Examining the Relationship Between Stroke and Labial Strength

Katie Weeks
David Dzielak
Elgenaid Hamadain
Jessica Bailey
University of Mississippi Medical Center, Jackson

ABSTRACT: Purpose: The purpose of this study was to determine if a significant difference in labial strength exists between healthy controls, individuals who had experienced a stroke with no deficits, individuals who had experienced a stroke and dysarthria, and individuals who had experienced a stroke with dysarthria and dysphagia.

Method: Four groups participated in the study: a control group of healthy adults and 3 experimental groups of patients with a diagnosis of stroke. The experimental groups were characterized according to the following features: labial weakness only, dysarthria, and dysarthria and dysphagia. All participants performed an oral motor evaluation, diadochokinet rates, clinical swallow evaluation, and bilateral measurements of labial strength using the Iowa Oral Performance Instrument (IOPI; Iowa Oral Performance Instrument Medical, 2010).

Results: Significant differences in labial strength were found on the side affected by the stroke among all of the experimental groups. Surprisingly, smaller yet significant differences in labial strength of the unaffected side were also discovered between the control and experimental groups. A correlation analysis showed a strong, negative relationship between labial strength and a participant’s stroke-related deficits.

Conclusion: Participants in the experimental groups displayed labial weakness on both the affected and unaffected sides. This study contributes to the body of knowledge regarding labial strength required for conducting particular tasks such as producing precise bilabial sounds for purposes of intelligible speech and maintaining adequate labial seal during drinking. This study also opens up areas for future research, including comparing the site of a stroke with resultant labial deficits.

KEY WORDS: stroke, dysarthria, dysphagia
risorius muscles develop tension and elevation of the lower lip to produce the phoneme /l/ (Peña-Brooks & Hedge, 2000). The orbicularis oris muscle also creates lip compression to form the phonemes /p, b, m/ and allows for the rounding of the lips to produce the phoneme /w/ (Peña-Brooks & Hedge, 2000; Seikel et al., 2005). For deglutition, the buccinator, orbicularis oris, and superior pharyngeal constrictor muscles coordinate to create an area of positive pressure in the oral cavity (Wijting & Freed, 2007). The orbicularis oris muscle also maintains labial seal throughout bolus preparation to prevent material from falling from the mouth (Logemann, 1998).

Shaker, Cook, Dodds, and Hogan (1988) studied oral cavity pressure during swallowing to analyze the contributions of varying anatomical structures to the swallow. The authors measured labial pressure, buccal pressure, supralingual pressure, and infralingual pressure during dry and wet swallows as well as voluntary maximal lip force in five healthy participants ranging in age from 20 to 37 years. Intralabial pressure was measured during swallowing as well as during a voluntary maximal squeeze via a transducer that was positioned between the participants’ lips. Buccal pressure was measured during dry and 5-ml water swallows and during a voluntary squeeze via a transducer that was placed within the buccal cavity 3 cm proximal to the angle of the lips.

Three of the participants in the Shaker et al. (1988) study demonstrated an increase in intralabial pressure preceding the intraoral pressure waves, and the remaining two participants did not. Of the three participants demonstrating an increase, the length of the increase in intralabial pressure ranged from 1 to 3 s. Four of the participants demonstrated varying changes in buccal pressure during swallowing. Shaker et al. (1988) noted that changes in buccal pressure were variable in configuration and amplitude and were not always present from one swallow to the next. The results of the study indicated wide ranges of interparticipant and intraparticipant variations in pressure during the oral phase of the swallow. Shaker et al. (1988, p. 83) concluded that increases in labial and buccal pressure do not seem to be necessary components of the oral phase of swallowing, nor are they required for bolus transit. However, labial and buccal pressure activity occurs commonly in association with bolus positioning during the preparatory phase of swallowing.

Wijting and Freed (2007) described the role of the muscles of the oral chamber, including the buccinator, orbicularis oris, and superior pharyngeal constrictor, as acting as a “sling” to contract and compress the oral cavity in order to create an area of positive pressure. When positive pressure is created in one area, it acts as a driving force to propel a bolus into areas of lower pressure. As such, one of the ways the buccinator, orbicularis oris, and superior pharyngeal constrictor may aid in the oral phase of the swallow is by creating positive pressure in the oral cavity.

Other research has focused on the role of labial strength in speech production. Thompson et al. (1995) studied maximum lip force in 16 participants following acute stroke and 16 healthy control participants using a transducer system that allowed for analysis of combined lip force. The experimental participants all demonstrated damage to the upper motor neuron system. Although the authors did not define the type of dysarthria beyond “upper motor neuron” dysarthria, per site of lesion listed, some participants had unilateral damage whereas others had bilateral damage. Four measurements of lip function were taken, including maximum lip force, sustained maximum lip force, repetition of maximum lip force, and fast rate of maximum lip force. Participants were also asked to read a standard passage, “The Grandfather Passage” (Darley, Aronson, & Brown, 1975), which was rated by two speech-language pathologists (SLPs) using 32 dimensions of speech. For the purposes of their investigation, only the four dimensions relating to articulation were included for comparison in the study (Thompson et al., 1995).

In the Thompson et al. (1995) study, statistical analysis of maximum lip force revealed that significantly lower force was generated by participants in the stroke group versus the control group. The authors noted that these differences were consistent with the nature of upper motor neuron dysarthria as damage to upper motor neurons may affect voluntary movements. Their observations were consistent with that of Darley et al. (1975), who characterized the possible effects of upper motor neuron damage on voluntary movements as spasticity, weakness, range limitations, and slowed movement. Further, the participants in the experimental group in the Thompson et al. study showed statistically significant differences in the other three measurements of lip function, including sustained maximum lip force, repetition of maximum lip force, and fast rate of maximum lip force. Participants in the experimental group also demonstrated a decline in maximum lip force during the repetition of maximum lip force task, which the authors contributed to a more rapid rate of fatigue in the labial musculature when compared to that of the participants in the control group.

An additional correlation analysis was conducted using scores on the articulation ratings of the participants in the stroke group and their maximum lip strength scores (Thompson et al., 1995). These results showed no significant correlation between lip strength
and overall intelligibility, \( r(16) = -0.067, p = 0.806 \). These results were in agreement with a previous study by Langmore and Lehman (1994), where the authors compared the perceived severity of dysarthria in speakers with amyotrophic lateral sclerosis (ALS) with their performance on strength measures involving the lower lip, tongue, and jaw. Langmore and Lehman found no significant correlation between the participants’ perceived severity of dysarthria and their performance on lower lip maximum strength tasks.

Barlow and Abbs (1984) studied fine force control of the labial musculature and speech intelligibility in participants with congenital spasticity and found a significant correlation between speech intelligibility and fine force control of the lips, jaw, and tongue force. The authors concluded that speech production is a result of precise control of submaximal muscle contractions, not maximum force, of the lips, jaw, and tongue (Barlow & Abbs, 1984). However, Thompson et al. (1995) noted that the lack of correlation between maximal labial strength and perceptual impairments of speech intelligibility in their study should not be taken to mean that there is no relationship between labial strength and articulation. Thompson et al. commented that perceptual tasks in their study may not have adequately targeted labial function, and that participants in the stroke group may not have demonstrated lip weakness below the level necessary to cause perceptual changes in speech intelligibility.

Clark, O’Brien, Calleja, and Corrie (2009) used the Iowa Oral Performance Instrument (IOPI; Iowa Oral Performance Instrument Medical, 2010) to evaluate the effects of exercise on lingual strength in 39 healthy adults. The IOPI provides objective measurements of lingual strength, labial strength, and hand strength, measuring pressure exerted by muscles in kilopascals (kPa). The authors also measured labial strength as an untrained control condition. Average labial strength was found to be 30 ± 10 kPa (Clark et al., 2009). No significant increases in labial strength were noted during the training period.

The effects of aging on muscle mass, as well as differences in muscle mass between the genders, is another area of recent attention with regard to speech production and deglutition. Clark and Solomon (2012) explored age- and gender-related differences in orofacial strength in 171 healthy adults. The results of their study showed that age did not affect labial strength or cheek compression, though tongue lateralization, tongue protrusion, and anterior and posterior tongue elevation were reduced in older patients when compared to younger patients. With regard to gender, men demonstrated significantly higher measurements of labial and cheek compression strength than women, but no significant differences were found with regard to anterior tongue elevation, posterior tongue elevation, tongue lateralization, or tongue protrusion (Clark & Solomon, 2012).

Although dysarthria secondary to labial weakness may occur in isolation, labial weakness causing dysphagia is typically accompanied by dysarthria. Daniels, McAdam, Brailey, and Fundas (1997) noted that in participants with a normal swallow or with mild dysphagia, as defined as a score of 0 or 1 on the Rosenbek Penetration-Aspiration Scale (Rosenbek, Robbins, Roeker, Coyle, & Wood, 1996), 45% of the participants presented with dysarthria. Of the participants with moderate, moderate-to-severe, or severe scores, 85% demonstrated one of the dysarthrias. As such, the categories used in our study to define the experimental groups were labeled as dysarthria only and dysarthria and dysphagia.

Pathologic conditions that affect labial strength have not been extensively investigated, even though neurological conditions such as stroke may result in multiple physical and social impairments including dysphagia and dysarthria (Gerzeli et al., 2005). Although SLPs have recognized that labial weakness may cause variable deficits, there are no studies available that have measured labial strength to quantify the deficits in speech and deglutition following neurological insult, including stroke.

The purpose of this study was to determine if a significant difference in labial strength exists between healthy controls, individuals who had experienced a stroke with no deficits, individuals who had experienced a stroke and dysarthria, and individuals who had experienced a stroke with dysarthria and dysphagia.

---

**METHOD**

**Participants**

Four groups of individuals participated in this study. The control group consisted of 42 healthy adult participants. The three experimental groups consisted of 31 patients who had been admitted to the University of Mississippi Medical Center with a diagnosis of stroke. This study was reviewed and approved by the University of Mississippi Medical Center Institutional Review Board.

Participants in the experimental groups were selected from acute care patients who had been admitted to the University of Mississippi Medical Center with a diagnosis of stroke and who had been referred to the adult acute care speech-language pathology service. Additional inclusion criteria included an observation of labial weakness by the admitting physician during a cranial nerve evaluation and no prior history
of stroke or transient ischemic attack (TIA), traumatic brain injury (TBI), myasthenia gravis, dementia, ALS, or other neurological disease. Patients who were unable to follow or model one-step commands or who were edentulous were excluded from the study.

Procedure

Patient charts were reviewed and pertinent demographic and diagnostic information was extracted. Information recorded for this study included the patient’s age; past medical, surgical, and social history; number of days from admission to time of the initial consultation with the speech-language pathology service; and type and location of stroke as reported via computed tomography (CT) scan, magnetic resonance imaging (MRI), or computed tomography angiography (CTA). Although the number of days post stroke would have been a more ideal measurement than the number of days from admission to initial consult, the day on which the stroke occurred was not always known. In addition, the participant’s composite score on the National Institutes of Health Stroke Scale (NIHSS; National Institutes of Health, 2013) was recorded. The NIHSS is a 15-item, 42-point assessment tool that provides a quantitative measurement of a patient’s deficits following a stroke. A maximal score of 42 represents the most severe stroke; a score of 0 indicates no stroke. A score of 1–4 indicates a minor stroke, 5–15 a moderate stroke, 16–20 a severe stroke, and a score >21 indicates a severe stroke requiring a high level of treatment.

Participants in the control group (Group A) were selected from adult volunteers within a similar age range as the participants in the experimental groups. Participants in this group were recruited via word-of-mouth or fliers that had been placed on acute care floors at the University of Mississippi Medical Center. To be considered a participant, volunteers had to confirm a negative history of stroke or transient ischemic attack (TIA), traumatic brain injury (TBI), myasthenia gravis, dementia, ALS, or other neurological disease. Patients who were unable to follow or model one-step commands or who were edentulous were excluded from the study.

Participants in the experimental groups received a complete swallowing evaluation per the clinical protocols of the speech-language pathology service of the University of Mississippi Medical Center. The experimental process, however, consisted of additional measures of oral motor function as well as conducting objective measurements of labial strength using the IOPI.

Participants in the experimental group were divided into three separate subgroups based on their diadochokinetic (DDK) rates and their ability to achieve adequate labial seal while drinking water from a cup. DDK rates associated with labial movement were recorded to evaluate the speed and accuracy of the participants’ speech movements. DDK rates were determined by having each patient repeat the bilabial sound /pa/ as quickly and accurately as possible for 10 s. Participants were instructed to “say /papapa/ as fast and good as you can” until instructed to stop. The number of repetitions produced was measured and the average alternating motion rate (AMR) per second was determined for each participant.

Data from previous studies have defined the average AMR for adults to range between five to seven repetitions per second (Hedge, 1996). Participants whose bilabial AMR productions were judged to be less than five repetitions per second were recorded as having dysarthria. Participants were then given a glass of water and were instructed to “drink one sip of water from the cup.” This task is referred to as the cup-edge drink task. Neither the total amount of water in the cup nor the total amount of each bolus was measured. Instead, the intent of this task was to evaluate each participant’s labial seal. This process was conducted three times. If a participant demonstrated anterior loss of water in any of the three trials, he or she was recorded as having oral dysphagia.

Based on the outcomes of the DDK and cup-edge drink tasks, participants in the experimental group were assigned to one of three subgroups. Group B included participants who had labial weakness according to the medical record yet performed within normal limits on both the DDK and the cup-edge drink tasks. This group was presumed to have no deficits other than labial weakness.

For purposes of this study, reduced AMR for the bilabial sound /pa/ was used to define Group C. This group included participants who had labial weakness and dysarthria as evidenced by a reduced AMR for the bilabial sound /pe/ but no evidence of anterior loss during the cup-edge drinking task. Group D consisted of participants who had labial weakness, dysarthria as evidenced by reduced AMR, and dysphagia as evidenced by anterior loss on the cup-edge drinking task. Oral dysphagia included only incidences of anterior loss on the affected side as this is an indication of decreased labial function. Oral clearance was not included because inadequate oral clearance may also be due to decreased lingual movement. Although decreased consonant production rate and anterior loss
are signs of dysarthria and dysphagia, they are by no means sole descriptors of these disorders; these signs were selected as they relate specifically to labial weakness, which was the focus of the current study.

The control group (Group A) consisted of 42 participants, ages 24 to 80. Participant demographics for the control and experimental groups are listed in Table 1. The average age of the participants in the control group was 43.67 ($SD = 2.06$) years. Twelve participants were male, and 30 were female. The experimental groups consisted of 31 participants, ages 25 to 82. Each participant in the experimental subgroups demonstrated labial weakness, as documented by their primary physician.

There were 13 participants in the weakness-only group (Group B), and their mean age was 49.31 ($SD = 4.4$) years (Table 1). Participants in this group included nine males and four females. The mean number of days from a patient’s admission until evaluation by the speech-language pathology service was 0.9 ($SD = 0.21$), and the mean NIHSS score was 5.38 ($SD = 1.25$). Group C (dysarthria) had 10 participants and a mean age of 63.60 ($SD = 3.48$) years. Four patients were male, and six were female. The mean number of days from a patient’s admission until evaluation was 1.3 ($SD = 0.45$), and the mean NIHSS score was 5.70 ($SD = 1.41$). Finally, Group D (dysarthria and dysphagia) included eight participants with an average age of 59.63 ($SD = 3.13$) years. Four patients were male and four were female. The mean number of days from a patient’s admission until evaluation was 2.88 ($SD = 1.19$), and the mean NIHSS score was 9.25 ($SD = 1.63$).

Three participants in the experimental group had hemorrhagic strokes, and 28 had ischemic strokes. The experimental groups included only patients with cortical or subcortical strokes. None of the participants in the study suffered brainstem involvement. The areas of the brain where the strokes occurred included the left-middle cerebral artery ($n = 9$); right-middle cerebral artery ($n = 8$); left basal ganglia ($n = 5$); right basal ganglia ($n = 4$); left thalamus ($n = 1$); right thalamus ($n = 1$); bilateral basal ganglia, originating in the left hemisphere with hemorrhagic transformation to the right hemisphere ($n = 1$); right fronto-temporal area ($n = 1$); and left anterior cerebral artery ($n = 1$). All of the participants in the experimental group demonstrated contralateral labial weakness. Reporting of stroke location was based on information that was collected from each participant’s chart. As such, some sites were listed by the artery where the stroke occurred, and others were listed by the structure affected.

### Instrumentation

Measurements of labial strength for all groups were obtained using the IOPI lip strength measurement method (IOPI Medical, 2010). The two labial measurements included measurements on the side of the face that had been affected by the stroke and the side of the face that was unaffected by the stroke. In the control group, the right side was labeled the affected side, and the left side was labeled the unaffected side.

Consistent with the method reported by Clark et al. (2009), an IOPI tongue bulb was placed in the lateral corner of the mouth toward the buccal surface and the participant was instructed to “squeeze the bulb with the cheek with maximum effort.” This procedure was conducted three times on both the affected and unaffected sides. The first two trials per side were provided to familiarize the participant with the tasks and allow him or her to practice performing the strength measurements. Only the third trial on each side was recorded and used in the data analysis. Although other studies have recorded the highest measurement, the final trial was selected for this study in order to allow the participants two trials to become familiar with the task.

The DDK rates and cup-edge drinking skills of the control group were also measured.

### Analysis

The Shapiro-Wilk test of normality was conducted to determine if the data were normally distributed. A

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Age M SD</th>
<th>Gender Male</th>
<th>Female</th>
<th>Days until consult M SE</th>
<th>NIHSS score M SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Control)</td>
<td>42</td>
<td>43.67 2.06</td>
<td>12</td>
<td>30</td>
<td>N/A N/A</td>
<td>5.38 1.25</td>
</tr>
<tr>
<td>B (Weakness only)</td>
<td>13</td>
<td>49.31 4.40</td>
<td>9</td>
<td>4</td>
<td>0.90 0.21</td>
<td>5.70 1.41</td>
</tr>
<tr>
<td>C (Dysarthria)</td>
<td>10</td>
<td>63.60 3.48</td>
<td>4</td>
<td>6</td>
<td>1.30 0.45</td>
<td>5.70 1.41</td>
</tr>
<tr>
<td>D (Dysarthria and dysphagia)</td>
<td>8</td>
<td>59.63 3.13</td>
<td>4</td>
<td>4</td>
<td>2.88 1.19</td>
<td>9.25 1.63</td>
</tr>
</tbody>
</table>

**Note.** NIHSS = National Institutes of Health Stroke Scale (National Institutes of Health, 2013).
two independent-samples $t$ test was conducted with labial strength as the dependent variable and group (patient status post stroke or control) as the independent variable. To further evaluate the differences in labial strength among the groups, a one-way analysis of variance (ANOVA) was conducted with labial strength as the dependent variable and group as the independent variable followed by post hoc testing using Tukey’s test. The Spearman rank correlation coefficient was conducted with measures of labial strength and a patient’s NIHSS score as well as his or her clinical deficits based on the experimental group in which he or she was placed. Because severity ratings of dysarthria and oral dysphagia were not conducted, the Spearman rank correlation coefficient was chosen. Use of this measure allowed the patients to be placed in groups based on symptoms (presence or absence of dysarthria and/or oral dysphagia) demonstrated and not severity. The ranks used in the correlation analysis were no deficits, dysarthria, and dysarthria and oral dysphagia. For participants in the control group, the Spearman rank correlation coefficient was conducted using measures of labial strength and a participant’s age and gender.

### RESULTS

The DDK rates and cup-edge drinking skills of the control group were also measured. The average AMR (with standard error in parentheses) for bilabial sounds was 6.21 (0.093) repetitions per second for Group A. In the experimental groups, patients who demonstrated reduced AMRs were labeled as dysarthric. Group B averaged 5.08 (0.18) repetitions per second, followed by Group C at 3.50 (0.17) repetitions per second and Group D at 2.38 (0.26) repetitions per second. No participants from Group A demonstrated imprecise/slurred speech. As can be seen, the mean AMRs distinguish the four groups, with the control participants (Group A) having the highest rate and those participants with both dysarthria and dysphagia (Group D) having the poorest or lowest rate.

Mean labial strength for the control group was 25.88 (0.52) kPa on the right side and 25.60 (0.61) kPa on the left side. Mean labial strength for Group B was 18.31 kPa (1.07) and 24.54 (0.79) kPa for the affected and unaffected sides, respectively. Group C had a mean labial strength of 12.8 (1.75) kPa on the affected side and 18.1 (1.74) kPa on the unaffected side, and Group D had a mean labial strength of 7.63 (1.12) kPa on the affected side and 14.88 (1.62) kPa on the unaffected side.

Table 2 summarizes the average labial strength for the affected and unaffected sides for each group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Affected side M</th>
<th>Affected side SE</th>
<th>Unaffected side M</th>
<th>Unaffected side SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Control)</td>
<td>25.88</td>
<td>0.52</td>
<td>25.60</td>
<td>0.61</td>
</tr>
<tr>
<td>B (Weakness only)</td>
<td>18.31</td>
<td>1.07</td>
<td>24.54</td>
<td>0.79</td>
</tr>
<tr>
<td>C (Dysarthria)</td>
<td>12.80</td>
<td>1.75</td>
<td>18.10</td>
<td>1.74</td>
</tr>
<tr>
<td>D (Dysarthria and dysphagia)</td>
<td>7.63</td>
<td>1.12</td>
<td>14.88</td>
<td>1.62</td>
</tr>
</tbody>
</table>

Note. Affected side refers to the side displaying the primary facial weakness (either right or left) following the stroke. For the control group (Group A), the affected side was always the right side of the face. Unaffected side refers to the participant’s stronger side (either right or left) following the stroke. For the control group (Group A), the unaffected side was always the left side of the face.

Figure 1 displays the average labial strength for the affected and unaffected sides for the control and experimental groups and for the results of the three experimental groups collapsed into a single group.

The Shapiro-Wilk test of normality was conducted for labial strength in the control and experimental groups to determine if parametric or nonparametric tests should be conducted. Labial strength for the control, $p = 0.153$ right; $p = 0.076$ left, and experimental groups, $p = 0.427$ affected, $p = 0.182$ unaffected, were found to be normally distributed. The age of the experimental groups followed a normal distribution, $p = 0.076$, but the age of the control group was not normally distributed, $p = 0.014$. Based on these results, it was determined that the parametric two independent-samples $t$ test and one-way ANOVA were appropriate.

### Labial Strength

**Experimental versus control group.** As labial strength for the control and experimental groups was found to be normally distributed, the parametric two-independent samples $t$ test was selected to compare labial strength between the control group and the combined experimental groups. A two independent-samples $t$ test was conducted for both the affected and unaffected sides. Significant differences were found between the two groups for each side with respect to mean labial strength, $t(70) = 10.69$, $p < 0.001$, affected side, and $t(70) = 4.80$, $p < 0.001$, unaffected side.

**Experimental subgroups versus control group.** The one-way ANOVA revealed significant differences in labial strength between at least two of the groups for the affected, $F(3, 69) = 73.84$, $p < 0.001$, and unaffected, $F(3, 69) = 21.52$, $p < 0.001$, sides. As
such, multiple comparison tests were conducted using Tukey’s test. Statistically significant differences were found in labial strength on the affected side between all groups. For the unaffected side, no significant difference in labial strength was noted between Groups A and B ($p = 0.847$) or between Groups C and D ($p = 0.351$). However, significant differences in labial strength were found between Group A and Groups C and D ($p < 0.001$) as well as between Group B and Groups C and D ($p = 0.002$ and $p < 0.001$). Tables 3 and 4 show the results of the post hoc testing. Figure 2 depicts group performance on measures of labial strength on the affected side.

A significant correlation (Spearman’s rho) was found between the labial strength of the participants in the experimental groups and deficits demonstrated using the experimental groups as ranks, $r(29) = -0.724$, $p < 0.001$ (affected side), $r(29) = -0.746$, $p < 0.001$ (unaffected side). Those persons in Group B had the greatest labial strength, whereas those in Group D had the least labial strength. The correlation coefficients of $-0.75$ for the affected side and $-0.72$ for the unaffected side indicate a strong, negative relationship between a participant’s labial strength and the deficits demonstrated. Interestingly, no significant correlation was found between the labial strength of the participants in the experimental groups and their NIHSS score, $r(29) = -0.28$, $p = 0.13$ (affected side), $r(29) = -0.16$, $p = 0.39$.

Because the participants in Groups B, C, and D were, on average, older than the participants in Group A, we conducted a correlation analysis. No significant correlation (Spearman’s rho) was found between labial strength and age for the participants in the control group, $r(40) = -0.071$, $p = 0.656$ (right side), $r(40) = -0.175$, $p = 0.267$ (left side). Because no significant correlation was found between age and labial strength for participants in the control group, the older average age of the patient groups was not felt to pose a threat to validity.

**DISCUSSION**

The purpose of this study was to evaluate labial strength in healthy adults as well as in patients who had suffered an acute stroke and were reported to exhibit facial weakness. Data were examined for differences in labial strength between groups and for significant correlations between labial strength and deficits. The results of this study found average labial strength to be $-25$ kPa for healthy adults. Labial strength was found to be symmetrical, with both sides having essentially the same strength characteristics.
These results are similar to those of Clark et al. (2009), who, using the same method of measurement, found labial strength to be 30 ± 10 kPa. The results from the current study were also in agreement with those of Clark and Solomon (2012), which showed no significant relationship between labial strength of healthy adults and their age.

Our study also examined labial strength in participants following a stroke. Significant differences in labial strength were found between the control and experimental subgroups on the affected and unaffected sides of the face. These differences in labial strength were not unexpected on the side affected by the stroke, but it was of interest to note the significant differences in labial strength on the unaffected side. Because the orbicularis oris is a sphincter muscle, it is possible that the right and left sides are unable to act independently of one another (Nakatsuka et al., 2011). As such, muscles on the affected side may influence labial strength on the unaffected side.

In the experimental group, labial strength on the unaffected side decreased as labial strength on the affected side decreased, although the differences were not always statistically significant. In the control group, the average labial strength for the right (affected) and left (unaffected) sides was very similar, 25.88 ± 0.52 kPa and 25.6 ± 0.61 kPa. Nakatsuka et al. (2011) compared the results of electromyogram (EMG) activity of the orbicularis oris with a novel multidirectional lip closing force (LCF) measurement system. Eight different directions of lip closing force were measured, including upper, right-upper, right, right-lower, lower, left-lower, left, and left-upper. No significant differences were found between directional LCF using EMG or the novel measurement system in

Table 3. Multiple comparison tests for the affected side. Testing compares the labial strength of each of the four subgroups with one another.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Group __ vs. Group __</th>
<th>Mean difference (kPa)</th>
<th>Standard error (kPa)</th>
<th>Significance (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labial strength, affected side</td>
<td>A vs. B</td>
<td>7.57</td>
<td>1.21</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td></td>
<td>A vs. C</td>
<td>13.08</td>
<td>1.34</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td></td>
<td>A vs. D</td>
<td>18.26</td>
<td>1.46</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td></td>
<td>B vs. C</td>
<td>5.51</td>
<td>1.60</td>
<td>0.05*</td>
</tr>
<tr>
<td></td>
<td>B vs. D</td>
<td>10.68</td>
<td>1.71</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td></td>
<td>C vs. D</td>
<td>5.18</td>
<td>1.80</td>
<td>0.027*</td>
</tr>
</tbody>
</table>

*Statistically significant at the p = 0.05 level.

Table 4. Multiple comparison tests for the unaffected side. Testing compares the labial strength of each of the four subgroups with one another.

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Group __ vs. Group __</th>
<th>Mean difference (kPa)</th>
<th>Standard error (kPa)</th>
<th>Significance (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labial strength, unaffected side</td>
<td>A vs. B</td>
<td>1.06</td>
<td>1.30</td>
<td>0.850</td>
</tr>
<tr>
<td></td>
<td>A vs. C</td>
<td>7.50</td>
<td>1.44</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td></td>
<td>A vs. D</td>
<td>10.72</td>
<td>1.58</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td></td>
<td>B vs. C</td>
<td>6.44</td>
<td>1.72</td>
<td>0.002*</td>
</tr>
<tr>
<td></td>
<td>B vs. D</td>
<td>9.66</td>
<td>1.84</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td></td>
<td>C vs. D</td>
<td>3.23</td>
<td>1.94</td>
<td>0.351</td>
</tr>
</tbody>
</table>

*Statistically significant at the p = 0.05 level.

These results are similar to those of Clark et al. (2009), who, using the same method of measurement, found labial strength to be 30 ± 10 kPa. The results from the current study were also in agreement with those of Clark and Solomon (2012), which showed no significant relationship between labial strength of healthy adults and their age.

Our study also examined labial strength in participants following a stroke. Significant differences in labial strength were found between the control and experimental subgroups on the affected and unaffected sides of the face. These differences in labial strength were not unexpected on the side affected by the stroke, but it was of interest to note the significant differences in labial strength on the unaffected side. Because the orbicularis oris is a sphincter muscle, it is possible that the right and left sides are unable to act independently of one another (Nakatsuka et al., 2011). As such, muscles on the affected side may influence labial strength on the unaffected side.

In the experimental group, labial strength on the unaffected side decreased as labial strength on the affected side decreased, although the differences were not always statistically significant. In the control group, the average labial strength for the right (affected) and left (unaffected) sides was very similar, 25.88 ± 0.52 kPa and 25.6 ± 0.61 kPa. Nakatsuka et
the horizontal or oblique directions (Nakatsuka et al., 2011).

In our study, the results of the strength comparison across the four patient groups showed significant differences between the control and experimental groups, with a minimum reduction of ~25% in strength for those patients in Group B when compared to the strength of Group A on the right side. For Group C, there was a 50% reduction in strength compared to the control group, and for participants in Group D, the reduction was 75%.

Within the experimental group, significant statistical differences were noted between the three subgroups of participants. The reductions in maximal labial strength in the current study may be important to compare against reductions in labial strength in future studies with a larger sample size and a more diverse group of stroke patients to see if significant correlations exist between maximum labial strength and speech intelligibility or maximum labial strength and achieving adequate labial seal when drinking.

Of interest to note were the significant differences in strength measurements on the unaffected sides between some of the groups. No differences were noted between pressures obtained on the unaffected sides between Group A and Group B. In fact, the average labial strengths of the two groups were nearly identical. However, those participants in Group C showed a 25% reduction of strength on the unaffected side when compared to the control group, and those participants in Group D showed a nearly 50% reduction in strength. It should be pointed out, however, that these results may not be reflective of other individuals with different degrees of stroke, dysarthria, or dysphagia. Therefore, further investigation is warranted.

Although the results of the current study showed a strong, negative correlation between labial strength and a participant demonstrating dysarthria or dysphagia and oral dysphagia, this is in contrast to other studies (Langmore & Lehman, 1994; Thompson et al., 1995), where no significant correlation between maximum labial strength and speech production was demonstrated. Barlow and Abbs (1984) found significant differences in speech intelligibility and fine force control of the lips, which may be a better indicator of speech intelligibility as opposed to maximum labial strength. Because some of the patients in the current study displayed overall reductions in maximum labial strength but no deficits in speech intelligibility, a certain level of labial weakness may be required to affect intelligibility. As such, the disproportionate number of patients with mild strokes and mild labial weakness as represented in the current study may have skewed the data. As the current study was limited by a small sample size, future research is warranted to further explore the relationship between maximum labial strength and speech production.

In the experimental subgroups, labial strength was significantly correlated with a patient’s deficits but not with his or her NIHSS score. One limitation of the study, however, was that patients had to be able to follow commands to meet the inclusion criteria. As such, patients with more severe strokes, and therefore a higher NIHSS score, were excluded from the study. One point of interest was that the mean NIHSS score for Group D was more than three points higher than that of the other two groups, particularly as dysphagia is not measured on the NIHSS. Future research may examine if a significant relationship exists between a patient’s NIHSS score and a diagnosis of dysphagia.

Another factor that may have contributed to the results is the time between admission and the time that the evaluation took place. For this study, the clinician could not control for the time between when a patient was admitted to the hospital and when the speech-language pathology consult was received. How this contributed to the results could not be determined, but the potential for decline in labial strength over time or the degree to which spontaneous recovery occurred must be considered. Finally, the site of the stroke was extremely variable in this population and, as such, the relationship between the site of the lesion and labial strength could not be examined.

**Conclusion**

For patients who are affected by stroke, significant differences in labial strength were found between the control group, the experimental subgroup with facial weakness only, the experimental subgroup with dysarthria, and the experimental subgroup with dysarthria and oral dysphagia. This study contributes to the body of knowledge regarding the labial strength required to conduct particular tasks such as producing precise bilabial sounds for purposes of intelligible speech and maintaining adequate labial seal while drinking. For the side unaffected by the stroke, there was a significant difference in labial strength between patients with facial weakness only and patients with dysarthria only or dysarthria and dysphagia. However, no significant difference was found in labial strength on the unaffected side for patients with dysarthria only and dysarthria and dysphagia. This study was limited in that it only examined one sign of dysarthria (imprecise bilabial consonant production) and one sign of dysphagia (anterior loss). Other limitations included the small sample size and the inclusion of patients with mild strokes, as defined by their NIHSS score.
REFERENCES


Contact author: Katie Weeks, University of Mississippi Medical Center, Department of Otolaryngology and Communicative Sciences, 2500 North State Street, Jackson, MS 39216. E-mail: kweeks@umc.edu.