ORAL EFFICIENCY DURING SWALLOWING IN AGING

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Abstract

The purpose of this study was to determine oral efficiency in swallowing for older healthy persons compared with younger healthy. Oral efficiency was determined by examining bites per trial, mastication cycles per bite, and oral mastication duration in varying textures: cracker, raw carrot, steamed green bean (single bite; ½ cup serving), and chicken sandwich. Twenty-seven participants, comprised of older healthy individuals (n=14, age 51-69 yrs.) and younger healthy participants (n=13, age 21-39 yrs.) completed oral intake trials in randomized order. Surface electromyography (sEMG), with sensors placed on the masseter and suprahyoid musculature, provided muscle activation signals to determine the number of mastication cycles and oral mastication duration. Tongue strength of younger (61.51 kPa ±12.47) and older healthy participants (58.36 kPa ±10.07) was not significantly different in a maximum tongue press task, (p=.475). Independent samples t-tests revealed that older healthy participants (M=21.79, SD=8.27) had increased mastication cycles per bite consuming the sandwich compared with younger healthy (M=28.70, SD 8.54), p=.047; however, cracker (p=.071), carrot (p=.056), single bite green bean (p=.728) and half cup serving green bean (p=.728) trials were not different between older and younger participants. Bites per trial and oral mastication duration did not differ in older and younger healthy, p>.05 across textures. In this pilot study, increased mastication cycles in the sandwich condition may suggest that persons develop reduced oral efficiency with aging when eating and need to exert more effort using increased mastication cycles per bite to intake at the same rate as younger healthy.

Background

By 2030, over 60 million, or 1 in 5 individuals, in the United States will be above the age of 65 (U.S. Census Bureau, 2010). Aging is a risk factor for chronic disease and rising related healthcare costs (Atella et al, 2019). Older persons with co-morbid diseases are at a higher risk for developing dysphagia (swallowing dysfunction) and aspiration (Marik & Kaplan, 2003). However, evidence suggests that swallowing is susceptible to the effects of aging in addition to disease processes (Ekberg & Feinberg, 1991). Identification of the effects of aging and development of preventive measures may decrease prevalence of chronic disease or delay its onset and improve a person's overall quality of life.

Swallowing entails a series of highly choreographed, sequenced motor movements in which the bolus, a well-formed mass of food or liquid, is prepared in the oral cavity and propelled down the pharynx and into the esophagus (Dellavia et al., 2018; Hayoun et al., 2015; Manning et al., 2016; Martin-Harris et al., 2003). Once a bolus is masticated, bolus movement though the oropharynx process is completed in approximately two seconds. Maintenance of daily nutrition and hydration in healthy persons is dependent on the presence of safe and efficient swallowing function. Altered coordination in the complex neuro-regulated mechanical movements requisite for a safe and effective swallow can result in bolus entry into the airway (aspiration), aspiration pneumonia and increased risk for mortality (Langmore et al., 1998; Marik & Kaplan, 2003).

In the oral preparatory phase of the swallow, bolus formation begins when food or liquid enters the mouth through the lips and is placed onto the tongue (Reddy et al., 1990). Solid foods are routed to the teeth on oral entry and masticated using a rotary pattern of movement by the masticatory muscles to maximize grinding of the solid material (Meenakshi & Paul, 2017). During mastication, the bolus is mixed with saliva to form a cohesive bolus. Then in the oral phase, the intrinsic and extrinsic tongue muscles along with the suprahyoid muscles drive the bolus towards the back of the oral cavity and into the pharynx (Manning et al., 2016; Martin-Harris, 2015), where contractile pressures propel the bolus through the pharynx to enter the esophagus.. The sequence of motor activation follows a prescribed timeline for what is considered typical and is controlled by the central pattern generator in the brainstem with sensory and cortical influences (Brandao et al., 2019; Martin-Harris et al., 2003). The motor pattern is responsive to sensory input such as bolus volume and bolus viscosity (texture).

Presbyphagia, swallowing impacted by the aging process, results in distinct but subclinical changes in oropharyngeal swallowing physiology and timing (Hiss et al., 2004; Lee et al., 2018). This aged swallow is considered normal and not a disordered process. Presbyphagia is characterized by increased muscle weakness and atrophy (sarcopenia), muscle stiffness (fibrotic connective tissue in the pharynx and larynx), and sensory changes that may impact swallowing function (Lee et al., 2018). Reduced tongue and pharyngeal muscle strength are risk factors for decreased bolus formation and bolus control in the oropharyngeal phases of the swallow (Manning et al., 2016). Alterations in bolus formation may decrease cohesion leading to residue in the oral cavity after the swallow. Reduced bolus control increases early bolus spillage into the pharynx prior to the onset of the pharyngeal motor sequence and may decrease airway safety. Piecemeal deglutition, parsing a single bolus into multiple swallows, occurs more frequently in older individuals and adds to swallowing inefficiency in this population (Wang et al., 2015). Collectively, reductions in the efficiency and effectiveness of the swallow may have consequences related to nutritional status and swallowing safety (Hiss et al., 2004; Lee et al., 2018).

Fatigue has been posited to negatively impact swallowing safety and efficiency. It is defined as an inability to maintain a required level of force for a task (Vollestad, 1997) with a self-perceived sense of increased effort to perform the task (Enoka & Stuart, 1992). The effect of fatigue on swallowing has been examined in the context of meal consumption in limited groups of disordered populations such as Parkinson's disease (Solomon, 2006) and long-term care patients (Namasivayam et. al, 2015). Endurance measures have also been conducted as a surrogate for fatigue, including examination of tongue endurance (Solomon, 2004). In this instance, persons are asked to perform submaximal tasks (e.g. pushing the tongue to the roof of the mouth at 50% of maximum) for as long as possible. The impact of fatigue on the swallow in the aging process has not been investigated. However, declines in oral function across the span of a meal due to fatigue should be considered a potential variable in both swallowing safety and overall quality of life for aging persons.

Clinical assessment of the oral phases of swallowing may be completed at the bedside which includes examination of oral structures and oral function during observation of oral intake. However, bedside testing to date has lacked quantitative measures to improve clinical diagnostic accuracy and clinical decision-making (Huckabee et al., 2018) and often relies on subjective determinations of normal versus abnormal oral phase swallow presentation. The Test of Masticating and Swallowing Solids (TOMASS) is a valid and reliable assessment to quantify clinical observations for masticatory function (Huckabee et al., 2018). Components of the assessment will be used to determine oral efficiency for swallowing in the comparison groups.

Project Aims

Swallowing requires precise, synergistic muscle movements to efficiently masticate and transport a bolus (food or liquid) through the oropharynx and esophagus to meet our daily nutritional needs. Aging impacts muscle function for swallowing and has been shown to increase the risk of malnutrition, dehydration, and airway safety (Eglseer et al., 2018; Wirth et al., 2016). The purpose of the current study was to determine oral efficiency in swallowing for older healthy participants compared with the young healthy group. We planned to meet this aim by examining quantifiable oral swallowing elements such as the number of bites for a prescribed solid volume, number of masticatory cycles in a bite, and duration measures for mastication. This study also aimed to examine the role of fatigue on oral efficiency in older participants by determining oral efficiency changes across a meal when compared with younger, healthy participants. The impact of fatigue on swallowing in aging (presbyphagia) persons is not known but is posited to alter swallowing efficiency and may lead to decreased airway safety.

Research Questions

Do older healthy demonstrate different oral efficiency in swallowing compared to younger healthy?

1. Do they vary by number of bites per consistency?
2. Do they vary by number of masticatory cycles per bite?
3. Do they vary by amount of time per consistency?

Hypotheses

We hypothesized that (1) older, healthy participants would demonstrate significant differences in swallow event timing and oral physiology during swallowing tasks compared with younger healthy and (2) older, healthy participants would also demonstrate reduced oral efficiency across time in a fatigue-inducing oral intake task.

Methods

Participants

This study recruited 27 participants that included 14 older healthy (aged $\geq$ 50) and 13 younger healthy (aged 18-40). Participants were recruited from TCU faculty, staff, and students per TCU's guidelines for in-person human-subject research due to COVID-19. This study did not recruit from the DFW community. All participants were recruited via email, flyers at TCU, word of mouth, and university advertising of the study on TCU Announce, an electronic platform for posting events and research opportunities.

Inclusion criteria to participate in the study for both groups included the following:

- Swallow screening score <3 on the Eating Assessment Tool (EAT-10)
- Able to eat a regular texture diet and drink thin liquids
- Able to self-administer food and liquids (no assistance required for eating)
- Presence of dentition or alternative dentition for mastication (partial or full dentures)
- Demonstration of typical oral structure and function on an oral mechanism examination
- Cognitive screening score of $\geq$ 21 points (21-24 points=mild 25-30 points=normal cognition) on the Mini Mental State Evaluation (MMSE)
- Reflux screening score of $\leq$ 13 on the Symptom Index (RSI)

- Respiratory function screening of FEV1/FVC $\geq$ .70 using a spirometer

Exclusion criteria for both groups included: a history of dysphagia; a history of brain injury, stroke, seizures, or other neurological disorders; a history of pulmonary disease; a history of intubation within the last month; a history of neck injury requiring treatment by a physician; a history of head and neck cancer or radiation treatment; inability to speak or understand English; symptoms of COVID-19 or inability to meet TCU prescreening guidelines.

Instrumentation and Calibration Procedures

The instrumentation for this study included: respiratory inductive plethysmography (Respitrace, ADInstruments), spirometry (Legend, KoKo), oral pressure manometry (Iowa Oral Performance Instrument [IOPI]), surface electromyography (sEMG) (Delsys Trigno), and a nasal canula with an airflow transducer (MS-110 A-D Unit, Glottal Enterprises). All instruments were calibrated adhering to the manufacturer specifications. A pulse generator button was used for synchronized signal marking of swallowing events. A camera recorded the head and neck region of the participants to determine the presence of motion artifact during signal analyses off-line as needed. All digitized signals were synchronized and input into a data acquisition system (PowerLab 16, ADInstruments).

Figure 1
Digital Scale Method for Carrot and Single Bite Green Bean Trials

A calibrated digital scale (Valor 4000W, Ohaus) was used to measure trials of carrot and green bean within 5% weight volume in ounces across trials. (Figure 1). An oral manometer with an air-filled bulb placed on the anterior tongue measured tongue force during a maximal tongue push to the roof of the mouth to determine tongue strength. The IOPI is a valid and reliable instrument for measures of tongue strength and endurance (Van den Steen et al., 2020) (Figure 2). The surface electromyography (sEMG) signal from the masseter, a muscle that contracts to close the mandible during mastication, was used to determine the number of masticatory cycles and the mastication duration. A sEMG sensor placed on the participant's left masseter measured the degree of muscle contraction force during mandibular movements in chewing. An additional sEMG sensor was placed on the suprahyoid muscles to determine the onset of hyoid movement- a gold standard for measurement of the onset of the pharyngeal swallow motor plan. An airflow transducer with a nasal cannula, as is used in oxygen delivery to the nares, determined the participant's airflow while the respiratory inductive plethysmography sum signals (rib cage and abdomen) measured thoracic movement for breathing. Both instruments provided cessation signals of airflow and thoracic movement to support the brief offset of respiration that occurs during swallowing, known as swallow apnea. These data points were triangulated with the hyoid movement signal in the sEMG sensor placed on the suprahyoid musculature to mark the swallow onset.

Figure 2
Tongue Strength Measures with Iowa Oral Performance Instrument (IOPI)

Study Procedure

An initial, 5-minute telephone screening was performed with each prospective participant to assure their eligibility for the study. Participants completed a medical history screening and a swallowing screening (EAT-10). If eligible to take part in the study, participants were then scheduled for their single visit to the Laboratory of Applied Swallowing Research in the Miller Speech and Hearing Clinic. All participants were instructed to abstain from oral intake for 4 hours prior to their study appointment.

Upon arrival, participants completed a COVID-19 screening and consenting paperwork. Screening paperwork included the Mini-Mental State Exam (MMSE), which is a cognitive screening to assure normal cognitive functioning. Participants also completed the Reflux Symptom Index (RSI), a nine question, self-rated screening for determining the presence of symptoms for gastroesophageal reflux (GERD). GERD is known to negatively impact the swallow (Bollschweiler et al., 2008). Participants then completed the Dysphagia Handicap Index (DHI), a 25-question patient self-rated dysphagia assessment of physical, emotional, and functional abilities of swallowing. Lastly, all participants were given an oral mechanism examination to assure adequate structure and function of oral musculature.

After completing consenting and inclusion screening tasks, participants completed a respiratory function screening with spirometry (Koko Legend). Participants were asked to insert a new, disposable filter between their lips to achieve a seal; the filter was attached to the spirometer transducer. A nose clip was applied to the nasal ala to prevent nasal airflow. Participants were given a verbal prompt to take a deep breath in and to blow out hard and fast. A ratio of forced expiratory volume in one second to total forced vital capacity (FEV1/FVC) of >0.70 assured adequate respiratory function (Rabe, 2007).

Participants were then fit with the remaining instrumentation. The sEMG sensors were adhered at the suprahyoid, above the thyroid notch, and on the masseter muscle with ideal placement determined using a jaw clinch task. A nasal canula was placed in the participant's nose to measure airflow during experimental tasks. Lastly, respiratory inductotrace stretchable bands were placed around the ribcage and abdomen to measure thoracic movement during breathing. A pulse oximeter was intermittently placed on the participants' index finger to assure that blood oxygenation levels did not fall below a healthy level of <90% SpO2. A baseline tongue strength measure using the IOPI was completed before participants began the experimental trials using the IOPI. The air-filled tongue bulb was placed on the anterior tongue and each participant completed three maximum tongue press trials to the roof of the mouth.

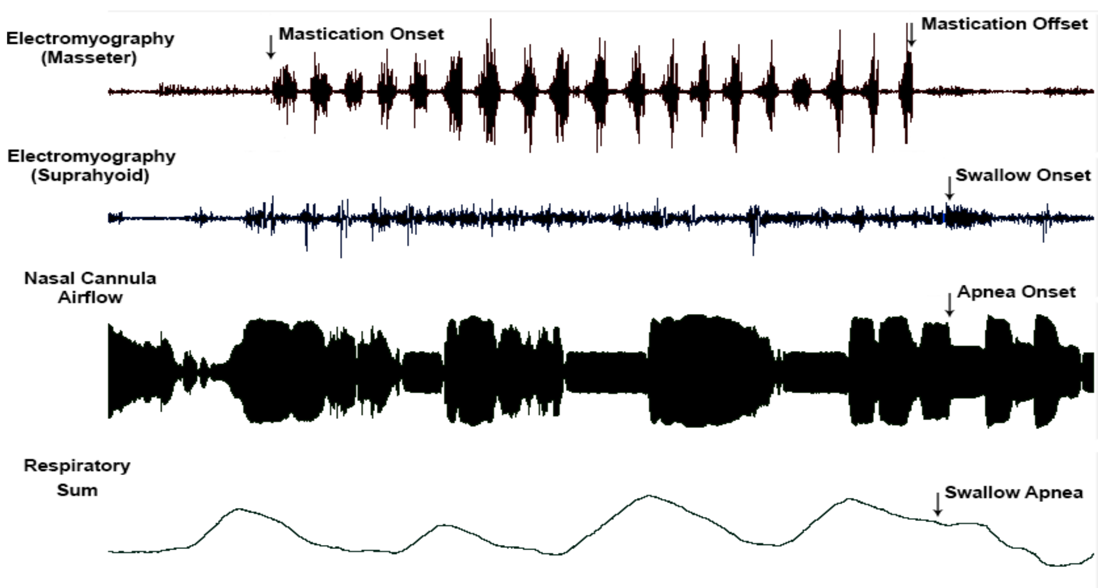
For this study, participants consumed four different trial textures: Nabisco saltine crackers, raw carrots, steamed green beans, and a Chik-Fil-A sandwich. Steamed green beans were trialed as a single bite (2-3 beans of similar weight) and a ½ cup serving. Carrot and single bite green bean texture trials weighed within 5% of other trials of that texture. Participants completed 6 trials of cracker, raw carrot, and steamed single-bite green bean. Textures were counterbalanced, except the sandwich was completed last with an aim to evoke fatigue. Participants were not provided any cues as to how to consume each trial. Carrots and single bite green beans were presented in plastic cups; participants self-administered all trials. Participants were instructed to consume the texture trials as they normally would in a natural setting. A minimum of three full breath cycles was completed between trials. The ½ cup green beans were presented to the participant in a bowl. They were instructed to consume the entirety of the bowl's contents. Lastly, the chicken sandwich (Chick- fil-A) was warmed for participants and given to them on a plate with verbal instructions to consume the sandwich in their normal manner.

Consenting, inclusion testing, and experimental tasks lasted 2.5 hours and participants were compensated with a $20 gift card. Following the completion of the study, participants were given a copy of their signed consent forms.

Data Analysis

Data was collected in asynchronized data acquisition system (LabChart, ADInstruments). Each peak amplitude in the masseter EMG signal represented a single mastication cycle (Figure 3). The number of mastication cycles were determined in off-line analyses. A participant's masticatory cycles mean for each condition was computed and entered into SPSS v 24 (IBM) for analysis.

Figure 3
Mastication Cycles for a Single Carrot Consumed in a Single Bite in a Young Healthy



Bites per trial (e.g., three bites to consume a saltine cracker) were also counted in real time by the research assistant and verified through the off-line sEMG signal of the masseter. The sEMG signal amplitude for a bite onset tended to have a higher peak amplitude than the signal amplitudes during the subsequent mastication cycles aiding in bite onset identification.

While duration measurements were completed for all bolus trials, for the purpose of this study, the first 3 carrot trials and the sandwich trials for each participant were analyzed for mastication duration. The duration was operationally defined as the time between the onset of the masseter contraction in the first mastication cycle to the completion of the last mastication cycle in the last bite for the trial, when the masseter contraction amplitude returned to zero. Duration mean values for carrot and sandwich trials were input into SPSS v 24 (IBM) for analysis.

Results

Twenty-seven healthy participants participated in this study, comprised of older healthy (n=14) and younger healthy (n=13). The older healthy mean age was 60 years (range: 51-69) and younger healthy mean age was 28.15 years (range: 21-39). Younger healthy scored a 2.23 (SD=2.09) on the Reflux Symptom Index (RSI) and the older healthy had a mean of 2.57 (SD=2.53). For the Mini Mental State Exam (MMSE), younger healthy scored a *M*= 29.69 (SD=0.48); Older healthy performed similarly with *M*=29.21 (SD=1.12). Lastly, younger healthy scored a M=1.08 (SD=1.55) on the Dysphagia Handicap Index (DHI) and older healthy was a M=2.17 (SD=2.33). Therefore, the older healthy performed similarly to the younger healthy on the screening measures in this study.

An independent samples t-test was completed to determine if tongue strength measures for a maximum tongue press to the roof of the mouth were different in older healthy participants compared to younger healthy participants (Table 1). Older and younger healthy participant's tongue strength was not different, *M*=3.15, 95% CI [-5.80, 12.11], $t(25) = .726$, $p=.475$.

Table 1
Tongue Strength (kPa) in Older and Younger Healthy Participants

Group	Mean Tongue Strength	Standard Deviation
Younger Healthy	61.51	12.47
Older Healthy	58.36	10.07

Note: kPa=Kilopascals. Mean tongue strength determined using a maximum tongue push to roof of mouth. Muscle contraction force measured using IOPI.

Mean and standard deviations for the number of mastication trials per bite on all textures are provided in Table 2. Independent samples t-tests were completed to determine differences between groups in number of mastication cycles, and the *p*-value for significance was set at $p<0.05$. Older healthy had significantly higher mastication cycles than the younger healthy in consumption of the chicken sandwich, $p=0.047$; however, older heathy also approached significantly higher mastication cycles in the cracker and carrot trials, $p= 0.071$ and $p= 0.056$ respectively. Figure 4 demonstrates the mean mastication bites per cycle in older and healthy persons across bolus type.

Table 2

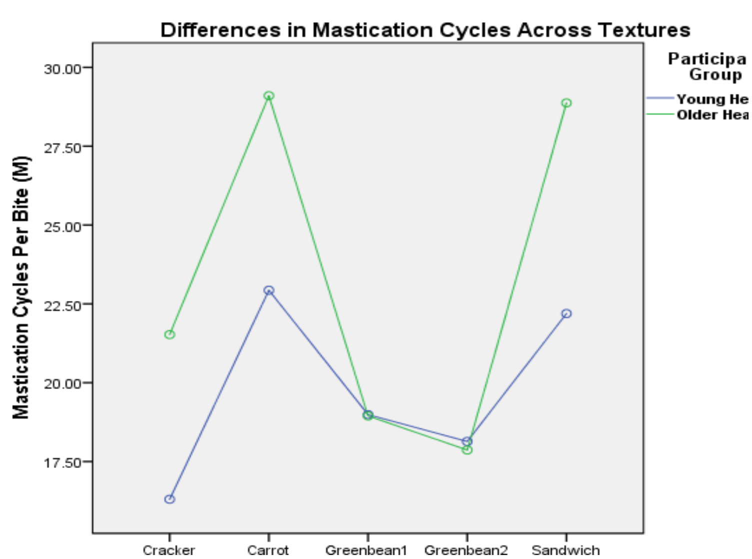
Number of Mastication Bites Per Trial in Younger and Older Healthy Participants

Texture	Younger Healthy (Mean and SD)	Older Healthy (Mean and SD)	*t*-test value (df)	*p*-value*
Cracker	*M*: 16.12 (SD=4.35)	*M*: 23.24 (SD=12.99)	-1.94 (16.07)	.071
Carrot	*M*: 22.64 (SD=6.36)	*M*: 28.34 (SD=8.03)	-2.01(24)	.056
Single-bite Green Bean	*M*: 18.99 (SD=11.27)	*M*: 20.67 (SD=10.25)	-.390 (23)	.700
½ Cup Green Bean	*M*: 18.14 (SD=9.83)	*M*: 19.65 (SD=11.43)	-.352 (23)	.728
Sandwich	M: 21.79 (SD=8.27)	M: 28.70 (SD=8.54)	-2.094 (24)	**.047***

Note: * Denotes $p<0.05$.

Mean and standard deviations for bites per trial are in Table 3. Independent sample *t*-tests were completed to determine differences between older healthy and younger healthy for bites per trial; the significance level was set at $p<0.05$. Bites per trial were not significantly different in older

Figure 4



healthy compared with younger healthy for cracker (*p*=.687), carrot (*p*=699), ½ cup green bean (*p*=.828), and chicken sandwich (*p*=.586) (Table 3).

Table 3
Bites Per Trial in Older and Younger Healthy Participants

Texture	Younger Healthy (Mean and SD)	Older Healthy (Mean and SD)	*t*-test (df), *p*-value*
Cracker	M= 2.09 (SD=0.78)	M= 1.95 (SD=0.94)	.408(25), p=.687
Carrot	M= 2.45 (SD=1.22)	M= 2.29 (SD=0.95)	.392(25), p=.699
½ Cup Green Bean	M= 12.33 (SD=3.31)	M= 12.69 (SD=4.68)	-.220(23), p=.828
Sandwich	M= 14.23 (SD=4.02)	M=13.54 (SD=2.07)	.552(24), p=.586

Mean and standard deviations for oral mastication durations in older healthy and younger healthy are in Table 4. Independent sample t-tests were completed with a significance level set at *p*<0.05. Oral mastication durations for older healthy were not significantly different than in younger healthy for carrot consumption (*p*=.247) and sandwich consumption (*p*=.220).

Table 4
Oral Mastication Duration in Seconds for Older and Younger Healthy Participants

Texture	Younger Healthy (Mean and SD)	Older Healthy (Mean and SD)	*t*-test (df), *p*-value*
Carrot	*M*= 37.90 (SD=17.08)	*M*=45.69 (SD=17.07)	-1.185(25), *p*=.247
Sandwich	*M*=288.15 (SD=98.51)	*M*=335.08 (SD=91.23)	-1.260(24), *p*=.220

Discussion

Older healthy had increased mastication cycles per bite when eating the sandwich compared with the younger healthy. The mastication cycles on the cracker and raw carrot textures tended to have increased mastication cycles in older healthy compared with the younger healthy. Examination of the overall mastication cycles across conditions also revealed that green beans (single bite and ½ cup) had the lowest mastication cycles regardless of group. This was expected given the bolus properties of carrot(crunchy), cracker (dry, crumbly texture) or the chewy or hard texture of the chicken sandwich compared with the soft, cooked green beans. It can be concluded that soft, cooked textures are likely easier to consume for both young and older healthy. However, the older healthy population may require additional mastication cycles per bite to consume dry, hard, piecemeal (crumbly) textures than younger healthy.

Our findings that older and younger healthy demonstrated a similar number of bites for each bolus texture condition as well as non-differing oral mastication durations was surprising. We had posited that older healthy might demonstrate less oral efficiency by taking a greater number of bites for consuming a given texture trial and that the overall mastication duration by texture might be increased. However, the number of mastication cycles being higher in the chicken sandwich and somewhat elevated, although not statistically significant, in carrot and cracker may suggest a requisite compensation that must occur as we age. The increased mastication cycles may suggest that older persons need to work harder to consume solid textures at the same rate as younger healthy. Older healthy persons may be using increased effort (increased mastication cycles) to achieve similar sandwich consumption durations as the younger healthy.

Analysis of the masseter muscle contraction amplitude during mastication was not an aim of this pilot study but may yield additional support related to compensations in older healthy persons' oromotor plan for bolus preparation that are requisite with aging to maintain oral efficiency. If decreased masseter contraction force is present, then this may explain why increased mastication cycles are needed to adequately prepare the bolus in a similar duration compared to the younger healthy. Future analysis of the masseter contraction amplitude, a surrogate measure of mastication strength, collected during this study may provide additional evidence related to a possible inverse relationship between muscle contraction force and number of masticatory cycles required to maintain oral efficiency. Importantly, masseter muscle strength changes across time should be analyzed to examine for potential muscle fatigue in the older healthy participants compared with the younger.

The TOMASS, a quantitative assessment of solid texture oral efficiency identified number of masticatory cycles per bite, number of swallows per bite, time per bite, and time per masticatory cycles/swallows as components that contribute to overall oral efficiency in swallowing solid textures with normative data provided by sex and age for cracker (Nabisco saltine) consumption (Huckabee et al., 2018). Our study examined the number of mastication cycles per bite, number of bites per trial, and time per trial- all components of the TOMASS assessment parameters. Similar to Huckabee et al. (2018), this study found differences in mastication cycles per bite based on age. Regardless of age, they reported a mean of 19.38 mastication cycles on the first bite of cracker that is similar to our 23.24 mastication cycles in older and 16.12 in younger healthy. Congruent with our findings, they found that the number of mastication cycles per bite increases with age. Further, Huckabee et al. (2018) found mastication cycles per bite differ by sex with greater mastication cycles completed in males than females.

This pilot study is the first to examine differences in oral efficiency parameters, as outlined in the TOMASS, across varying bolus texture types. Further investigation is needed to examine differences in age and sex in oral efficiency measures.

Limitations and Future Directions

While this study included individuals from the younger healthy and older healthy populations, we had a reduced number of older healthy persons 65 years of age or older- the age typically considered to demonstrate swallowing changes secondary to aging (presbyphagia). Only two of our participants were over this age marker, which likely influenced our findings and reduced the ability to look at the role presbyphagia may play in oral phase swallowing. Due to recruitment restrictions on in-person research at TCU during COVID-19, participation was limited to TCU faculty, staff, and students which also significantly impaired our ability to recruit a diverse population in terms of race, age, and ability. Future studies should focus on recruiting a larger sampling of participants that fall into the 70+ age category to truly assess the influence of presbyphagia.

Conclusion

This pilot study suggests that older healthy persons may be working harder than younger healthy persons to consume complex textured solids. Additional analyses determining differences between older healthy and younger healthy mastication muscle contraction should be completed. A larger study is needed to comprehensively examine factors, including fatigue, that may be impacting oral swallowing efficiency and reduce quality of life in aging persons. A future study should also examine oral efficiency differences between older healthy and persons with oral phase swallowing impairments (dysphagia) secondary to neuromotor diseases or injury.

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References

Atella, V., Piano Mortari, A., Kopinska, J., Belotti, F., Lapi, F., Cricelli, C., & Fontana, L. (2019). Trends in age-related disease burden and healthcare utilization. *Aging cell*, *18*(1), e12861.

Belafsky, P.C., Mouadeb, D.A., Rees, C.J., Pryor, J.C. Postma, G.N., Allen, J., & Leonard, R.J. (2008). Validity and Reliability of the Eating Assessment Tool (EAT-10). *Annals of Otology, Rhinology & Laryngology*,117(12), 919-924.

Brandão, B. C., Silva,Magali Aparecida Orate Menezes da, Cola, P. C., & Silva, R. G. d. (2019). Relationship between oral transit time and functional performance in motor neuron disease. *Arquivos De Neuro-Psiquiatria, 77*(8), 542-549.

Bollschweiler, E., Knoppe, K., Wolfgarten, E., & Hölscher, A.,H. (2008). Prevalence of dysphagia in patients with gastroesophageal reflux in germany. *Dysphagia, 23*(2), 172-176.

Dellavia, C., Rosati, R., Musto, F., Pellegrini, G., Begnoni, G., & Ferrario, V. F. (2018). Preliminary approach for the surface electromyographical evaluation of the oral phase of swallowing. *Journal of Oral Rehabilitation, 45*(7), 518-525.

Ekberg, O. & Feinberg, M.J. (1991). Altered swallowing function in elderly patients without dysphagia: Radiologic findings in 56 cases. *American Journal of Roentgenology, 156*(6), 1181-1184.

Enoka, R.M. & Stuart, D.G. (1992). Neurobiology of muscle fatigue. *Journal of Applied Physiology,72*, 1631-1648.

Hayoun, P., Engmann, J., Mowlavi, S., Le Reverend, B., Burbidge, A., & Ramaioli, M. (2015). A model experiment to understand the oral phase of swallowing of newtonian liquids.

Journal of Biomechanics, 48(14), 3922-3928.

Hiss, S. G., Strauss, M., Treole, K., Stuart, A., & Boutilier, S. (2004). Effects of age, gender, bolus volume, bolus viscosity, and gustation on swallowing apnea onset relative to lingual bolus propulsion onset in normal adults. *Journal of Speech, Language, and Hearing Research, 47*(3), 572-83.

Huckabee, M., McIntosh, T., Fuller, L., Curry, M., Thomas, P., Walshe, M., . . . Sella-Weiss, O. (2018). The test of masticating and swallowing solids (TOMASS): Reliability, validity and international normative data. *International Journal of Language & Communication Disorders, 53*(1), 144-156.

Kays, S. A., Hind, J. A., Gangnon, R. E., & Robbins, J. (2010). Effects of dining on tongue endurance and swallowing-related outcomes. *Journal of speech, language, and hearing research : JSLHR*, *53*(4), 898–907.

Langmore, S.E., Terpenning, M.S., Schork, A., Chen, Y., Murray, J.T…. Loesche, W.J. (1998). Predictors of aspiration pneumonia: How important is dysphagia?. *Dysphagia*, 13, 69-81.

Lee, M.-L., Kim, J.-U., Oh, D.-H., Park, J.-Y., & Lee, K.-J. (2018). Oropharyngeal swallowing function in patients with presbyphagia. *Journal of Physical Therapy Science, 30*(11), 1357-1358.

Manning, M., Casey, V., Conway, R., Saunders, J., & Perry, A. (2016). A study of healthy adults' oro-lingual effort during swallowing using OroPress, A new portable wireless measurement tool. *Dysphagia, 31*(3), 442-451.

Marik, P.E. & Kaplan, D. (2003). Aspiration pneumonia and dysphagia in the elderly. *Chest, 124*(1), 328-336.

Martin-Harris, B. (2015). *Standardized training in swallowing physiology.* Northern Speech

Services.

Martin-Harris,B, Brodsky, M.B., Price, C.C., Michel, Y. & Walters, B. (2003). Temporal coordination of pharyngeal and laryngeal dynamics with breathing during swallowing: single liquid swallows. *Journal of Applied Physiology*, 94, 1735-1743.

McCullough, G. H., Wertz, R. T., & Rosenbek, J. C. (2001). Sensitivity and specificity of clinical/bedside examination signs for detecting aspiration in adults subsequent to stroke. *Journal of Communication Disorders, 34*(1), 55-72.

Meenakshi, A. & Paul, P. (2017). Human chewing pattern: Prosthodontic overview. *International Journal of Oral Health and Medical Research, 4*(1), 80-85.

Namasivayam, A. M., Steele, C. M., & Keller, H. (2016). The effect of tongue strength on meal consumption in long term care. *Clinical Nutrition (Edinburgh, Scotland), 35*(5), 1078-1083.

Rabe, K. F. (2007). Global Initiative for Chronic Obstructive Lung Disease. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. GOLD executive summary. *Am J Respir Crit Care Med*, *176*, 532-555.

Reddy, N. P., Costarella, B. R., Grotz, R. C., & Canilang, E. P. (1990). Biomechanical measurements to characterize the oral phase of dysphagia. *IEEE Transactions on Bio-Medical Engineering, 37*(4), 392-397.

Solomon, N. P. (2004). Assessment of tongue weakness and fatigue. *The International Journal of Orofacial Myology : Official Publication of the International Association of Orofacial Myology, 30*, 8-19.

Solomon, N. P. (2006). What is orofacial fatigue and how does it affect function for swallowing and speech? *Seminars in Speech and Language, 27*(4), 268-282.

Van den Steen, L., Baudelet, M., Tomassen, P., Bonte, K., De Bodt, M., & Van Nuffelen, G. (2020). Effect of tongue-strengthening exercises on tongue strength and swallowing-related parameters in chronic radiation-associated dysphagia. *Head & neck*, *42*(9), 2298–2307.

Vøllestad, ,N.K. (1997). Measurement of human muscle fatigue. *Journal of Neuroscience Methods, 74*(2), 219-227.

Wang, C., Chen, J., Chuang, C., Tseng, W., Wong, A. M. K., & Pei, Y. (2015). Aging-related changes in swallowing, and in the coordination of swallowing and respiration determined by novel non-invasive measurement techniques. *Geriatrics and Gerontology International, 15*(6), 736-744.

Wirth, R., Dziewas, R., Beck, A. M., Clavé, P., Hamdy, S., Heppner, H. J., . . . Volkert, D. (2016). Oropharyngeal dysphagia in older persons – from pathophysiology to adequate intervention: A review and summary of an international expert meeting. *Clinical Interventions in Aging, 11*, 189-208.