Facial and Lingual Strength and Endurance in Skilled Trumpet Players

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Trumpet players produce and manipulate sound through their instrument by articulating the lips, cheeks, and tongue to create a proper airflow. These sustained muscle contractions may result in increased facial and lingual strength and endurance. The purpose of this study was to determine if adult trumpet players who practice at least 6 hrs/wk differed from adult non-trumpet-playing controls in strength and endurance of the lips, cheeks, and tongue. **Methods:** This case-control study involved 16 trumpet players, 16 healthy controls balanced for age and sex, and 1 trumpet player 25 years post-Bell's palsy. Strength and endurance of lip, cheek, and tongue muscles were measured using the Iowa Oral Performance Instrument (IOPI Medical, Redmond, WA). Maximum strength was the greatest pressure value of three encouraged trials. Endurance was the length of time the participant was able to sustain 50% of maximum strength. **Results:** The findings indicate that trumpet players had greater facial strength and endurance, which was objectively quantified using commercially available equipment. The trumpet players had greater cheek strength and greater lip endurance than controls. Tongue strength and endurance did not differ between the trumpet players and controls. Tongue strength was negatively associated with age, which is consistent with previous studies. The trumpet player with a history of Bell's palsy had decreased cheek strength and endurance on his affected side compared to his unaffected side, although this difference was comparable to the differences between right and left cheek strength in trumpet players without a history of facial nerve damage. *Med Probl Perform Art* 2015; 30(2):90–95.

Trumpet players produce and manipulate sound through their instrument by articulating the lips, cheeks, and tongue to direct airflow and create a proper embouchure.[1] The term *embouchure* is used to describe the purposeful contraction of the facial muscles to produce a sound on a wind instrument. Fundamental frequency, perceived as pitch or musical tone, is changed by tightening the lip and cheek muscles to minutely alter the muscular contractions of the embouchure. Producing musical tone relies on the control of pressure at the lips, the contractile force on the mouthpiece, intra-oral air pressure, and lingual articulatory movements. Orofacial musculature must maintain a high level of physical integrity to resist the intense, focused column of air. Highly skilled trumpet players exercise their lip and cheek muscles to develop a strong embouchure, capable of enduring hours of strenuous muscle activity.

Unlike skeletal muscles, which originate on bone and insert on bone, most facial muscles originate on bone and insert into the skin or cutaneous layers of the face.[2,3] The primary muscle responsible for closing and puckering the lips, the *orbicularis oris*, is comprised of four quadrants (right upper, right lower, left upper, and left lower) of interlaced muscle fibers that together function as a sphincter; these fibers include intrinsic muscle fibers, which do not originate on bone but are fully contained within the lips, and extrinsic muscle fibers, which originate on the maxilla (upper jaw), mandible (lower jaw), or nasal areas and insert into the lips.[4]

The principle muscle of the cheek, the *buccinator*, is a paired facial muscle that compresses the lips and cheeks against the teeth as well as draws the corners of the mouth laterally. The interdigitations of the face and lip muscles result in collaborative function necessary for fine lip and cheek movement.[5,6] There are eight muscles, four intrinsic and four extrinsic, responsible for creating tongue tension and shape. The intrinsic muscles have their origins and insertions within the tongue and form a kinetic chain with the extrinsic muscles, which originate on the styloid process, palate, mandible, or hyoid bone.

Integrity of facial and lingual musculature can be objectively assessed with the Iowa Oral Performance Instrument (IOPI; IOPI Medical, Redmond, WA).[7,8] The IOPI is a hand-held device that measures pressure generated against a soft PVC air-filled bulb (Fig. 1). Previous studies have used the IOPI to measure changes in facial and lingual strength resulting from exercise targeting the orbicularis oris and buccinator muscles or the intrinsic and extrinsic muscles of the tongue in individuals with facial nerve dysfunction, geriatric adults with swallowing disorders, and geriatric adults without swallowing disorders.[9–11]

In most adults, lip and cheek strength remain constant across age.[7] Tongue strength increases slightly up to age 60 years and then progressively declines. Men have been

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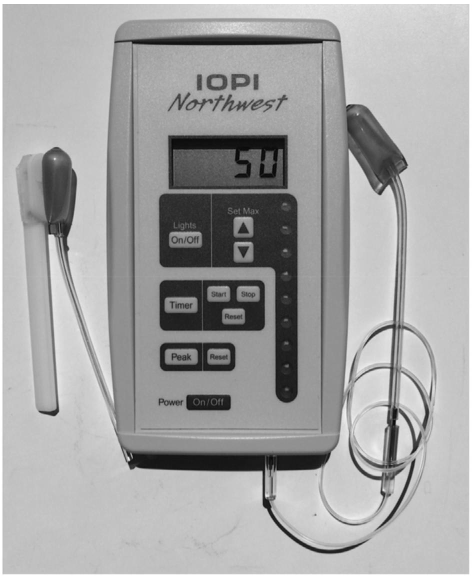

FIGURE 1. The Iowa Oral Pressure Instrument (IOPI) with bulb-holder adapter (on left).

shown to have 22% greater cheek and 33% greater lip strength compared to women, but tongue strength is typically equivalent or only slightly increased in men. Endurance, as measured by the IOPI, has been defined as the length of time 50% of maximum strength is sustained.[12] Repetitive use, resulting from a functional activity such as trumpet playing or competitive debate, has been reported to increase tongue endurance, but not tongue strength, in healthy individuals when compared to age- and sex-matched controls.[13] No known studies have used the IOPI to examine lip and cheek strength and endurance in trumpet players.

The purpose of this study was to examine how trumpet playing influences: 1) lip strength and endurance, 2) cheek strength and endurance, and 3) tongue strength and endurance. We hypothesize that trumpet players who spend hours per week practicing their instruments are likely to demonstrate increased strength and endurance in lip, cheek, and tongue muscles.

METHODS

The Institutional Review Board of Washington State University approved the study. All participants provided written informed consent.

Participants

Participants in this case-control study included 33 participants: 16 trumpet players and 16 controls balanced for age and sex, and 1 trumpet player 25 yrs' post-onset of Bell's palsy (Table 1). Trumpet players were recruited through posted announcements and emails to university music departments and professional orchestras in eastern Washington State. Inclusion criteria for trumpet players required self-reporting a minimum of 8 yrs experience playing the trumpet, at least 6 hrs/wk of practice time, and instrumental rest for 12 hrs or more prior to data collection to prevent possible muscle fatigue. The younger trumpet players (18 to 27 yrs of age, *n*=13) were students from a university music department, and the older trumpet players (45 to 74 yrs of age, *n*=3) were professionals from a jazz orchestra. As shown in Table 1, 14 of the 16 trumpet players (87.5%) were male, which is typical of the distribution by sex for trumpet players.[14] This underrepresentation of female compared to male trumpet players has shown little change over the past 60 years. No individuals between 27 and 45 yrs of age volunteered to participate in the study. Control participants were recruited through posted announcements and emails to university and community groups. Inclusion criteria for controls required self-reporting no experience playing a wind instrument. All participants performed within normal limits on an orofacial structure-function exam and self-reported a negative history of neurological impairment.

Although this study did not intentionally recruit trumpet players with a history of neurologic impairment, one trumpet player (age 52 yrs) who was 25 yrs post-onset of left unilateral Bell's palsy volunteered to participate. Due to his history of neurologic impairment, his data were excluded from the group analysis; however, his results are discussed as they are of clinical interest. His orofacial structure-func-

TABLE 1. Demographic Characteristics of Trumpet Players and Controls

Group	Male *n*	Female *n*	Mean Age *yrs* (SD)	Experience *yrs* (SD)	Mean Practice *hrs/wk* (SD)
Trumpet players	14	2	28.7 (17.4)	18.5 (16.7)	12.9 (7.4)
Younger	11	2	21.1 (2.7)	11.2 (2.6)	14.2 (7.6)
Older	3	0	61.7 (15.0)	50.0 (15.0)	7.3 (2.3)
Controls	14	2	28.9 (16.6)	0	0
Younger	11	2	21.6 (3.2)	0	0
Older	3	0	60.3 (13.4)	0	0
Bell's palsy*	1	0	52	42	30

*Trumpet player post-Bell's palsy.

tion exam showed range of motion within normal limits and symmetry between his affected and unaffected sides.

Procedures

Strength and Endurance Measurements

The IOPI was used to measure lip, cheek, and tongue strength in kilopascals (kPa) and endurance in seconds (sec). For strength, participants were instructed to press against the bulb with maximum effort. Peak pressure values of three trials were recorded and the greatest pressure value was used as maximum strength.

For endurance, the participants and examiner monitored the IOPI light array in real time to sustain 50% of maximum strength for as long as possible. Each trial began when 50% of maximum strength was achieved and ended when a 2-sec drop of >10% was observed.[12] The experimental order was identical for all participants. Measurements were collected with 30-sec rest periods between regions in the following order: left cheek strength, right cheek strength, left cheek endurance, tongue strength, tongue endurance, right cheek endurance, lip strength, and lip endurance. This design order minimized the possible effects of fatigue from the right and left cheek endurance tasks on the endurance of the interdigitized lip muscles.

Bulb Placement

Lip strength and endurance were assessed with the IOPI bulb sandwiched between two wooden tongue blades.[7] This configuration ensured correct placement against movement of the smooth surface of the bulb over the lip and distributed the pressure exerted on the blades evenly across the entire surface of the bulb. The participants were instructed to lightly place their teeth together, separate and protrude their lips, and squeeze on the blades, which were placed at midline.

Cheek strength and endurance were assessed with the IOPI bulb attached to the IOPI bulb-holder adapter with double-sided surgical-grade tape (Fig. 1) and placed in the lateral position with teeth lightly clamped on bite cushions. The IOPI bulb faced laterally toward the ipsilateral buccal surface, and participants were instructed to contract the cheek against the bulb.

Tongue elevation strength and endurance were assessed with the IOPI bulb positioned just posterior to the participant's upper incisors. Participants were instructed to elevate and squeeze the anterior portion of their tongue against the bulb while keeping their teeth parted to avoid biting down on the IOPI tubing.

Data Analysis

Two-tailed *t*-tests were used to test for group differences, and Pearson's correlation tests were used to assess association between variables of interest. For all tests, an uncorrected alpha-criterion of 0.05 was used.

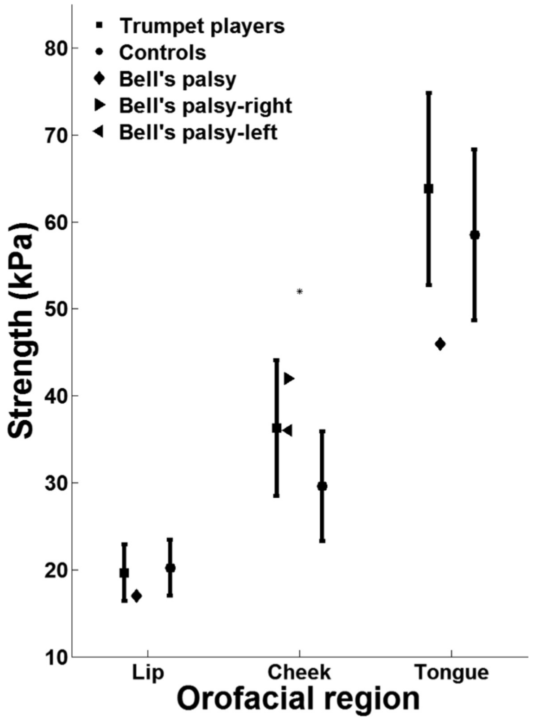

FIGURE 2. Strength measurements for trumpet players, controls, and a trumpet player 25 yrs post-left-side Bell's palsy.

RESULTS

Strength and Endurance

Lip: As shown in Figure 2, lip strength did not differ between trumpet players and controls (p>0.05). As shown in Figure 3, the trumpet players had greater lip endurance compared to controls [$t(31)=2.98$, $p<0.05$]. Greater lip strength was negatively associated with lip endurance for both the trumpet players and controls ($r=-0.45$, $p<0.05$) (Table 2). Among the trumpet players, age and years of experience were confounded, because the older trumpet players had many more years of experience than the younger trumpet players. Greater age/experience was associated with increased lip strength ($r=0.60$, $p<0.05$) in the trumpet players but not in controls ($p>0.05$).

Cheek: The possibility of a difference in right and left cheek strength was examined. Although as individuals, trumpet players and controls varied between their right and left cheek strength by as much as 25% ($\Delta M=3.47$ kPa, SD 2.97, range 0–13 kPa), the difference was not significant within the trumpet playing group [$t(30)=1.00$, $p>0.05$], within the control group [$t(30)=0.45$, $p>0.05$], or within the pooled group [$t(62)=0.98$, $p>0.05$]. Therefore, maximum strength from the right and left cheeks was averaged within individuals to produce a single measure of cheek strength for each participant. As shown in Figure 2, trumpet players had greater cheek strength than the controls [$t(31)=2.65$, $p<0.05$]. Cheek endurance did not differ between trumpet players and controls. Cheek strength and

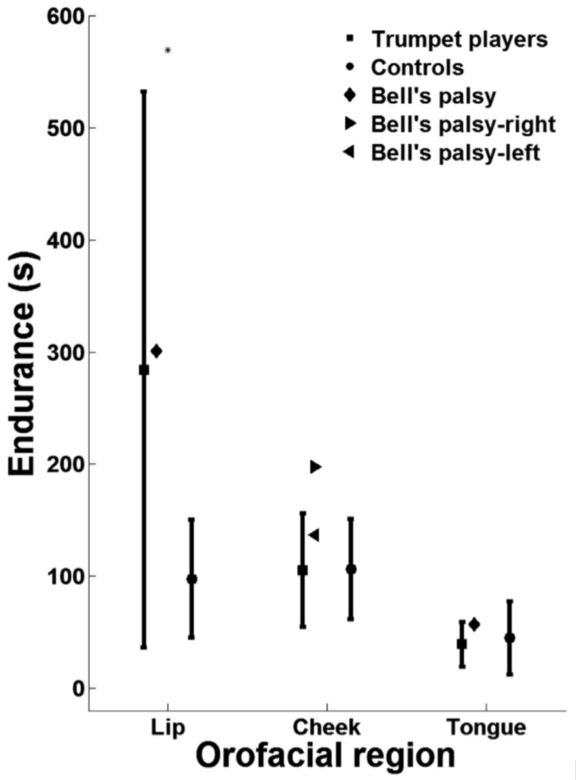

FIGURE 3. Endurance measurements for trumpet players, controls, and a trumpet player 25 yrs post-left-side Bell's palsy.

endurance did not differ by age between younger and older trumpet players or controls.

Tongue: Tongue strength and endurance did not differ between the trumpet players and controls. Tongue strength was negatively correlated with age across all participants (r=–0.37, p<0.05).

Practice Effects on Endurance

We tested whether there was an order effect in which earlier endurance tasks adversely affected later endurance performance in trumpet players and controls. The interdigitized lip and cheek muscles were not affected in the trumpet players (p>0.05), but following the cheek endurance tasks, there was a performance decline in lip endurance in the controls (r=–0.59, p>0.05).

Participant with Bell's Palsy

The trumpet player with a history of unilateral Bell's palsy demonstrated a 15% reduction in cheek strength on his affected side (right cheek = 42 kPa, left cheek = 36 kPa) and 31% reduction in endurance on his affected side (right cheek = 198 sec, left cheek = 137 sec). Evidence of contralateral variability in lip strength could not be determined because the measurement was taken in a central position. His tongue strength was within normal limits.

TABLE 2. Mean Strength and Endurance Measurements in Three Muscle Regions for Trumpet Players and Controls

	Cheek	Tongue	Lip
Mean strength, *kPa* (SD)			
Trumpet players	36.3 (7.8)†	63.8 (11.0)	19.6 (3.3)
Controls	29.6 (6.3)	58.5 (9.8)	20.2 (3.2)
Bell's palsy*	42 (R) 36 (L)	46	17
Mean endurance, *sec* (SD)			
Trumpet players	105 (51)	39 (20)	284 (248)†
Controls	106 (45)	35 (32)	98 (53)
Bell's palsy*	198 (R) 137 (L)	57	301

*Trumpet player post-left-sided Bell's palsy (L, left; R, right)
† p<0.05.

DISCUSSION

This study compared lip, cheek, and tongue strength and endurance measures of trumpet players and controls. We predicted that, compared to controls, trumpet players would demonstrate greater lip and cheek strength and increased endurance. We also predicted that trumpet players would demonstrate equivalent tongue strength with increased tongue endurance, as reported in previous work.[13] However, contrary to our predictions, trumpet players had increased lip endurance, but not greater lip strength; greater cheek strength, but not increased cheek endurance; and no difference in tongue strength or endurance compared to the controls. Interestingly, only the controls showed reduced lip endurance after fatiguing the interdigitized cheek muscles.

Lip

The results of the present study suggest that repetitive sustained contractions of the lips, associated with maintaining an embouchure to withstand high levels of pressure for extended periods of time, likely contribute to increased lip endurance. We found that lip strength was not different across the trumpet players and controls, but the trumpet players were able to sustain 50% of their maximum strength for nearly three times (290%) longer than the controls.

Lip endurance was influenced by lip strength for both groups. Greater strength pressures were sustained for shorter durations and lesser strength pressures were sustained for longer durations. Anecdotally, the trumpet player with the weakest observed lip strength (14 kPa) sustained 50% of his maximum lip strength for 1,000 seconds. Although he was stopped at the request of the examiner, he reported that he could have held this pressure indefinitely.

Cheek

We found trumpet players had greater cheek strength but not increased endurance compared to the controls. The trumpet players' greater cheek strength is likely a result of years of maintaining a strong embouchure. The lack of a difference in cheek endurance between the trumpet players and controls may have been a function of the method used for determining endurance. For the endurance measurement, pressure was held at 50% of the individual's maximum cheek strength. Therefore, the trumpet players had to maintain higher levels of pressure than the controls for the endurance task. The difference in the required pressure levels may have resulted in the shorter endurance measures observed in the trumpet players with the greatest cheek strength. This finding is consistent with previous studies reporting that participants have shorter endurance at higher levels of pressure.[12,13] Given the finding that trumpet players were able to maintain a greater pressure level for a comparable duration compared with the controls, it is likely that if the endurance measurements had been collected at a predetermined pressure independent of each individual's maximum strength, trumpet players may have shown greater endurance than the controls.

Tongue

Converging with previous studies, we found decreasing tongue strength with age in adults.[7] The older participants in both groups had decreased tongue strength compared to the younger participants. Robin et al.[13] found no difference in tongue strength but increased endurance in 12 trumpet players and 5 debaters, and thus we expected that trumpet players would have similar tongue strength but increased tongue endurance than controls. However, we found that tongue strength and endurance did not differ between the trumpet players and the controls. The difference between studies may be due to differences in instrumentation, as Robin et al. used an earlier model of the IOPI with a different bulb to assess strength and endurance, or due to relatively small sample sizes in both studies. Further research may clarify these conflicting findings.

Participant with Bell's Palsy

The participant with a history of Bell's palsy reported that his trumpet playing was impaired during the acute stage, but he was able to return to professional playing 5 yrs post-onset. He demonstrated a reduction in cheek strength and endurance on his affected side compared to his unaffected side. Interestingly, the differences between his right and left sides were comparable to the differences between right and left cheek strength in trumpet players without a history of facial nerve damage. During conversation, this individual had observably reduced functional range of motion in his lip and cheek on his affected side; however, on his orofacial structure-function exam, his maximum range of motion was symmetrical across sides. This finding could be accounted for with the phenomenon of learned non-use.[9] Learned non-use is characterized by a functional decrease in range of motion after the underlying problem is adequately resolved. It is likely that the trumpet player with Bell's palsy had become accustomed to limited movement on his affected side and this non-use continued after recovery. If lip strength had been measured on each side, differences may have been detected; however, in the present study lip strength was only taken in a central position for all participants. This participant reported that, his tongue deviated to the contralateral side during the acute stage of Bell's palsy. Tongue involvement has been reported in Bell's palsy but is not typically affected since motor control of the tongue is innervated by the hypoglossal nerve (cranial nerve XII), as opposed to the lip and cheek, which are innervated by the facial nerve (cranial nerve VII). This participant's tongue strength was less than that of the other trumpet players and controls but within the normal range for individuals his age.

Future Studies and Implications

Future studies measuring facial muscle endurance should consider using a set absolute pressure level independent of an individual's maximum strength. Based on the findings of the controls in the present study, 15 kPa for cheek and 30 kPa for lip are reasonable absolute pressure levels to use for endurance measurements in adults using the IOPI. In addition, future studies might consider a larger participant pool, including the middle age range not represented in this study.

Although all participants were provided with the same instructions and encouragement, it was apparent to the examiner (LJ) that some participants were more enthusiastic and competitive than others. It is possible that motivation to perform strength and endurance tasks or other individual differences could have contributed to individual variation in results.

Maintaining an embouchure sufficient for playing the trumpet requires sustained lip and cheek strength and endurance. Using objective measures, we found that trumpet players have greater cheek strength and increased lip endurance. We also found that the trumpet player with a history of Bell's palsy had average (±1 SD) bilateral cheek strength, lip strength, and cheek endurance on his affected side and increased cheek endurance on his non-affected compared to the other trumpet players. This raises the question of whether a functional activity such as trumpet playing could be utilized as a therapeutic activity for facial rehabilitation. Production of a musical tone could be explored as a form of biofeedback used to increase facial strength and endurance.

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