M. Steele

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TONGUE CONTROL FOR SPEECH AND SWALLOWING IN HEALTHY YOUNGER AND OLDER SUBJECTS

Janice W. Bennett, M.H.Sc., Pascal H.H.M. van Lieshout, Ph.D., Catriona M. Steele, Ph.D.

ABSTRACT: Current literature on oral motor control reports contradictory findings regarding physiological, functional and sensory changes that occur in the muscles of the tongue with normal aging. It has been suggested that the high level of activity required of tongue muscles in mastication and speech may play a role in preserving them when other skeletal muscles are more likely to show functional effects of such changes. To test whether indeed tongue movements remain unaltered in both speech and swallowing tasks as a function of aging, kinematic measures of tongue dorsum movements were taken as 21 healthy young (20-30) and older (65-74) adults performed repeated iterations of speech tasks and a sequential water swallowing task. Tongue motion was recorded using electromagnetic articulography and from these data information was extracted with respect to movement range, duration, and variability. The findings suggest that in general tongue movements for swallowing were slower and more variable than for speech, and most importantly, more variable among older than younger participants. As well, the findings show that aging does influence the nature of tongue motions, in particular by inducing a more extreme distinction in the variability of movements for speech (less variable) and swallowing (more variable) tasks.

Keywords: aging, swallowing, speech, kinematics, tongue control, articulography

INTRODUCTION

The literature reports a wide variety of findings regarding structural, physiological, and sensory changes that occur in the muscles of the tongue with normal aging. However, thus far the evidence that such anatomical and physiological changes manifest themselves in functional consequences for speech or swallowing functions is still limited. If indeed normal aging does not affect speech and swallowing, it could be argued that any speech or swallowing dysfunction in older people must be the sequelae of a disorder. Therefore, understanding the differences between the effects of normal aging and of speech and swallowing disorders has important implications for rehabilitative and compensatory treatments offered by speech-language pathologists and other health care practitioners. In addition, it means that information about speech and swallowing impairments might reliably be used to inform differential diagnoses.

Baum, Caruso, Ship, and Wolff (1991) offered an important caveat in interpreting many of the reports in the literature that attempt to describe age-related changes. They pointed out that many reports are based on patients with diseases and using medications, rather than on healthy aging people. They also noted that the corpus of research studies are cross-sectional rather than longitudinal, which introduces into the equation differences between individuals that cannot be controlled. Although the latter issue is difficult to address, including healthy aging subjects is important if one wishes to investigate in a systematic way the influence of age on the use of articulators in different oral motor functions. It is also important to use objective measures of articulator function in order to be able to quantify subtle changes in their motion patterns. The next sections provide a short overview of physiological and functional changes in the tongue associated with aging.

Changes in tongue tissue due to aging
The tongue is composed of skeletal muscle, which is known to be affected by atrophy and sarcopenia as it ages. Sarcopenia results in reduced muscle strength due to decreases in the size and number of muscle fibres, and an increase in noncontractile tissue. Other reported changes include atrophy of the surface epithelium (Bassler, 1987), degeneration of underlying connective tissue, and thinner, less elastic tongue muscles (Caruso, Mueller, and Shadden, 1995). Neuromuscular changes have been reported in other muscles with age, such as an increase in the number of muscle fibres per motor neuron. This may cause larger regions of muscle to function as a unit, decreasing its "degrees of freedom" (Nicosia et al., 2000). There is some evidence that the muscle atrophy and loss of muscle fibres in sarcopenia can experience some regeneration, however, this is not sufficient to reverse the effects of sarcopenia on functional muscle mass (Edstrom et al., 2007).

Lipomatosis, the narrowing of muscle fibres, and fibrosis of the perimysium of the tongue have been associated with aging (Bassler, 1987). Amyloid deposits, that is, deposits of a hard waxy substance consisting of protein and polysaccharides that result from the degeneration of tissue, have been reported in the tongues of individuals 60 years of age and older (Yamaguchi, Nasu, Esaki, Shimada, and Yoshiki, 1982).

Aging has also been associated with a decrease in tongue thickness (Sonies, Baum, and Shawker, 1984), but others have argued that an increase in fatty tissue due to lipomatosis compensates for the loss of muscle fibres, preserving the form and volume of the tongue in senescence (Bassler, 1987). The tongue, like the outside parts of the nose and ear, continues to grow in later life (Rother, Wohlgemuth, Wolff, and Rebentrost, 2002). Rother et al. hypothesized that skeletal muscle fibres in the tongue decrease in thickness later in life than in other skeletal muscles. He concurred that lipomatosis results in increased fat tissue in the glands and musculature of the tongue.

Changes in tongue function due to aging
Age-related changes in tongue function that have been reported include decreased strength (Crow and Ship, 1996, Price and Darvell, 1981; Robbins, Levine, Wood, Roecker, and Luschei, 1995), and speed, and increased variability in the rhythm of tongue movements (Hirai, Tanaka, Koshino, and Yajima, 1991). Crow and Ship documented greater tongue strength in males than females across the lifespan, and found that tongue strength decreased from age 79. Their study investigated extrinsic tongue muscles using pressure generation with the Iowa Oral Performance Instrument. Although decreased tongue strength did not appear to impact negatively on the speech or swallowing of healthy, aging individuals, they argued that it is possible that such changes, combined with illness or injury, might contribute to functional pathology. If so, age-related changes may be said to decrease the "functional reserve" for these essential life activities. Nicosia et al. (2000) drew similar conclusions in their study of isometric and swallowing pressure generation.

There is evidence that sensory function is also affected by age. The ability to perceive pressure on the tongue may diminish with aging. For example, perception of the intensity of liquids of different viscosities, and perception of local pressure on the tongue may decline with age (Smith, Logemann, Burghardt, Zecker, and Rademaker, 2006; Sonies and Caruso, 1990). The tongue's role in generating swallowing pressures appears to be preserved in normal aging, although it is likely that the pressure reserve - that is the difference between maximum isometric pressure and swallow pressure, is reduced with age (Robbins et al., 1995).

With respect to tongue control in speech tasks, Goozee, Stephenson, Murdoch, Darnell, and Lapointe (2005) found that younger and older adults used the same strategies to increase speech rate; they increased syllable repetition rates by decreasing the distances traveled by the tongue, and thereby decreasing movement duration (that is, the time taken to travel the shorter distances). Although not significant, the older adults did not decrease the distances traveled by as much as the younger adults. The authors proposed that if, as others have suggested, aging results in reduced neuromotor control of the tongue (Sonies et al., 1984), and if smaller articulatory movements are associated with decreased maintenance of stability in the oromotor system (Van Lieshout, Bose, Square, and Steele, 2007), this might explain why the older adults did not decrease the distances traveled by as much as the younger group. They referred to this compensatory phenomenon as a speed-accuracy trade-off, possibly employed by older adults to maintain stability in the system while increasing speech rate.

Flanagan and Dembowski (2002) found no significant differences in tongue speed and range of motion in diadochokinesis tasks between younger and older subjects. Others have hypothesized that reduced flexibility in fine oral motor control is suggested by increased muscle coupling of the lips as seen in older versus younger women on speech tasks (Wohlert, 1996).

In sum, the functional impact of physiological and structural changes on the speech of aging individuals appears to be small (Bassler, 1987), unless conditions of stress and high demand are present (Caruso et al., 1995). Studies of Caruso and his colleagues found that older speakers lengthened vowel and word durations, and exhibited dysfluencies under conditions described as cognitively stressful. However, they suggested that under normal conditions speech is sufficiently robust to resist the influence of age-related structural and functional changes. Under normal stress conditions, small adjustments in tongue position or movement for speech may be employed to compensate for age-related structural changes (Sonies et al., 1984).

With respect to age-related changes in swallowing, several issues have been documented. These include changes in positioning of the bolus in the oral cavity, the timing of oral-pharyngeal-esophageal stages of swallowing, and swallowing duration (Caruso et al., 1995; Tracy et al., 1989). However, the majority of these changes were pharyngeal and not oral, and hence does not permit us to draw conclusions about tongue control in swallowing. However, Tracy and colleagues identified a significant oral stage finding: older adults held the bolus more posteriorly on the tongue and oral transit time was consequently faster. In general terms, the oral and pharyngeal stages of the swallow tended to overlap temporally among younger adults, and tended to be more sequential in older adults. However, these observed changes did not result in any instances of penetration or aspiration in the older subjects, suggesting that they represent functional age-related changes that did not impact negatively on swallow function itself.

Nicosia et al. (2000) found that maximum lingual pressure generation decreased with age on an isometric task but not on liquid swallowing tasks. The time required to reach peak pressure decreased with age on both isometric and swallowing tasks. Although not statistically significant, older subjects demonstrated a higher incidence of multiple lingual gestures, termed “pressure building”, in order to reach peak pressure on liquid swallows. The authors proposed that these age effects are likely due to factors such as: decreased strength due to sarcopenia, an increase in connective tissue relative to muscle tissue resulting in a “stiffer” tongue, and neuromuscular changes having the effect of decreasing the lingual “degrees of freedom”. Multiple tongue gestures during swallowing were also reported in elderly subjects by Sonies, Ship, and Baum (1989), but this did not result in increased oropharyngeal swallow time. Interestingly, tongue base movement has been reported to decrease significantly with age in elderly women, but not in men (Logemann, Pauloski, Rademaker, and Kahrilas, 2002). The issue of gender differences in aging effects has not been studied in great detail thus far.

In a review of the literature at the time, Baum et al. (1991) argued that their interpretation was that there was no evidence to suggest that normal aging substantially alters the functions of speech and swallowing, and that compensatory adjustments are frequently made in response to age-related oral changes. They reported that speech production appears to be the oral motor function most resistant to aging, although effects on vocal intensity (Baker, Ramig, Sapir, Luschei, and Smith, 2001) and changes in vocal tract resonance (Linville and Rens, 2001) have been noted. Studies of normal aging have produced evidence of slowed oral reaction times, mild reduction of oral neuromotor function, mild muscle atrophy, and tongue weakness, but articulatory compensatory measures appear to occur so that the impact of these phenomena do not interfere with intelligible speech production. This may be due to the nature of speech as "a well-established, overlearned, redundant process" (Sonies and Caruso, 1990). They suggested that the swallowing mechanism may be less able to compensate for age-related changes in muscle tissue, sensory function, salivary flow, and other factors. It is conceivable that the high level of activity required of tongue muscles in mastication, and the abundant blood supply of the tongue, may play a role in preserving them when other skeletal muscles are more affected (Price and Darvell, 1981). In addition to mastication, speech and swallowing also require high levels of tongue activity.

CURRENT INVESTIGATION

Given the existing (but largely untested) claim that aging effects may be different for speech and swallowing functions, the current study investigated the impact of age-related changes on swallowing and motor speech function in the healthy, aging population as evidenced by quantifiable changes in movement range, movement duration, and variability in tongue movements. To address potential gender issues in aging (Logemann et al., 2002), we included both male and female participants. Based on past work on swallowing in our lab it was hypothesized that older participants would show increased movement durations and greater kinematic variability for tongue movements in liquid swallows (Steele and van Lieshout, 2004b). These effects were expected to be stronger in older females than males (Logemann et al.). In addition, gender differences between young males and females were expected in movement range and duration, with young males having larger movement ranges and longer durations (Tasko, Kent, and Westbury, 2002). Based on the current literature, age effects on speech may be limited to a difference in movement duration, with older adults showing longer durations, perhaps as part of a speech-accuracy trade-off phenomenon to increase speech monitoring time (Goozee et al., 2005).

Methods

Participants

Data will be reported for 21 participants recruited in two age groups, 20 - 30 and 65 – 74 years of age. The younger group was comprised of 5 females and 5 males, and the older group had 6 females and 5 males. Participants were healthy with no reported speech, language, hearing, swallowing or neurological problems and free of any medication that could possibly interfere with motor control functions. A certified speech-language pathologist conducted an oral mechanism exam and clinical swallowing assessment prior to acceptance into the study. These standard clinical speech-language pathology assessments identify signs of possible neurological, speech, and/or swallowing impairments, and the presence of signs resulted in exclusion from the study.

Procedures

Data was collected using the AG100 electro-magnetic midsagittal articulograph (EMMA), described below. The EMMA system traces the movement of sensor coils attached to the tongue, face and neck. For the purposes of this study, sensor coils were attached to the tongue midline at tongue blade, body and dorsum, to a dental impression on the lower incisors that captured mandible movement, and over the hyoid bone to capture laryngeal elevation during swallowing. A reference coil was attached to the bridge of the nose (a non-moving structure) that allowed calculation of the distance travelled during palatal approach and release in a two-dimensional space (Van Lieshout et al., 2007). For this study, we will focus on tongue body and tongue dorsum data only.

Instrumentation

The AG100 articulograph (Carstens Medizinelektronik, Germany) with automated calibration (Hasegawa-Johnson, 1998; Schönle et al., 1987) uses a large helmet (62 cm diameter) connected to a smaller inner helmet worn by the subject. Transmitters on the helmet generate an alternating complex magnetic field which permits computerized tracing of the movements of the sensor coils attached to the articulators. The entire helmet complex moves in unison with head movement(s). Movement data were sampled at 400 Hz, while time-aligned speech data were acquired simultaneously through the AG100 system at 16 kHz (for more details, see Van Lieshout, Alfonso, Hulstijn, and Peters, 1994; Van Lieshout and Moussa, 2000).

Data collection procedures

Once participants were set up in the EMMA system they performed a number of speech and swallowing tasks. Analysis was completed on three speech tasks and two repetitions of a swallowing task. The speech tasks consisted of a 6 second reiteration of /ipɑ/ (i.e., "ipa ipa ipa") at an habitual speech rate, a 6 second reiteration of /ɑpi/ (i.e., "api api api"), and a 6 second reiteration of /pətəkə/ (i.e.," pataka pataka pataka"), also at habitual rates. The swallowing task was a trial-set of 6 sequential water swallows, with the instruction, "Keep the cup to your lower lip and take 6 sips at a normal speed for you." Each subject performed these three speech tasks (referred to as IPA, API and PTK) and two repetitions of the water swallow task (referred to as SWAL) within a single session. To sample normal variability over time (Alfonso & van Lieshout, 1997), each subject came back for a second session, doing the same trial sets. The trial sets analyzed in this study were mixed with other (swallowing) tasks, not reported here. So, in total there were 6 speech trial sets and 4 water swallow trial sets across two sessions with (at least) 6 repetitions for each task within a trial-set.

Data processing

The procedures described here follow standard methods used in our lab (for more details see Steele & van Lieshout, 2004a; Van Lieshout & Moussa, 2000; Van Lieshout, Rutjens, and Spauwen, 2002). Movement data were imported into MATLAB (Version 6.5, Release 13, The Mathworks, Inc.) and band-pass filtered between 0.1 Hz (removing slow varying baseline drifts) and 6 Hz (all relevant movement frequencies were found below this cut-off point) using a 7th order Hamming window Butterworth filter. Position signals were transformed to velocity versus time functions using a point differentiation method and the velocity signals thus obtained were band-pass filtered in the same way as the position signals.

An automated peak-picking algorithm was used to detect directional changes in the band-pass filtered position and velocity signals based on specific time interval (1.5 seconds) and amplitude (highest peak/lowest valley in a windowed signal that is within 20% of min/max within-trial value) criteria. The identified peaks and valleys were used to calculate discrete movement parameters and an index of movement cycle variability called cSTI, as detailed next.

Dependent variables

The dependent variables measured were movement range, movement duration, and the variability of individual movement cycle patterns (cyclic Spatio-Temporal Index or cSTI). Movement range was defined as the average distance travelled by the tongue dorsum and tongue body coils during palatal approach and release phases in a 2-dimensional space without subtraction of mandible movement (Van Lieshout et al., 2007). The combined duration of these phases was used as an index of movement cycle duration (see figure 1). Both movement range (RANGE), measured in millimeters, and movement cycle duration (DURATION), measured in milliseconds, were averaged across the corresponding trial sets for each task.

In addition to these two kinematic parameters, we also calculated cSTI values for repeated cycles of tongue dorsum and tongue body movements (Van Lieshout et al., 2002). This measure is based on the STI measure described by Smith and colleagues (Smith, Goffman, Zelaznik, Ying, and McGillem, 1995; Smith & Goffman, 1998). cSTI values capture variability in cyclic patterns beyond (linear) changes in amplitude and duration as a measure for the stability of speech motor execution. Individual movement cycles (as defined above) were amplitude and time normalized and aligned with each other using procedures reported in the literature (Smith et al., 1995; Van Lieshout et al., 2002).

Figure 1. Example of a tongue body gesture position trajectory, illustrating the kinematic measures of movement cycle duration (Duration 1 + Duration 2), and movement range (average of Range 1 + Range 2). See text for more details.

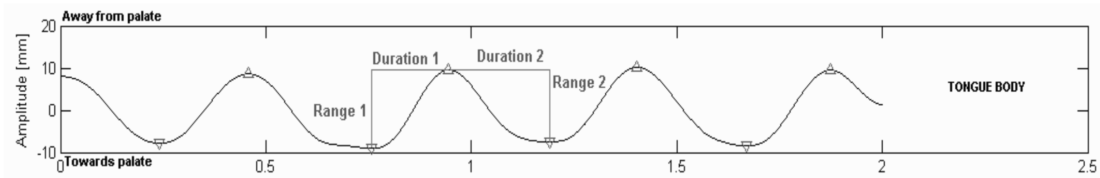
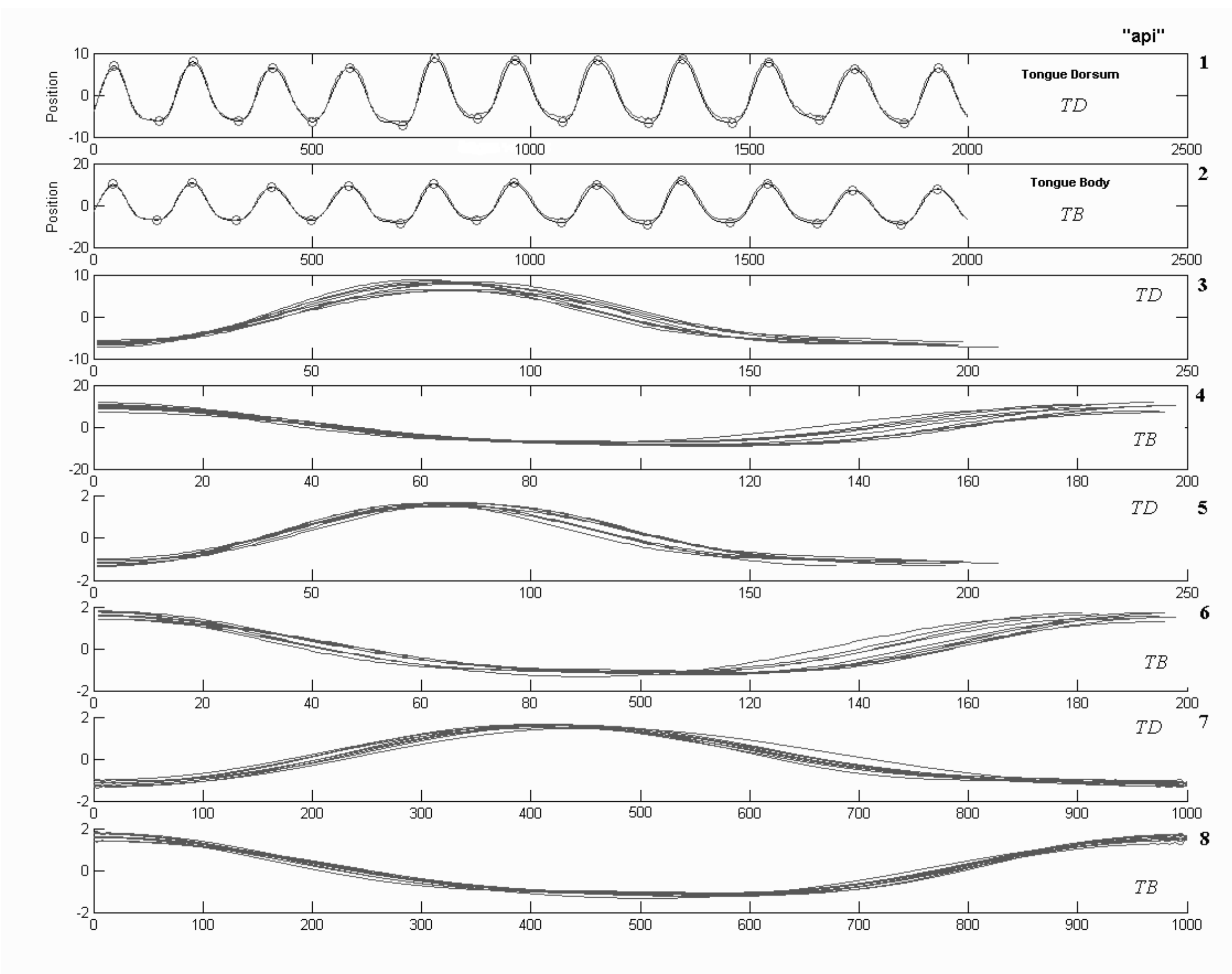


Figure 2. Illustration of cSTI measure for tongue dorsum (TD) and tongue body (TB) signals. The two (overlapping) traces in each of these two panels show the filtered and unfiltered data (the former was used for data analysis). Panels 3 & 4 show individual movement cycles, segmented by the peaks and/or valleys in the two original time series. Panels 5 & 6 show the same cycles, but amplitude normalized. Panels 7 & 8 show the amplitude and time normalized cycles from which the cSTI values were calculated. For these examples cSTI values were 6.4 for TD and 4.9 for TB. See text for more details.



Standard deviations across these overlapping cycles are computed successively at 2% intervals in relative time. Since all movement cycles are time normalized to 1000 points, this yields 1 standard deviation value for every 20 points (total of 50 standard deviations); the sum of all standard deviations gives the cycle-to-cycle combined spatio-temporal variability of the articulatory trajectory for a given trial set. Figure 2 shows an example of the cSTI analysis for tongue dorsum and tongue body movement cycles for the speech task “api”.

Together, these variables can provide specific information on the temporal and spatial characteristics of individual tongue motions related to speech and (liquid) swallowing tasks as a function of aging and gender.

Analyses

Statistical comparisons were made using a mixed-design repeated measures ANOVA with age cohort and gender as between-subject factors, and task (speech vs. swallowing) as within-subject factor, separate for tongue body (TB) and tongue dorsum (TD) variables (RANGE, DURATION, cSTI). Tukey-Kramer post-hoc tests were used as appropriate. Level of significance was set at 0.05.

RESULTS

Mean and standard deviation values for movement range, movement duration and cSTI, averaged across age cohort/gender groups and the four tasks, are listed in Table 1 for tongue body and tongue dorsum. The results of the statistical analysis are summarized in table 2.

Table 1 Means and standard deviations (italics) for Cohort x Gender (OF = Older Females, OM = Older Males, YF = Younger Females, YM = Younger Males) and Task (API, IPA, PTK, and SWAL), separate for movement range (RANGE), movement duration (DURATION), and cSTI.

	OF	OM	YF	YM	***TD***	OF	OM	YF	YM	***TB***	
API	12.97	14.01	12.50	14.07		13.46	14.14	13.39	19.23		RANGE (in mm)
	4.78	*4.18*	*2.86*	*4.85*		*4.25*	*2.88*	*4.03*	*7.28*		
IPA	13.67	15.73	10.09	12.53		13.12	15.16	10.59	17.63		
	3.44	*6.09*	*3.85*	*4.09*		*3.19*	*5.00*	*4.52*	*7.46*		
PTK	8.87	11.68	9.51	8.65		8.04	11.78	7.35	8.74		
	3.26	*3.52*	*3.73*	*2.54*		*2.98*	*2.53*	*2.54*	*2.97*		
SWAL	8.83	10.66	7.30	8.56		9.47	9.52	5.44	8.43		
	4.73	*5.61*	*3.91*	*2.89*		*5.91*	*5.73*	*2.80*	*3.94*		
API	289.11	261.16	256.03	310.50		288.46	260.82	256.19	327.64		DURATION (in msec)
	62.54	*37.21*	*22.24*	*130.95*		*62.17*	*37.20*	*22.05*	*180.14*		
IPA	307.92	258.87	264.19	272.96		308.39	258.85	258.48	273.42		
	66.33	*65.85*	*33.66*	*85.95*		*65.77*	*65.85*	*36.51*	*86.35*		
PTK	325.72	289.51	269.58	283.20		349.09	289.00	269.14	276.98		
	50.12	*36.60*	*29.71*	*111.48*		*91.52*	*36.27*	*29.83*	*90.67*		
SWAL	1100.76	1055.78	1046.16	591.47		1134.87	1088.23	1078.34	634.69		
	359.32	*369.97*	*429.76*	*169.08*		*361.21*	*332.23*	*635.35*	*189.07*		
API	6.37	5.23	6.10	7.31		4.35	4.37	5.40	6.56		cSTI (a.u.)
	3.35	*2.33*	*2.36*	*4.56*		*2.13*	*1.55*	*1.63*	*4.67*		
IPA	6.93	6.98	9.84	7.64		6.94	6.57	7.55	6.08		
	3.76	*4.00*	*5.71*	*3.20*		*3.75*	*4.06*	*3.30*	*2.90*		
PTK	9.55	6.82	10.23	12.29		11.56	5.97	11.14	11.50		
	6.26	*2.85*	*4.09*	*7.31*		*8.08*	*3.14*	*4.53*	*5.85*		
SWAL	21.09	17.49	18.45	15.43		19.81	20.69	18.00	17.38		
	9.49	*5.27*	*6.62*	*6.56*		*7.95*	*10.93*	*6.99*	*10.32*		

Table 2. **Overview of statistical findings for tongue dorsum (TD) and tongue body (TB), separate for movement range (RANGE), duration (DURATION) and cyclic spatio-temporal variability (cSTI). * p ≤ 0.05 ** p ≤ 0.01 *** p ≤ 0.001**

	RANGE			DURATION			cSTI		
TD	df1,df2	F	p-value	df1,df2	F	p-value	df1,df2	F	p-value
AGE COHORT [A]	1,17	1.77	0.201	1,17	2.46	0.135	1,17	0.48	0.499
GENDER [B]	1,17	1.5	0.237	1,17	2	0.175	1,17	0.9	0.356
TASK [C]	3,51	15.12	0.000***	3,51	143.77	0.000***	3,51	65.81	0.000***
A X B	1,17	0.11	0.741	1,17	0.34	0.570	1,17	0.31	0.586
A X C	3,51	1.03	0.389	3,51	4.99	0.004**	3,51	3.06	0.036*
B X C	3,51	0.17	0.917	3,51	4.85	0.005**	3,51	1.31	0.280
A X B X C	3,51	0.54	0.658	3,51	4.54	0.007**	3,51	0.88	0.460
TB									
AGE COHORT [A]	1,17	0.17	0.682	1,17	1.93	0.183	1,17	0.13	0.724
GENDER [B]	1,17	6.57	0.020*	1,17	1.51	0.236	1,17	0.37	0.552
TASK [C]	3,51	26.07	0.000***	3,51	141.22	0.000***	3,51	45.88	0.000***
A X B	1,17	1.34	0.262	1,17	0.15	0.708	1,17	0.23	0.636
A X C	3,51	2.69	0.056	3,51	4.28	0.009**	3,51	1.45	0.240
B X C	3,51	0.91	0.441	3,51	4.17	0.01**	3,51	0.45	0.716
A X B X C	3,51	1.35	0.269	3,51	4.07	0.011*	3,51	0.69	0.564

None of the variables for TB or TD showed a main effect for age cohort or gender, except for TB movement range, where female subjects on average showed smaller values (10.1 mm) compared to males (13.1 mm). Task effects were highly significant for all dependent variables. Based on Tukey-Kramer post-hoc tests, it was found that in general swallowing movements were slower, more variable, and (compared to API and IPA but not PTK), smaller in movement range.

With the exception of cSTI values for TD, significant interactions were limited to duration data. For TD cSTI there was a significant interaction between age cohort and task (figure 3). A Tukey-Kramer multiple-comparison test mainly showed differences for both groups between swallow and speech movements, but the interaction has its origin in the fact that for speech tasks cSTI values were consistently higher for the younger subjects, whereas the reverse occurred for the swallow trial sets. In other words, for TD movements younger subjects were more variable in speech and less variable during swallowing when compared to older subjects.

For movement duration, both TD and TB movements showed significant cohort by task and gender by task interactions, as well as a significant cohort by gender by task interaction (see Table 2). We ran separate ANOVA's for males and females on cohort and task effects. Female subjects showed no main effects for age, but (as can be expected) a significant difference between speech and water swallow tasks (longer duration for the latter). This is in line with the main task effects reported above. For male subjects however, we found a significant interaction effect for cohort by task in TD [$F(3,57) = 9.61$, $p < .001$] and TB [$F(3,57) = 8.53$, $p < .001$]. This interaction is shown in figure 4 for TD. Whereas younger and older males are virtually identical in movement duration for speech tasks, younger males show a significant shorter duration for water swallows. Again, this age difference in water swallows was not found for female subjects.

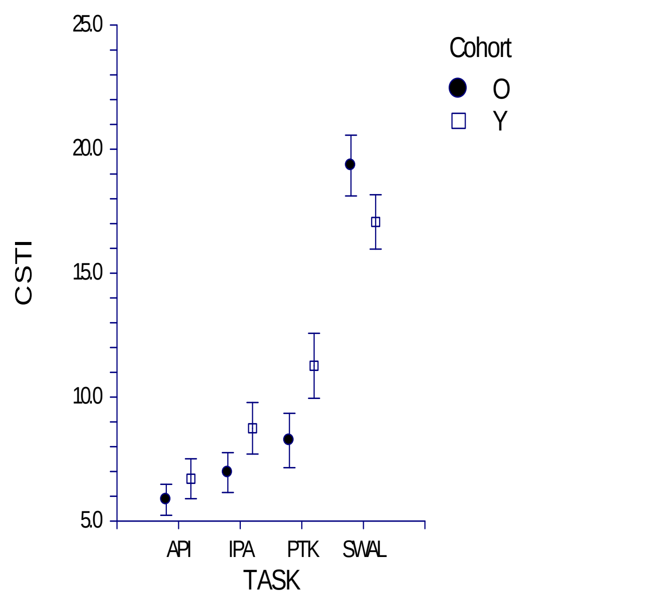


Figure 3. **Tongue dorsum cSTI values for the speech and swallowing tasks, separated for younger (Y) and older (O) subjects. Error bars indicate standard errors of the mean.**

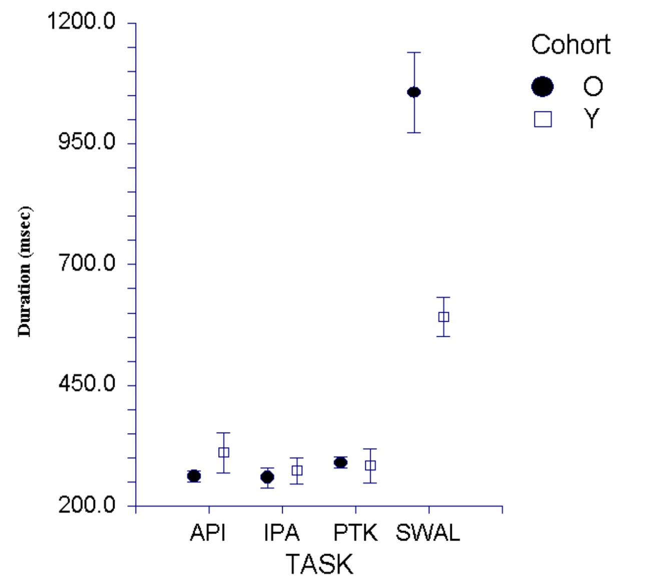


Figure 4. **Tongue dorsum cycle duration values for the speech and swallowing tasks separated for younger (Y) and older (O) male subjects. Error bars indicate standard errors of the mean.**

DISCUSSION

In summary, tongue movements in swallowing in general were slower and more variable than in speech. We also found smaller movement ranges at both tongue positions in swallowing when compared to speech tasks involving more than one vowel. This is likely due to the mandible and tongue remaining in a relatively stable position (in relation to the palate) during swallowing compared to the bilabial speech tasks where the tongue has to move from an extreme high front position for /i/ to a low back position for /ɑ / and vice versa . When the speech task contained only one vowel, (i.e., /pətəkə/), movement ranges for speech and swallowing were actually quite similar. Main effects for age or gender were absent, except that males showed significantly larger movement ranges than females for TB. For TD movements, it was found that younger subjects were more variable in speech and less variable during swallowing when compared to older subjects. Finally, based on significant three-way interactions for movement duration, it was found that younger and older males are virtually identical in movement duration for speech tasks, but during swallowing younger males showed shorter durations. A similar effect was not seen for female subjects.

The main purpose of this study was to explore the possible effects of aging on speech and swallowing tasks. Based on the existing literature as discussed in the introduction, we hypothesized that older participants would show increased movement durations and greater kinematic variability for tongue movements in liquid swallows (Steele & van Lieshout, 2004b). We also expected these aging effects to be stronger in females than males (Logemann et al., 2002). Our findings did not uniformly support these claims. It is clear that tongue movements in swallowing are more variable compared to speech. Perhaps a more appropriate way of phrasing this is to say that for swallowing, tongue movements have more flexibility to accommodate bolus flow compared to the more stringent requirements on movement accuracy for speech. Interestingly, our data suggest that this inherent difference in variability for both tasks may become more extreme when people age, which fits the original hypothesis regarding more variability in swallowing movements for older subjects (regardless of gender). It is possible that this reflects a direct consequence of physiological changes due to aging (see Introduction) but in the absence of corresponding age related changes in movement range or duration, we think it is more likely a characteristic of adaptation allowing older adults to compensate for age-related changes in the tongue or other structures involved in swallowing and speech (see also Baum et al., 1991). For both functions, the basic requirements (flexibility in tongue movements for bolus flow control and precision for speech) seem to be met in older people, although with a more extreme distinction in the variability of movements for speech (less variable) and swallowing (more variable) tasks when compared to the performance of younger people. This suggests that, despite potential age-related changes in tongue strength, impairment in either function is not likely in the absence of a disease process.

Our finding that younger males show shorter movement durations for swallowing compared to older males is not surprising (e.g., Logemann et al., 2000; Steele & van Lieshout, 2004b), but it is surprising that this did not occur for female subjects. We could confirm that males showed larger movements than females during liquid swallowing similar to what was reported by Tasko et al. (2002). Tasko et al. suggested that larger movement ranges of the tongue in males might be a consequence of the larger oral cavities in males, which necessitate larger tongue to palate movements to position the bolus for swallowing. However, unlike their study we did not find longer movement durations for males. In fact, young males showed the shortest duration of all groups (see Table 1). In combination with the larger movement ranges found for young (and older) males, this means an increase in peak movement velocity, which often is associated with more effort (McClean & Tasko, 2003; Perkell, Zandipour, Matthies, and Lane, 2002). These findings suggest a stronger effort in liquid swallows on part of the young males compared to older males (and females in general).

Limitations of this study are that the sample size was small with 10 younger and 11 older adults, and that only two speech and one swallowing task were used. Data have been collected for a larger group and are presently being analyzed. Future research in this area should include multiple speech and swallowing tasks. Another limitation is the cross-sectional design, which does not allow for the control of differences between individuals.

This study provides corroboration that individuals experiencing normal aging appear to be able to compensate for age-related structural, physiological, and sensory changes that occur in the muscles of the tongue, such that speech and swallowing function are preserved. Although kinematic differences in tongue movement were found between younger and older participants, all participants had normal speech and swallowing function, indicating that the older participants had compensated for changes they may have experienced. For the clinician, this means that speech or swallowing dysfunction in older people can be assumed to be the sequelae of a disorder, and should not be dismissed as impairments that are "only to be expected" with advancing age. Since a speech or swallowing impairment can be the first sign of the onset of a neurological illness or event, its early identification can contribute to the physician's diagnosis and the timely initiation of pharmacological and therapeutic rehabilitative interventions. Further, identification of different types of speech impairments (e.g., dysarthria type) can be useful to the physician in the differential diagnosis of neurological illness.

CONCLUSIONS

The current study investigated tongue motions in healthy young and older subjects of both genders. The findings show that aging does influence the nature of tongue motions, in particular by inducing a more extreme distinction in the variability of movements for speech (less variable) and swallowing (more variable) tasks. This seems an adequate compensatory mechanism for potential age related structural and physiological changes in the tongue. In general, males tend to make larger movements and especially young males seem prone to make more effortful swallows compared to the other groups. The reason for this difference in the young males is unclear. However, a larger corpus of data has been collected, and its analysis should permit the positing of potential theories to explain this result, if confirmed in the larger scale dataset.

CONTACT AUTHOR:
Janice W. Bennett, M.H.Sc., SLP(C), Reg. CASLPO[1,2,3]
Speech-Language Pathologist
St. Joseph's Health Centre,
30 The Queensway, Room 6M-18,
Toronto Ontario, Canada, M6R 1B5.
Email:bennej@stjoe.on.ca

Pascal H.H.M. van Lieshout, **Ph.D**.[2,4,5,6]
Speech Scientist

Catriona M. Steele, **Ph.D., SLP(C), CCC-SLP**, Reg. CASLPO[2,3]Swallowing Scientist

Affiliations:
[1]St. Joseph's Health Centre, Toronto, Ontario
[2]Oral Dynamics Laboratory, Department of Speech-Language Pathology, University of Toronto
[3]Swallowing Rehabilitation Research Laboratory, Toronto Rehabilitation Institute
[4]Institute of Biomaterials and Biomedical Engineering, University of Toronto
[5]Toronto Rehabilitation Institute
[6]Department of Psychology, University of Toronto

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