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Objective physiological measures of lingual and jaw function in healthy individuals and individuals with dysphagia due to neurodegenerative diseases

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Method Article

Objective physiological measures of lingual and jaw function in healthy individuals and individuals with dysphagia due to neurodegenerative diseases

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A B S T R A C T

Swallowing is a neuromuscular process that involves a complex sequence of sensorimotor events, which are executed to efficiently and safely transport food and liquid from the mouth to the stomach. Safe oropharyngeal swallowing involves the activation, modulation, and coordination of oral, pharyngeal, laryngeal, and esophageal structures and musculature. Impaired or atypical patterns of swallowing are considered characteristic of a swallowing disorder, otherwise referred to as dysphagia, and affect the performance of all stages, i.e., oral preparatory, oral transit, pharyngeal, and esophageal. Lingual and jaw musculature play critical roles in mediating swallowing function, particularly during the oral preparatory and oral transit stages. This current study presents an adapted simple, economical, and clinically relevant protocol that may be used to quantify lingual and jaw movement in healthy and disordered swallowing, and thus track physiological changes in lingual and jaw musculature over time in individuals with dysphagia due to neurodegenerative diseases.

- Jaw ROM tasks, adapted from [1,2], were adapted and utilized to measure the jaw during three postures: opening, lateralization, and protrusion.
- Adapting a scale developed by Lazarus and colleagues [3], objective lingual ROM values were obtained using the TheraBite® tool [4] and categorized according to functional status.
- Upon methodological adaption and collation of lingual ROM and jaw ROM tasks, a comprehensive set of images clearly depicting each procedural task and a clinically friendly form were developed to guide data collection for research and clinical use.

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Name and reference of original method::	S.M. Shaffer, J.M. Brism ée, P.S. Sizer, C.A. Courtney, Temporomandibular disorders. Part 1: anatomy and examination/diagnosis, J Man Manip Ther 22 (1) (2014) 2–12, 10.1179/2042618613Y.0000000060 K.H. Zawawi, E.A. Al-Badawi, S.L. Lobo, M. Melis, N.R. Mehta, An index for the measurement of normal maximum mouth opening, J. Can Dent. Assoc 69 (11) (2003) 737–741. https://jcda.ca/index-measurement-normal-maximum-mouth -opening. C. L. Lazarus, H. Husaini, A.S. Jacobson, et al., Development of a new lingual range-of-motion assessment scale: normative data in surgically treated oral cancer patients, Dysphagia 29 (4) (2014) 489–499, 10.1007/s00455-014-9534-9. L.L. Gingrich, J.A. Stierwalt, C.F. Hageman, L.L. LaPointe, Lingual propulsive pressures across consistencies generated by the anteromedian and postromedian tongue by healthy young adults, J Speech Hear Res 55 (3) (2012) 960–972, 10.1044/1092-4388(2011/10-0357).
Resource availability:	*N.A.*

Prior to participation in the study, prospective healthy younger, healthy older, and individuals with Parkinson's Disease (PD) completed a series of screening protocols that were conducted to determine if participants met study inclusion criteria. Specifically, a demographic screening was completed that included questions regarding health and medical history, demographic data, and eligibly inclusion criteria [5]. Additionally, participants participated in an oral mechanism and cranial nerve exam to determine baseline orofacial and laryngeal muscle function. With regard to motor speech, the motor programming assessment of speech [6] was conducted. In addition, study participants completed the Reflux Symptom Index [7] and temporomandibular pain disorder screening instrument [8] to rule out interfering factors related to reflux and temporomandibular disorders. In terms of swallowing function, participants completed a questionnaire regarding swallowing ability and diet tolerance. In addition, a clinical swallowing examination was completed to identify and describe any apparent signs and symptoms of oropharyngeal dysphagia. For participants with a documented diagnosis of PD, a brief cognitive linguistic screen was conducted using the Montreal Cognitive Assessment (MoCA®, Version 8.1 English). Participants with PD also completed a questionnaire regarding the onset and course of PD. The Functional Oral Intake Scale [9] was also administered to determine the oral intake of study participants with PD-related dysphagia. Lastly, information regarding PD participants' medical diagnoses and medical management of PD was obtained from a form that was completed by the participants' neurologists. All lingual and jaw measures were recorded with the participant seated in an upright position in a chair. Six counterbalancing sequences were generated across the lingual strength, lingual ROM, and jaw ROM. Within each participant group (healthy younger individuals, healthy older individuals, and adults with PD), tasks were counterbalanced to control for potential order effects.

Methodological adaptations for lingual ROM

Building upon the foundational work by Lazarus and colleagues [3], Oommen et al. [5] obtained maximum lingual displacement measures in millimeters (mm) for lingual elevation, protrusion, and lateralization. Slight variations in protocol were adopted. For example, lingual elevation and

lateralization displacement measures were recorded outside the oral cavity, while Lazarus et al. [3] recorded lingual displacement measures inside oral cavity, i.e., lingual elevation to the alveolar ridge and lingual lateralization to the corners of the mouth were obtained. The study also extended the populations from which data has been previously collected. While Lazarus obtained measures for healthy individuals between 20 to 50 years and individuals with head and neck cancer, Oommen et al. [5] obtained measures in healthy younger adults (ages 18 to 60 years), healthy older adults (61 years and above), and individuals with PD.

Methodological adaptations for jaw ROM

Based upon the work of Shaffer and colleagues [1]), Oommen et al. [5] recoded jaw lateralization measures for displacement to the right and left side using the TheraBite®. In contrast, Shaffer et al. [1] used a Boley gauge and TheraBite® [4] to measure right and left jaw lateralization and obtained normative measures in young healthy adults. In contrast, Oommen, Cuellar, and colleagues [5] sought to expand measures from healthy individuals, as well as individuals with PD, a progressive degenerative disease that is known to significantly reduce range of motion systemically over time.

Another jaw ROM procedure that Oommen and colleagues [5] employed, based upon initial work by Zawawi and colleagues [2], sought to determine maximum jaw opening measures. While Zawawi et al. [2] inserted three or four fingers into the oral cavity and subsequently utilized a TheraBite® to measure "maximum mouth opening," Oommen et al. [5] used the TheraBite® [4] to directly measure maximum jaw opening, demarcating points of measurement based upon the maxillary and mandibular incisal edges of the central incisors. Another point of expansion from the work of Zawawi et al. [2] can be seen in the number of recorded measurements to determine the 'average' measurement of jaw opening. While Zawawi et al. [2] recorded jaw opening measurements five times, Oommen et al. [5] recorded measurements three times to obtain task average ROM measurement values.

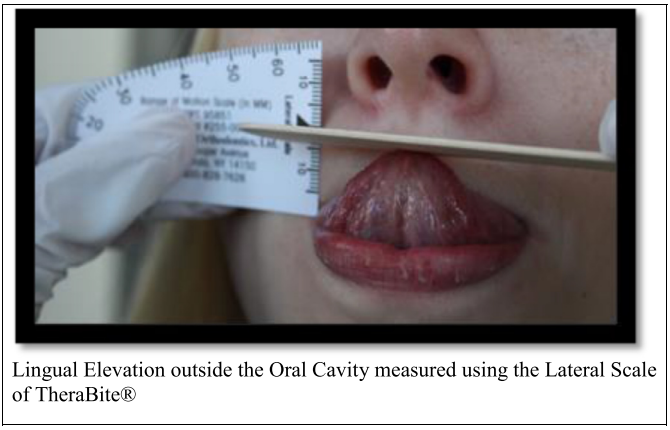
Summary of methodological adaptations

In all, the methodological variations in the original article published in Physiology and Behavior by Oommen and colleagues [5] added a few key points of methodological adaptation. First, the authors sought to determine ROM values across the adulthood, i.e., younger healthy adults, older healthy adults, and individuals with PD, a progressive degenerative disease. Second, the procedural testing methods and participant instructions for lingual and jaw ROM were recorded using a novel image reference guide and record form developed and included in the current publication, which was created for quick and consistent data collection in one clinical session. Lastly, lingual and jaw ROM measurements were obtained in an objective, simple, timely, economical fashion using the TheraBite® measurement tool. Lingual pressures were also obtained according to the protocol outlined by Gingrich et al. [10] and Pitts et al. [11] using the IOPI®.

Lingual range-of-motion measures

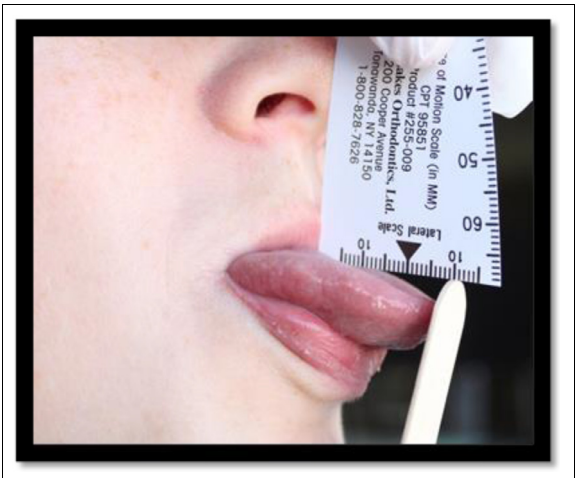
This study focused on obtaining distance-based measurements for maximum lingual ROM during different lingual tasks. For lingual elevation, participants were asked to place their tongue outside the oral cavity and attempt to touch their nose with the tongue tip [5]. The participants were asked to attempt this posture without lip spread. As indicated in the Fig. 1, the lateral scale of the TheraBite® [4] was placed at the corner of the lips. Then, by using a gloved finger or tongue depressor, the lingual displacement during elevation was recorded in mm by using the lateral scale. A tongue depressor placed at the level of the tongue tip against the lateral scale of the TheraBite® [4] provided more precise displacements.

During lingual protrusion, the participants extended their tongue forward with maximal effort and maintained their lips closed around the tongue [3,5]. As indicated in Fig. 2, the lateral scale of the TheraBite® [4] was positioned on the superior lingual surface and a tongue depressor was used to



Lingual Elevation outside the Oral Cavity measured using the Lateral Scale of TheraBite®

Fig. 1. Lingual elevation.



Lingual Protrusion Outside the Oral Cavity as Measured by the Lateral Scale of TheraBite ®[4]

Fig. 2. Lingual protrusion.

record the displacement of the tongue tip beyond the border of the upper lip on the lateral scale (image also illustrated in [3]; Fig. 3, p. 492).

Lingual lateralization was recorded by asking the participants to extend their tongue towards the right and left sides to the maximum extent possible [5]. As indicated in Fig. 3, which depicts lingual lateralization to the left, the lateral scale of the TheraBite® [4]was positioned at the midline of the philtrum and upper lip. A tongue depressor was placed at the tongue tip and used to measure the corresponding displacement on the curved scale of TheraBite® [4] in mm.

For the lingual displacement to the right, the lateral scale was positioned at the point of maximum lingual displacement with the aid of a tongue depressor (Fig. 4). The displacement was then recorded on the curved scale of the Therabite ® [4] in mm: from the point of intersection between the lateral and curved scale of the Therabite® [4] to the measure on the curved scale corresponding to the midline of the philtrum.

Lingual Lateralization outside the Oral Cavity Measured using the TheraBite ® [4]

Fig. 3. Lingual lateralization (left).

Lingual Lateralization outside the Oral Cavity Measured using the TheraBite ® [4]

Fig. 4. Lingual lateralization (right).

For all lingual displacements, the rating scale developed by Lazarus et al. [3] was used to classify ROM as “normal”, “mild to moderately impaired/moderately impaired,” or “severely impaired” (p. 492). Lingual elevation was assessed inside the oral cavity by instructing the participants to elevate their tongue to the roof of the mouth. Lingual protrusion and lateralization were assessed with the same tasks during which the displacements were measured. In addition to categorizing the displacements, a score was also assigned based on the categorization, which ranged from 0 (totally impaired) to 100 (normal; [3]).

Lingual pressure measures

Anterior and posterior lingual pressures during three lingual strength tasks were recorded using Iowa Oral Performance Instrument, IOPI®. Anterior lingual tasks were recorded with an anteromedian positioning based on the illustration in [10] 12 (Fig. 1, p. 963). Consistent with [10], paper tape was placed on the IOPI® tubing anterior to the labial seal to ensure consistent placement across multiple

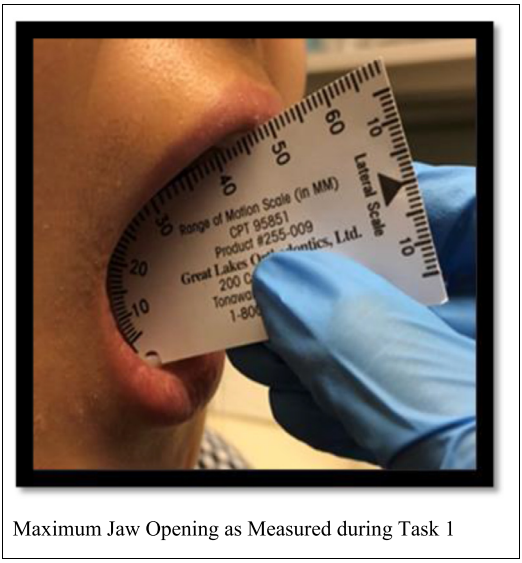


Fig. 5. Task 1 for jaw opening.

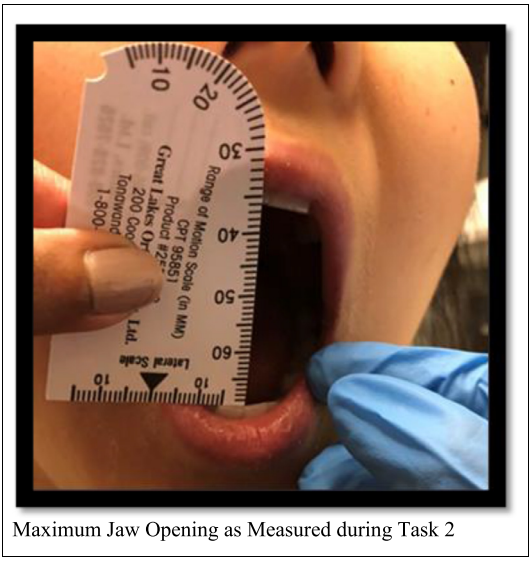
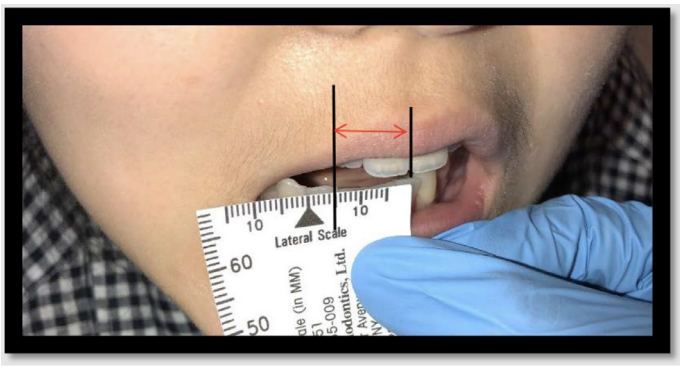


Fig. 6. Jaw opening method II.

trials. Instructions for the anterior maximum isometric pressure (MIP) tasks were also adopted from Gingrich et al. [10], where each participant was asked to, "...push the bulb against the roof of your mouth as hard as you can" (p. 964). The peak lingual pressure was recorded for each trial and the highest measure from three consecutive trials was entered as the MIP [10–12]. Peak pressures during saliva swallows were also recorded with the bulb in the same position and participants were instructed to swallow their saliva as normally as possible [10]. For the saliva swallows, the average of the peak pressures across three trials were calculated [10,12]. Posterior MIP was recorded with

Reference points used to record baseline jaw position

Fig. 7. Jaw lateralization to the right, baseline position.



Reference points used to record maximal jaw displacement to the right

Fig. 8. Jaw lateralization, maximal displacement to the right.

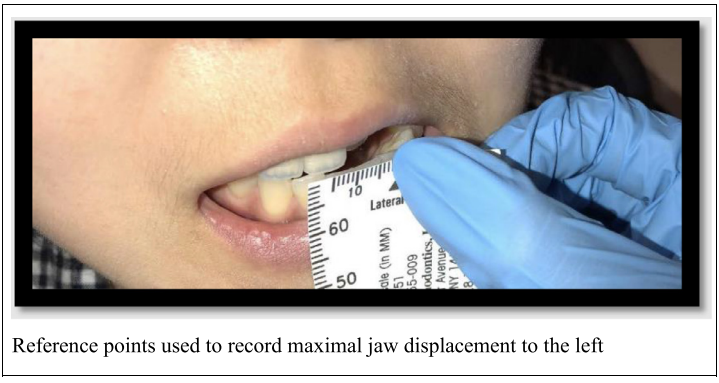
the IOPI® in the posteromedian position as illustrated by Gingrich et al. (2012, Fig. 2, p. 963). The instructions for posterior MIP were similar to that provided during anterior MIP tasks.

Jaw range of motion measures

ROM was obtained by instructing individuals to complete maximal jaw opening, lateralization, and protrusion postures. These measures were obtained from healthy younger and older individuals, as well as individuals with PD. The protocol outlined by Shaffer et al. [1] and Zawawi et al. [2] was adopted to obtain the measures. Maximal jaw opening was recorded by having the participants open their mouth as wide as possible without experiencing discomfort for approximately two seconds. For Task 1, measurements were obtained by placing the TheraBite® [4] between the central incisors to obtain orofacial measurements in mm (Lazarus et al., 2014). The notch on the TheraBite® [4] was placed on the lower central incisor as displayed in Fig. 5.

Reference points used to record baseline jaw position

Fig. 9. Jaw lateralization to the left, baseline position.



Reference points used to record maximal jaw displacement to the left

Fig. 10. Jaw lateralization, maximal displacement to the left.

A second maximal jaw opening measure (Task 2) was obtained by measuring the distance from the incisal edge of the central incisors on the maxilla to the incisal edge of the central incisors on the mandible using the TheraBite® [4,2]. This is displayed in Fig. 6. The participants were asked to maintain maximum mouth opening while maintaining comfort for Task 2 as well. Across all participant groups, younger individuals, older individuals, and older individuals with PD, maximum jaw opening was greater adopting Task 1 than Task 2. Therefore, it seems logical to consider using Task 1 as the sole method for obtaining the greatest degree of maximal jaw opening in clinical populations moving forward.

Jaw lateralization ROM tasks required participants to maximally move their jaw to the right and left sides and maintain the posture for approximately 2 seconds. Jaw lateralization to the right was recorded as from two positions. First, the baseline position, where the distance from the incisal edge of the midline of the upper central incisors to the incisal edge of the right lower lateral incisor was noted using the TheraBite® [4] before the jaw was moved to the right (Fig. 7;[1]). Second, the same reference points were used but when the individual moved their jaw maximally to the right [1] and this is displayed in Fig. 8. Then, the difference between the two positions (maximum right displacement – baseline) was calculated. Importantly, the incisors of the lower jaw served as reference in case participants did not have canine teeth and thereby to increase the precision of measurements [1].

Fig. 11. Jaw protrusion.

In terms of left sided jaw lateralization, the distance from the incisal edge between the upper central incisors to the medial edge of the left lower lateral incisor was also measured in two positions. First, the measure was recorded at baseline, as this was before the participant moved the jaw maximally to the left [1] as displayed in Fig. 9. Second, the measure was recorded as the participant maintained maximum displacement to the left as displayed in Fig. 10.

The final task within the context of jaw ROM involved obtaining maximal jaw protrusion. Jaw protrusion was recorded by having the participant push their lower jaw forward as much as possible without discomfort [1]. The lateral scale of the TheraBite® [4] was used to determine the distance from the incisal edge of the upper right central incisors to that of the lower right central incisors [1], as displayed in Fig. 11.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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[OPTIONAL. This is where you can acknowledge colleagues who have helped you that are not listed as co-authors, and funding. MethodsX is a community effort, by researchers for researchers. We highly appreciate the work not only of authors submitting, but also of the reviewers who provide valuable input to each submission. We therefore publish a standard "thank you" note in each of the articles to acknowledge the efforts made by the respective reviewers.]

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.mex.2021.101461.

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