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To Play or Not to Play: Can an Instrument Really Impact Lip and Tongue Performance?

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Abstract: (1) Background: Increasing tongue and lip strength may help improve various speech and swallowing disorders, but it is unclear if instrumentalists who use these muscle groups for long periods of time have greater strength and endurance compared to controls. It is also unclear if instrumentalists can more accurately estimate various exercise intensities. The purpose of this study was to determine differences in lip and tongue strength and endurance between instrumentalists and non-instrumentalists (controls). A secondary purpose was to assess differences in ability to estimate various exercise intensities between the two groups. (2) Methods: Instrumentalists and controls' maximum strength and endurance were measured using the IOPI Pro medical device. In addition, 40%, 60% and 80% of maximum strength were estimated in a randomized order. (3) Results: No significant differences were found between instrumentalists and controls in strength or endurance or the ability to estimate various intensities. Overall, participants were better at estimating tongue strength at moderate intensities and lip strength at higher intensities. (4) Conclusion: Tongue and lip strength and endurance and the ability to estimate exercise intensities are not impacted by years of instrumentalist training compared to healthy controls.

Keywords: orofacial muscles; instrumentalists; exercise intensity

1. Introduction

The orofacial muscles are important for daily activities, such as swallowing, making facial expressions and speaking [1]. Some of the major orofacial muscles include the orbicularis oris superior, orbicularis oris inferior, buccinator, and risorius, which are vital for helping to keep food in the mouth, producing facial expressions and creating sounds [1]. The tongue is another orofacial muscle that is especially important as it plays a key role in swallowing. It helps propel food towards the oropharynx and begins the deglutition process of every bolus that is ingested [1]. However, for some individuals, these tasks are not so easy. With aging, there is a significant decline in swallowing ability and tongue strength [2]. In addition, some individuals who have had surgery for head and neck squamous cell carcinoma continue to have significant difficulties swallowing up to 5 years post-surgery [3].

While some individuals may experience declines in orofacial muscle function, one group of individuals who may be less likely to have such dysfunctions are instrumentalists. Instrumentalists such as brass and woodwind players use their orofacial muscles to alter airflow and thus produce various tones [4]. Some studies have demonstrated greater lip and tongue endurance for trumpet players. For example, one study noted that tongue endurance was greater in trumpet players and debaters when compared to a control group [5]. Another study demonstrated that there was no difference between trumpet players and control subjects for tongue strength or tongue endurance, but the authors did find a significant difference in lip endurance in trumpet players compared to control subjects [6]. Both studies suggest that instrumentalists may have improved tongue and/or lip endurance but the small number of studies and differences found between them makes the results uncertain at the moment.

In order to diminish orofacial muscular deficiencies, such as in swallowing, various studies have used tongue resistance training [7–9]. For example, a randomized controlled trial investigating the effect of three different resistive loads, i.e., 60%, 80%, and 100% of maximal tongue elevation strength, on tongue strength in healthy older adults showed that training-induced increases in the tongue strength were not different between the three groups [10]. Surprisingly, no other study has explored the difference in training effect due to different training conditions. Despite studies training the tongue and lips, there is not a consensus on the intensity, duration or frequency of what is needed to improve tongue and lip strength and endurance [11,12]. The ability to estimate different exercise intensities may be useful when prescribing exercises for individuals trying to strengthen their lip and tongue strength. Considering that the instrumentalist controls the activity of the lips and tongue during the playing of an instrument, it is plausible that instrumentalists may be able to estimate these different intensities better than non-instrumentalists. However, this has not yet been investigated.

The purpose of this study was to measure differences in (1) lip and tongue muscle strength and endurance and (2) ability to estimate various exercise intensities, between instrumentalists and non-instrumentalists (controls). Based on the study by Potter et al. [6], we hypothesized that instrumentalists would have similar tongue strength and endurance but that they would be able to estimate different intensities better than controls. We also hypothesized that instrumentalists' lip strength would not differ compared to controls but that their lip endurance would be greater and the ability to estimate different intensities would be better when compared to controls.

2. Materials and Methods

2.1. Participant Characteristics

Twenty-six college-age students (i.e., 6 males, 20 females) with ages ranging from 18 to 28 were separated and tested in two groups, instrumentalists (i.e., 2 males, 10 females) and controls (i.e., 4 males, 10 females). Age, body mass, height, and body mass index (BMI) were recorded for each participant. To qualify as an instrumentalist, a participant needed to have at least 6 years of experience playing a woodwind or brass instrument for at least 6 or more hours per week over the past year. Individuals who self-reported having never played a woodwind or brass instrument were classified as controls. Exclusion criteria consisted of a history of neurological impairment, a risk of having seizures, past or current problems with pain disorders involving jaw muscles of temporomandibular joints, and any facial surgeries within the last 6 months. This study was approved by the Institutional Review Board (IRB) of Brigham Young University, Idaho.

2.2. Study Design

The study was an observational case-control study [13]. Each participant had their maximum tongue and lip strength and endurance tested on two separate occasions. Participants' ability to estimate tongue and lip strength values at 40%, 60% and 80% of their maximum strength values were also measured. The first visit was used as a familiarization visit for the different protocols and the data on the second visit was used for analysis. The order of testing was the maximum strength of the tongue and then estimation of intensities for the tongue. After those tests, lip maximum strength testing was done followed by lip intensity estimations. The last tests were tongue endurance followed by lip endurance.

2.3. Tongue and Lip Strength

Tongue and lip strength were measured using an Iowa Oral Performance Instrument Pro (IOPI® Pro, IOPI Medical LLC, Redmond, WA, USA), tongue bulbs, connective tubing, and two wooden blades made from a ruler. Pressure placed on the bulb by the tongue and lips was measured in kilopascals (kPa) for each test and was used as a measurement of strength.

To measure the tongue strength, the bulb was placed in the mouth of the participant, against the hard palate, posterior to the alveolar ridge and compressed in an upward direction by the tongue. Participants pressed on the bulb exerting a maximal effort for 2–3 s. The participant performed 3 trials with a 30 s rest period between each trial. The administrator then recorded the value of each trial upon completion as well as the participant's peak value (the highest value of the three trials was considered the maximum voluntary contraction (MVC) value). Anterior tongue elevation test–retest reliability using the minimal difference has been reported to be 4.5 kPa [14]. Another study also reported that anterior tongue elevation strength test–rest reliability using the intraclass correlation coefficient (ICC) varied from 0.83 to 0.93 and the minimal difference varied from 3.96 to 6.41 kPa [15].

The strength of the lips was measured by placing the bulb between the two wooden blades [16]. The participant then clenched their teeth, puckered their lips, and placed the wooden blades and bulb between the midline of the lips far enough in to slightly touch the teeth. The participant was then told to exert as much pressure as possible on the wooden blades and bulb using only the lips, while keeping the teeth together, for 2–3 s. The participant then rested for 30 s. This was repeated two more times. The highest value was then used for data analysis. Lip compression strength test–retest reliability using the minimal difference has been reported to be 2.9 kPa [14].

2.4. Tongue and Lip Relative Strength Estimations

Estimated tongue and lip exertion was tested by having the participant try to produce a pressure that was equal to a percentage of 40%, 60%, and 80% of the previous determined peak pressure. In a randomly generated order, the patient was told which percentage to aim for. Each participant performed 3 trials for each intensity with each trial lasting 2–3 s. A 30-s rest period was given between each trial.

2.5. Tongue and Lip Endurance

Tongue endurance was measured by taking 50% of the participant's peak pressure value from the tongue strength test and inputting that data into the IOPI device as a target value. The patient placed the bulb on the hard palate and pressed up on the bulb with the tongue until the top green light was lit, indicating that the target pressure was reached. The participant held that set target pressure until volitional fatigue or until the pressure was not maintained at the target value for more than 2–3 s. The administrator recorded the time in minutes/seconds that the target value was maintained. Only one trial was performed for the endurance test. Tongue endurance test–retest reliability has been reported with ICCs varying from 0.47 to 0.56 and minimal differences varying from 12.63 to 13.47 s [15].

Lip endurance was measured using the same set up as described for the tongue endurance test. Previously determined max strength values were used to identify the participant's 50% max strength. That value was then inputted into the IOPI medical device. The participant was told to place the wooden blades and bulb between their lips and exert pressure until the top light on the device was turned on. The participant then exerted pressure on the bulb and the wooden blades and held that pressure until volitional failure or when the light remained off for 2–3 s. Only one endurance trial was performed.

2.6. Statistical Analysis

Results are expressed as means and standard deviations (SD) for all variables. Independent *t*-tests were used to calculate differences between instrumentalists and controls for tongue and lip strength and endurance. Normality was checked using Shapiro–Wilk analysis, and, if normality was violated, the Mann–Whitney independent samples *T*-test was used. Two-way repeated mixed-measures ANOVA (Group $\times$ Condition) was used to calculate if the ability to estimate different intensities was influenced by instrument playing. Mauchly's W test was used to check for sphericity and, if this was violated, a Greenhouse–Geisser correction was used to assess within-subject effects. The average of the recorded values for the three tries of each intensity was used for analysis. The difference from the average measured value and calculated value was used for analysis. For example, if the MVC was 60 kPa, the calculated value of 40% MVC would be 24 kPa. If the recorded value of the estimated intensity was 30 kPa, the difference would be 6 kPa, indicating that the intensity was overestimated by the participant. Holm's post-hoc tests were used if significant main effects were found.

Bland–Altman plots were used to determine the mean bias and lower and upper limits of agreement for estimations of different intensities. The difference between measured and calculated values was plotted on the y-axis, and the averages of the calculated and measured values were plotted on the x-axis. Lower and upper limits of agreement were calculated by multiplying 1.96 by the standard deviation of the differences and subtracting or adding from the mean difference. The statistical significance was set at an alpha of 0.05.

3. Results

3.1. Participant Characteristics

Instrumentalists had an average age of 22 (1) years, BMI of 27.4 (5.3) kg/m^2, and 9.9 (2.4) years playing their respective instruments and practiced on average 14.3 (6.2) hours per week. Controls had an average age of 22 (3) years and an average BMI of 27.6 (5.0) kg/m^2.

3.2. Tongue and Lip Strength and Endurance.

3.2.1. Tongue Strength and Endurance

- Tongue strength was not significantly different between instrumentalists and controls (59 (10.6) vs. 60 (8.4) kPa, $p = 0.785$).
- Tongue endurance was also not significantly different between instrumentalists and controls (40.1 (22.5) vs. 35.0 (18.2) seconds, $p = 0.494$).

3.2.2. Lip Strength and Endurance

- There was not significant difference between instrumentalists and controls for lip strength (28.0 (10) vs. 24.0 (5.9) kPa, $p = 0.380$) or lip endurance (118.7 (57.3) vs. 159.4 (99.7) seconds, $p = 0.225$).

3.3. Tongue Relative Strength Estimations

3.3.1. Tongue Relative Strength Differences

- The ability to estimate different tongue intensities was not impacted by instrumental ability (Condition*Group, $p = 0.941$). Neither was there a group main effect ($p = 0.544$). Table 1 shows the values for each group. However, a significant condition main effect was found such that the magnitude of differences from measured and calculated values varied based on intensity ($p < 0.001$).

Table 1. Tongue and lip estimated intensities. † $p < 0.05$ compared to the 40% differences for condition main effect. * $p < 0.05$ compared to the 80% differences for condition main effect.

	Control			Instrumentalist		
	Measured	**Calculated**	**Difference**	**Measured**	**Calculated**	**Difference**
Tongue Strength (kPa)						
40% MVC *	30.6 (8.4)	24.0 (3.4)	6.6 (6.8)	28.4 (9.0)	23.6 (4.2)	4.8 (7.9)
60% MVC *,†	35.9 (9.5)	36.0 (5.1)	−0.1 (7.4)	33.8 (11.3)	35.4 (6.4)	−1.6 (10.5)
80% MVC	45.5 (9.3)	48.0 (6.7)	−2.5 (6.1)	42.4 (10.6)	47.2 (8.5)	−4.8 (10.2)
Lip Strength (kPa)						
40% MVC *	12.9 (5.4)	9.6 (2.3)	3.3 (4.2)	15.0 (3.7)	11.2 (4.0)	3.8 (4.8)
60% MVC *,†	15.8 (6.3)	14.4 (3.5)	1.4 (4.4)	18.7 (3.5)	16.9 (6.0)	1.8 (6.0)
80% MVC	17.6 (5.6)	19.2 (4.7)	−1.9 (3.5)	21.4 (4.5)	22.5 (8.0)	−1.1 (9.6)

- Post-hoc analysis for the condition main effect revealed that the 40% differences (marginal mean: 5.8 kPa) were significantly different from the 60% (marginal mean: −0.8 kPa) and 80% (marginal mean: −3.6 kPa) intensities ($p < 0.001$, Figure 1). The 60% differences were also significantly different from the 80% differences ($p = 0.007$, Figure 1). Combing instrumentalist and control data, the mean difference for the 40% differences was 5.8 kPa, and the standard deviation was 7.3 kPa. The mean difference for the 60% differences was −0.8 kPa, and the standard deviation was 8.8 kPa. The mean difference for the 80% differences was −3.6, and the standard deviation was 8.1 kPa.

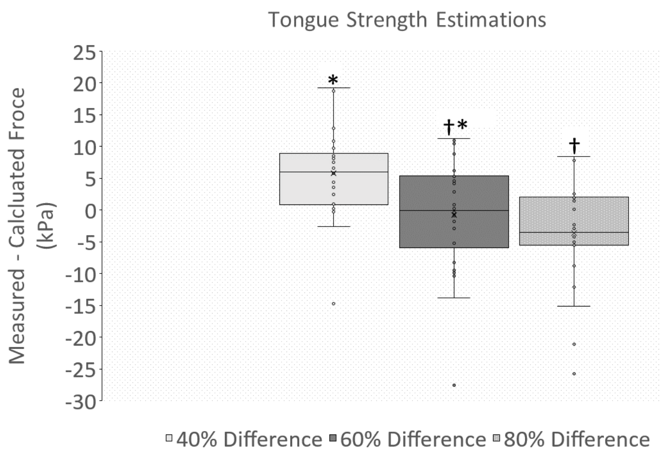

Figure 1. Calculated differences for exercise intensities for combined data of instrumentalists and controls. † $p < 0.05$ compared to the 40% differences. * $p < 0.05$ compared to the 80% differences. The upper bounds represent the upper (75th percentile + 1.5 * interquartile range) and lower (25th percentile—1.5 * interquartile range) quartiles.

3.3.2. Bland–Altman Plots

- Bland–Altman plots using pooled data revealed that the 40% intensities were overestimated by 5.77 kPa with the limits of agreement being −8.44 to 19.98 kPa (Figure 2).

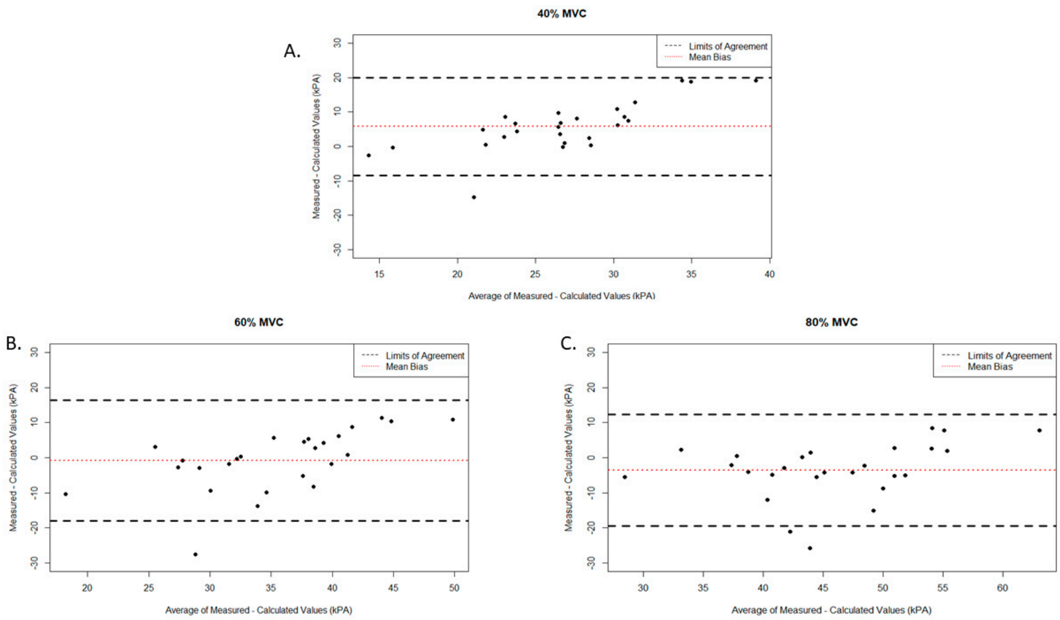

Figure 2. Bland–Altman plots of tongue intensity estimates. MVC = maximal voluntary isometric contraction. (**A**). 40% MVC; (**B**). 60% MVC; (**C**). 80% MVC.

- For 60% intensities, the mean bias was −0.81 kPa (limits of agreement: −18.06 to 16.43 kPa) and for 80% intensities, the mean bias was −3.59 kPa (limits of agreement: −19.54 to −13.85 kPa) (Figure 2).

3.4. Lip Relative Strength Estimations

3.4.1. Lip Relative Strength Differences

- Only a condition main effect was found for estimating lip strength intensities ($p = 0.001$). A group main effect was not found ($p = 0.800$). The difference between the calculated and measured values for 40% (marginal mean: 3.52 kPa) was statistically different compared to the 60% (marginal mean: 1.60 kPa, $p = 0.001$) and 80% (marginal mean: −1.50 kPa, $p < 0.001$) differences. The 60% difference was also significantly different from the 80% ($p < 0.001$) difference. Combing instrumentalist and control data, the mean difference for the 40% differences was 4.0 kPa, and the standard deviation was 3.8 kPa. The mean difference for the 60% differences was 2.3 kPa, and the standard deviation was 3.8 kPa. The mean difference for the 80% differences was −0.4, and the standard deviation was 3.6 kPa.

3.4.2. Bland–Altman Plots

- Bland–Altman plots using pooled data revealed that 40% and 60% intensities were on average overestimated (3.53 kPa and 1.61 kPa) while 80% intensities were underestimated (−1.51 kPa) (Figure 3).

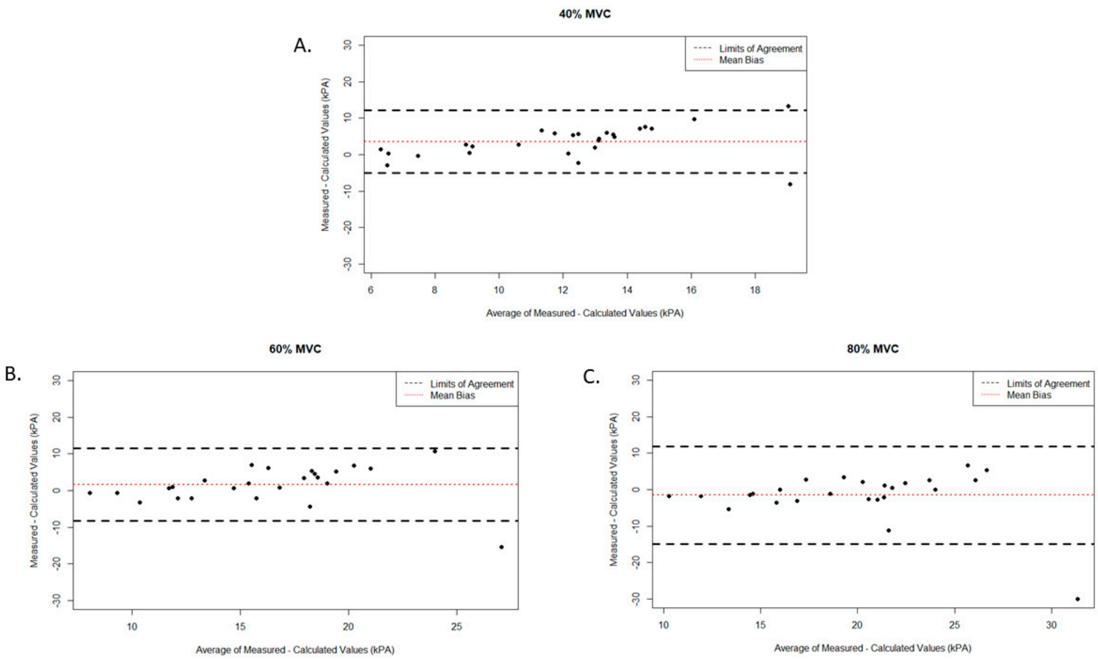

Figure 3. Bland–Altman plots of lip intensity estimates. MVC = maximal voluntary isometric contraction. (**A**). 40% MVC; (**B**). 60% MVC; (**C**). 80% MVC.

4. Discussion

In this study, we sought to determine if tongue and lip strength and endurance varied between instrumentalists and controls and if instrumentalists could better estimate various intensities. We hypothesized that instrumentalists would have similar tongue strength and endurance and better ability to estimate different strength intensities when compared to controls. We also hypothesized that instrumentalists' lip endurance would be greater and their ability to estimate different strength intensities would be better. Our hypotheses were partially supported, as our results demonstrate no difference in tongue strength and endurance between instrumentalists and controls. Additionally, our data revealed no difference in lip strength and endurance or ability to estimate various tongue and lip intensities between instrumentalists and controls. Although no group differences existed in ability to estimate tongue and lip intensities, collectively, our subjects were better at estimating certain percentages of lip and tongue strength; estimating tongue intensity at 60% produced the smallest mean bias while estimating lip intensity at 80% produced the smallest mean bias.

Instrumentalists use their tongue to adjust the airflow sent to their lips. As air passes by the lips, the lips vibrate, and instrument tones are produced. Alternating either the airflow or vibration of the lips by contracting the orofacial muscles can alter the tone produced by the instrument. In our current study, we failed to find a significant difference in instrumentalist tongue strength (59 vs. 60 kPa) or endurance (40 vs. 35 s) compared to controls. Our results were strikingly similar to Potter et al. [6], who found no difference in maximal tongue strength or endurance between 16 trumpet players and controls (Strength: 63.8 vs. 58.5 kPa, Endurance: 39 vs. 35 s). However, Robin et al. [5] noted greater tongue endurance in twelve trumpet players compared to controls. Their trumpet players had a mean age of 22 years and had been playing for at least 8 years. Our instrumentalists (trumpet, trombone, tuba, French horn and one flute player) had a mean age of 22 years and had an average of 10 years playing with roughly 14 h of practice a week. Similar devices and procedures were used for testing, so it is unclear why differences were seen between our study and the study by Robin et al. [5]. Part of the difference could be due to the various instruments used in this study. Based on our study and the study by Potter et al. [6], tongue training through playing an instrument over multiple years fails to produce significant differences in tongue strength and endurance compared to a control population.

Contrary to our hypothesis, we also failed to find differences in lip endurance. We originally hypothesized that lip endurance would be greater based on the many hours that instrumentalists practiced. However, the average endurance time for instrumentalists was 118 s, and for controls, it was 159 s. A previous investigation did find that lip endurance was greater in trumpet players compared to controls. The average endurance time for trumpet players was 284 s and 98 s for controls [6]. In that study, trumpet players had a mean playing experience of 19 years, which was considerably higher than the 10 years of playing by our instrumentalists. It may be possible that longer periods of training are needed for endurance to start to differ from healthy controls. Another factor that could be influencing the results is that 50% of the MVC was used but the absolute value used would be higher for those with stronger lips, resulting in shorter endurance times. Indeed, a significant inverse correlation was found between max lip strength and tongue endurance ($r = -0.41$, $p = 0.036$) in the current study. Potter et al. [6] also found a similar negative correlation ($r = -0.45$), and one trumpet player in their study sustained their lip endurance for over 1000 s and had a maximum lip strength of only 14 kPa. Therefore, when using 50% MVC, lip strength may have a large influence on endurance performance.

When it comes to having the ability to estimate different tongue and lip intensities, no other studies have examined this. We did not find a difference between groups, but several studies examining electromyography (EMG) amplitudes of the orofacial muscles may help explain this. For example, one study compared the muscle EMG amplitude of the lower and upper lips during chewing and speaking activities for trumpeters vs. controls and found no difference between them [17]. It is possible that, despite instrumentalists needing to finely adjust orofacial muscle activation, it is not manifest when trying to estimate percentages of a max intensity. This could be partially due to the EMG amplitude of orofacial muscles being considerably lower compared to the possible maximum EMG amplitude that could be produced. For example, trumpet players' masseter and temporalis muscles only reach EMG amplitudes of 10 and 6% of their maximum capacity when they are playing high-pitched tones [18]. Therefore, it is possible that high levels of activation are not necessarily used in some muscles when playing these instruments, which may explain why they were not necessarily better at estimating relative strength outputs compared to controls.

When both instrumentalists and control data were combined to examine the ability to estimate various intensities, some interesting results were found. For the tongue relative strength estimations, individuals tended to overestimate values when trying to produce a strength equivalent to 40% MVC, while for the 80% intensity they tended to underestimate values. The least amount of error was found at 60% MVC. It appears that the ability to estimate a moderate intensity produces a smaller mean bias than low or high intensities for individuals. For lips, 40% and 60% intensities were overestimated, while the 80% intensity was only underestimated by −1.5 kPa. The lip muscles appear to more accurately estimate higher intensities than lower intensities.

The reason(s) for the phenomenon described above is not clear in this study. However, the ability to accurately adjust pressure produced by the lips and tongue is likely influenced by multiple muscle groups, making it more of a challenge to estimate various intensities. For instance, the anterior tongue elevation pressure is produced through intrinsic (superior longitudinal, inferior longitudinal, vertical and transverse muscles) and extrinsic (genioglossus, geniohyoid, suprahyoid, infrahyoid muscles) muscles, which are mainly innervated by the hypoglossal nerve. When measuring changes in suprahyoid and infrahyoid muscle EMG amplitudes between 80% and 100% of maximum anterior tongue pressure, a significant difference was found but no significant changes in vertical movement were seen, suggesting that these extrinsic muscles are important when trying to produce various intensities [19]. The major muscles involved with lip closure pressure are the orbicularis oris muscles, but others include the buccinator and risorius muscles, all of which are innervated by the facial nerve. The muscles used in playing instruments may not be accustomed to exerting the pressures used in this study, making it a novel stimulus for them and thus decreasing the ability to more accurately estimate various intensities. This may also explain the large variability found in the study for estimating various intensities. Due to the sparsity of literature systematically investigating the optimal intensity and repetitions needed to improve tongue and lip strength and endurance, it is unknown how much variability might be acceptable if only estimates of intensity were used for training [12]. Further, more studies are needed to examine how reliable the measurement is for estimating different tongue and lip exercise intensities.

5. Conclusions

In conclusion, tongue and lip strength and endurance are not impacted by years of instrumentalist training compared to healthy controls. In addition, the ability to estimate different relative intensities does not differ between instrumentalists and controls. However, moderate intensities are better estimated with the tongue, while higher intensities are better estimated by the lips. Future studies need to systematically investigate what intensity is optimal for tongue and lip training and determine if estimating intensities for training would be appropriate.

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