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Review Article

Surface Electromyographic Activity of Sub Mental Muscles during Swallow of Masticated Bolus across Age and Gender

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ABSTRACT

Previous researchers have documented changes in sub mental muscle activity during single liquid swallows across demographic and bolus characteristics. As aging increases fatigue and alters muscle properties, we hypothesized that sub mental muscle performance during swallows of masticated boluses in young and older individuals would be different.

Methods: The potentials were recorded from sub mental muscles of forty seven healthy individuals of 18 years-40 years and 40 years-60 years. Each sEMG trace associated with swallow was analysed for its amplitude and temporal measures and were subjected to statistical comparisons across gender, age and bolus volumes.

Results: The results revealed that the measures of sEMG were not significantly different across gender or bolus volume, but was different across the two age groups. The peak sEMG amplitude was lesser in older individuals for ½ cookie and 1 cookie bolus indicating age-associated changes in sub mental muscle performance. The relaxation rate of sub mental muscles was slower for large bolus swallows in older individuals compared to younger, probably as to prevent secondary aspiration.

Conclusion: These findings suggest that sub mental muscle performance changes before 60 years of age with weaker peak contraction without altering the durational aspects of swallow. These subtle changes, if picked up could help understand age-associated decline in swallowing efficiency in typically aging population.

Keywords: Deglutition; Healthy; Chew; Solid; Rehabilitation; Dysphagia

INTRODUCTION

Swallowing is a semi-volitional sensory-motor act that facilitates movement of food/water (known as the bolus) from oral cavity to the stomach. The process of swallow is often described in three stages (sometimes four) that include oral preparatory (only when mastication is involved), oral phase, pharyngeal phase and oesophageal phase. Physiological processes involved in this function are rapid and internal, and are masked from direct visualization. Speech and swallow therapists are in constant search for simple, affordable, minimally skilled, non-invasive technologies that can assist them in quick, but appropriate clinical decision making [1-3]. Surface Electromyography (sEMG) has been extensively debated for its application in swallowing sciences and has emerged as a reliable non-invasive tool for understanding human swallowing, and also as a bio-feedback tool for training persons with swallowing disorders [4-7].

The sub mental group of muscles represent a subset of muscles involved in swallowing that are peripheral, accessible for sEMG procedure, and closely related to lingual propulsion and hyo-laryngeal elevation and marks the transition from oral phase to pharyngeal phase of swallow [8-11]. Located in the anterior neck region, between the mandible and hyoid, the sub mental triangle or the suprahyoid triangle is formed by the anterior belly of right and left digastrics as lateral borders, geniohyoid and the mylo-hyoid muscles as floor of the triangle. The apex of this unpaired triangle is located at the chin and the base is on the hyoid bone. Study of sEMG characteristics at the sub mental triangle (SM-sEMG) provide speech and swallow clinicians with valuable

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insights related to swallow function in typical and in persons with swallowing difficulties [12].

Prevailing literature suggests that the SM-sEMG for swallow of non-masticated boluses obtained from healthy individuals vary with age, bolus volume, bolus consistency, and ingestion method, but were not different across gender [13-18]. The sequence and latency of muscle activation were independent of age. These studies incorporated a range of boluses for reporting their findings on SM-sEMG with majority using saliva and controlled liquid swallows [19-20]. Little is known about the SM-sEMG performance in thicker boluses. Complex eating processes that include mastication has not been studied in detail, except for the report by Hiramatsu, et al. Their study compared the muscle activity before and after consumption of a full meal in young and older individuals and reported no significant difference in peak SM-sEMG amplitude or duration in these individuals. Clearly, there is little information on the SM-sEMG performance before, during and after individual solid bolus intake during more natural, and complex eating behaviours.

Mastication or chewing involves repeated movements of jaw, tongue and cheeks that aim at mixing the food with saliva, and positioning the food between the occlusal surfaces for preparing a cohesive bolus that can be safely transported into the pharynx with a quick anterior-posterior lingual sweep. Compared to liquid bolus, the sub mental muscles are active for a longer period in masticated bolus swallows as they stabilize the floor of the mouth during oral preparation followed by lingual propulsion and hyo-laryngeal elevation. It is not known if the SM-sEMG characteristics during swallow post-mastication of solids are any different from that of non-masticated boluses such as liquids.

Aging is a significant factor that alters swallow physiology and performance in healthy individuals. Age associated changes in muscle properties were seen as variations in the number of sEMG peaks, increase in pre-reflex peak and reduction in peak SM-sEMG amplitude. These differences have not been gender specific but varied with the consistency of bolus swallowed. The increase in number of chewing cycles and chewing duration, and the changes in sub mental muscle properties associated with aging may lead to differences in SM-sEMG measures during swallow of masticated solid boluses in typical aging population, but is not well understood. Therefore, the current study aimed at comparing the sub mental sEMG measures in young and older individuals during swallow of masticated solid boluses. For the purpose of this study, a 'swallow' is initiated when the masticated solid bolus is propelled into the pharynx with a lingual sweep (oral phase) and hyolaryngeal elevation (pharyngeal phase). The change in myogenic potentials of the sub-mental muscle group during this process was recorded, analyzed and compared across age and gender to meet the objectives of the study.

LITERATURE REVIEW

The methodology was approved by the bio-behavioural research and ethical committee of the institute (Ph.D/ SP-4/2016-17). Written consent was obtained from all participants before enrolling them into the study methodology.

Participants

Sample size was estimated for paired sample t-test using MedCalc software (M/S MedCalc Software Ltd, Belgium) at 0.50 alpha significance and 0.80 power. Difference of mean and standard deviation for each outcome measure from the first twelve participants was provided as input to the MedCalc software, and the predicted minimum sample size ranged from 11-21. A minimum of 21 participants was aimed as the required sample size for the study. This estimated number was also supported by the number of participants included in majority of the previous studies conducted in similar direction.

The final data set included a total of forty seven healthy volunteers of 18->40 years (N=27; 13 males, 14 females; mean age: 28.67 ± 5.33) and 40 years-60 years (N=20; 9 males, 11 females; mean age: 48.50 ± 7.27) recruited over one year from among the caregivers/companions of patients visiting the special clinic for dysphagia in the host institute. A detailed interview ruled out any evident history of structural alterations of head/neck, oro-pharyngeal swallowing, oral sensory-motor, neurological, psychological, or cognitive issues in these participants. Though the number of teeth retained was not accounted, all participants had adequate natural dentition for normal mastication and did not alter diet for any known or unknown reasons.

Procedure

The sub mental triangle was cleaned with alcohol swabs before placing a single, disposable, disk electrode of 5.72 cm diameter on the participant's skin. Each disk array consisted of three inbuilt silver electrodes (2 active, 1 reference) arranged in a triangular pattern at a distance of 2 cm from each other. The adhesive side of the electrode array was placed on the sub mental triangle with the ground electrode oriented towards the laryngeal side. The array was connected to the swallowing signals lab 7120 following the manufacturer's guidelines. The change in muscle potentials during the swallow activity were obtained from the recording site at a sampling rate of 500 Hz, band pass filtered (50 Hz-250 Hz), rectified, and integrated by the system. The difference in the sEMG potentials across the active and reference electrodes were displayed on screen as waveforms. The recording window was set for 200 seconds for all recordings. The synchronized nasal module monitored the nasal airflow during the recording.

Participants were instructed to eat a ½ cookie and a full cookie (standard bolus sizes used for swallowing evaluation) bolus as they would typically do, in any order they chose to randomize the bolus volumes. They were also instructed to try clear the bolus in a single swallow. SM-sEMG was recorded from the time of first bolus ingestion till the end of second bolus swallow and return of sEMG to the baseline, including SM-sEMG for mastication, 'swallow' and clearance of two solid boluses by each participant.

Data analysis

The investigator carefully tagged the SM-sEMG peak that was simultaneous with respiratory apnoea (monitored by the nasal module) and that followed quick, repetitive masticatory cycles. The data included in the final analysis of this study included the SM-sEMG related to swallow (transferring of bolus from oral to pharyngeal) of masticated bolus only and excluded data related to chewing. In an event of multiple swallows for a bolus, the data was obtained from first swallow only so that the swallow with maximum bolus clearance was included. Each of the tagged swallows was analyzed for a total of eight measures.

The amplitude and temporal measures obtained from each tagged swallow. The analysis of individual swallow data revealed that the baseline SM-sEMG potential after mastication of solid bolus was always higher than zero. Therefore, the relative change in SM-sEMG potential specific to the oral propulsion was calculated as the difference between peak sEMG amplitude and the baseline. The 'offset' data was only used to consistently identify the end of a swallow for measurement of offslope, relaxation time and total duration of the specific SM-sEMG trace and was not included in statistical analysis. The slope of SM-sEMG (onslope and offslope) was calculated by the swallowing signals lab software and was expected to provide insights into the rate of sub-mental muscle group contraction and relaxation while the temporal measures (contraction time, relaxation time and the total duration) revealed the duration of muscle activity involved.

To estimate inter-judge reliability, the data from a set of randomly selected five participants was re-tagged for swallows and re-analyzed by another research assistant blinded to the purpose or procedure of the study based on the operational definitions provided above.

The Shapiro-wilk's test of normality was run on the adjusted peak amplitude of sEMG (PEMG), onslope, offslope, Contraction Time (TC), Relaxation Time (TR) and the total duration of sEMG activity (TOT) for each solid bolus swallow in young and older individuals. The result revealed that the data was significantly tailed. Hence, non-parametric comparisons were made across gender, age and bolus volumes using statistical package for social sciences (version 20), followed by post-hoc analysis. This method restricted the authors from understanding the interaction effects of variables considered but revealed the individual effects on each outcome measure considered in this study.

Strong inter-judge reliability was established for the outcome measures before further statistical analysis was run. Piece meal swallows were observed for majority of large solid swallows (1 cookie) though they were instructed otherwise. The mean and standard deviation of the amplitude and temporal measures obtained from SM-sEMG tracings are provided. Mann-Whitney test was used to compare the data across gender and age and Wilcoxon's sign rank compared the measures across bolus volumes.

Gender

The result of comparison of SM-sEMG measures across male and female participants in younger and older group during swallow of two cookie boluses are presented. There was no significant difference across gender in any of the measures considered. Therefore, the data was combined for gender in each group for further analysis.

Age

The result of comparison of SM-sEMG measures across younger and older group of participants during swallow of ½ and 1 cookie boluses are presented. The adjusted peak amplitude for swallow of ½ cookie and 1 cookie was significantly different across the two age groups. The off slope measure for swallow of full cookie also revealed statistically significant age effects. No other measures were statistically significant at $p<0.05$ level. The results indicated a significantly lesser change in the sub mental muscle potentials and slower release of muscle contraction for larger bolus volume in older individuals compared to younger.

Bolus volume

Comparison of amplitude and temporal sEMG measures in younger and older group of participants across ½ and 1 cookie boluses are presented. There was no significant effect of bolus volume in any of the sEMG measures in younger or older individuals.

DISCUSSION

The current study investigated the effect of aging on sub mental electromyographic potentials during swallow of masticated bolus in young and older individuals. The amplitude and temporal measures obtained from the electromyographic recordings were compared across gender, age and solid bolus volumes. Overall, the results suggested that the sub mental muscle activity is affected by age, but not gender or bolus volume. Large standard deviation was found in all the sEMG measures indicating inter-subject variability in sub mental muscular performance for solid bolus swallow in young and older healthy individuals. This variability is inherent in deglutition science, and is previously reported in oro-pharyngeal swallowing physiology. Inter-subject variability was therefore expected and observed in this study.

The tongue is continuously active for positioning, mixing, segregating and collecting the masticated bolus followed by quick anterior-posterior lingual propulsion and hyo-laryngeal elevation. Though sub mental muscles are considered primarily as hyolaryngeal elevators, they are active during the mastication process as well. It is possible that during swallow of masticated bolus, the sub mental muscles do not completely relax to the baseline before initiating the swallow. Data points obtained in the current study support this notion as they revealed that the onset potentials were always higher than zero. This may be similar to the physiology of sequential drinking. The fatigue generated in these muscles could also contribute to poor hyo-laryngeal elevation, and reduced upper-oesophageal sphincter open time in older leading to presbyphagia.

Normal aging process changes the oro-pharyngeal musculature and demands recruitment of larger number of motor neurons for oral preparation. It is not known if sub mental muscles undergo any evident age-related atrophy. This investigation hypothesized that the prolonged activation of sub mental muscles would influence its activity during hyo-laryngeal elevation for swallow of masticated bolus, and this may be seen in the electromyographic measures. The results of statistical comparisons were in accordance with this assumption and revealed significantly lower sub mental activation in older adults during masticatory swallows. Previous researchers also reported similar trend with decrease in peak sub mental EMG during dry or liquid swallows in older participants. The current study extends this finding to solid bolus consistency. Further studies should compare the solid boluses with other consistencies to understand if the reduction in muscle activation in older participant is significant. Work in this direction has been initiated, but controlling the bolus volume will remain a challenge. Also, the current study notes that the age related changes in sub mental performance appear before 60 years of age as the trend remains similar compared to other studies that have considered wider age ranges.

The slope of sub mental EMG trace (rate of change of sEMG amplitude) represented the rate of contraction (onslope) and relaxation (offslope). This measure has not been explored previously. Crary, et al. uses the term 'onslope' and 'offslope' for the sEMG recordings in their study, but by definition these corresponded to the contraction time and relaxation time measures in the current study. Significantly lesser offslope in larger bolus volume swallows of older individuals suggest that the muscles relaxed gradually from its peak contraction state. Discussed the higher superior and anterior velocity and magnitude during large volume swallows in older individuals as an aspiration prevention strategy but neglected the velocity of hyolaryngeal descent. It is possible that the gradual sub mental relaxation (increased offslope) in older individuals observed in the current study is associated with slow hyolaryngeal descent as a preventive strategy against secondary aspiration associated with large solid bolus swallows (1 cookie). A recent exploration of swallow related performance in healthy aging population reported reduced hyo-laryngeal ascend velocity in older individuals compared to younger. Though our research does not directly measure the hyo-laryngeal velocity, the statistically insignificant difference in the onslope measure indicate the speed of hyolaryngeal ascent may not be very different across the two groups.

Vaiman, Eviatar, et al. in their large population study of liquid swallow sEMG and the report of Dantas and Dodds, et al. reported no change in the timing or durational measures across age. The sub mental activity during swallow is related to the oral transit of bolus and therefore to oral transit time. A systematic review of transit time reported, concluded that oral transit time do not appear to change with age. Drawing support from these previous literatures, the current study also found no significant effect of age on the durational measures of (contraction time, relaxation time and total muscle activity for swallow) of sub mental electromyography across the younger and older age groups.

Gender effects have been previously explored during saliva and liquid swallows in children and adults. In support with these studies, the current study also found no significant difference across gender in younger and older individuals.

Though two bolus volumes were included in the experiment protocol, no control could be implemented in the bolus size swallowed. However, the investigator assumes that the bolus size would be larger for 1 cookie bolus compared to ½ cookie chewed bolus. Comparing across the volumes, the electromyographic measures were not significantly different across the two volumes. Ko and team 14 compared the sEMG amplitude and latency measures across 2 cc and 5 cc liquid swallows in young and older individuals and found no bolus volume effect. Similar reports were reported earlier across 2 ml to 20 ml liquid and paste bolus as well. All these evidences indicate that the sub mental muscles manage large and small bolus volume with the same activation characteristics. It should also be noted that the older individuals preserve the muscle adaptation, in spite of lesser peak activation potential.

CONCLUSION

The current study was the first to explore sub mental muscle potentials post masticatory swallows across age and gender. We recorded sub mental electromyographic data from forty-seven typical young and older individuals during mastication and swallow of a ½ cookie and a 1 cookie bolus. Each sEMG trace for swallow was analysed for onset, peak, offset, onslope, offslope, contraction time, relaxation time and total duration of muscle activity and compared across gender, age and bolus volumes. The overall results indicated that the sub mental muscle activity was influenced by age but not gender or solid bolus volumes. The peak sEMG was significantly lower in older individuals for ½ and full cookie bolus. The rate of sub mental muscle relaxation was also slower in older individuals for large bolus swallows. We conclude that the sub mental muscle performance undergo age related changes during swallow function which may possibly contribute to poor swallow efficiency in older adults. These changes may be picked up by the surface electromyography method before turning into any clinical symptomatology.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS

Author GK was involved in conceptualizing, executing, data collecting, analyzing, and writing the original draft of the manuscript. Author GSP mentored author GK during the process and proof read the manuscript for publication.

INSTITUTIONAL REVIEW BOARD STATEMENT

The study was conducted according to the guidelines of the declaration of Helsinki, and approved by the institutional review board (or ethics committee) of All India institute of speech and hearing (Ph.D/ SP-4/2016-17).

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study.

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