French horn embouchure:
An electromyographic facial kinematic study

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This study investigated embouchure-related muscle activities and related facial skin movement in trained French horn players. In relation to pitch and intensity of tone produced, amplitude of surface electromyogram (EMG) from five selected facial muscles and related facial skin kinematics were examined during pre- and post-attack phases. There was no difference in EMGs and facial kinematics between these two phases, indicating importance of appropriate preparation for embouchure formation. EMGs in all muscles increased linearly with an increase in pitch, and they also increased with tone intensity without interacting with the pitch effect. Facial skin movement remained constant across all pitches and intensities, except for lateral retraction of the lips during high-pitch tone production. These findings indicate that contraction of the embouchure-related muscles is fundamentally isometric for flexible sound parameters in order to modulate lip tension and firmness. Horn players seem to have developed a specialized ability to precisely balance facial muscle contraction with inter-oral pressure.

Keywords: French horn; embouchure; EMG; skin movement; pitch

Human facial muscles are basically built and developed for speech, mastication, and expressing affections and emotions. The same muscles also play a vital role in singing and playing musical instruments. While playing a brass instrument, muscles located in the middle-to-lower front of the face, throat, and tongue act together to form a playing-related face/lip configuration adjusting to the mouth piece: the so-called “embouchure.” There have been
some attempts to study the functional role of the embouchure-related muscles (Heuser and McNitt-Gray 1991, White and Basmajian 1973). Unfortunately, only qualitative electromyographic (EMG) data were dealt with in these studies, and thus, there was no statistical testing of the results. Quantitative EMG data prior to the tone commencement and during the tone production could explain the control of muscular tension for pitch and intensity modulations. Additionally, information on accompanying skin movement during embouchure formation is also lacking. The purpose of the study, therefore, was to investigate the effects of pitch and intensity on facial muscle activity and facial skin movement during two phases of sound production: prior to tone commencement and during the tone production.

**METHOD**

**Participants**

Thirteen trained French horn players (mean age=23.2 years) with more than 7 years of horn training each served as participants.

**Materials**

Using his/her own French horn with the mouthpiece, each participant performed four sets of three successive 6 second sustained tone productions at different levels of sound intensity (pp, mf, and ff) twice. Each set had a target pitch randomly selected from Bb1, F3, F4, and Bb4 tones. Surface EMG signals from the levator labii superioris (LLS), depressor anguli oris (DAO), zygomaticus major (ZYG), risorius (RIS), levator labii superioris (LLS), and depressor labii inferioris (DLI) muscles on the right side of the player’s face were collected using an 8-channel EMG recording system (x 500) and PC sampling at 1 kHz. For the kinematics of the facial skin, 1 mm diameter reflecting markers were attached to the skin over each of the target muscles on the left side of the face (see Figure 1).

**Procedure**

Two high-speed digital cameras (sample frequency=50 Hz) were used to record movements of these markers during the experimental tasks. A sound signal was collected simultaneously with the EMG using a sound-level-meter mounted on a wooden frame attached to the side of the horn bell. The mean value of the EMG, the kinematic data for the duration of 375 ms prior to the onset of sound production (the “pre-attack phase” in Figure 2) and 750 ms 3
Figure 1. EMG electrode and facial marker placement. EMG electrodes were attached on the right side of the face, and kinematic markers were attached on the left side. Marker-to-marker distance for each muscle: a=LLS, b=ZYG, c=RIS, d=DAO, e=DLI.

Figure 2. A representative time-history curve of rectified sound and EMG signals for the five muscles examined during Bb4 tone (466 Hz) with ff production task in one participant.

seconds after the onset of sound production (the “sustained phase” in Figure 2) were computed.

RESULTS

Bursts of EMG in all muscles commonly started about 750 ms before the tone commencement (Figure 2). For example, the mean values of the pre-attack activity duration for DLI at pp, mf, and ff were $760 \pm 56$, $723 \pm 108$, and $766 \pm 189$ ms, respectively. The activity reached a sustained level before the tone commencement, and this pre-activity was also clearly intensity-dependent. EMGs indicated that all muscles examined participated in embouchure formation. MANOVA performed on the EMG data revealed significant main
effects of intensity (p<0.001) and pitch (p<0.001). The phase effect and all of
the interaction effects were non-significant. Post hoc univariate tests for each
muscle revealed a main effect of intensity for ZYG, DAO, LLS, DLI, and RIS
(see Figure 3). Univariate tests also revealed a significant pitch effect for ZYG,
DAO, DLI, and RIS. MANOVA on the distance in ten participants revealed a
significant main effect of pitch (p=0.032). Univariate tests for each muscle
revealed a significant pitch effect only for the markers placed on RIS, which
decreased from 92% at Bb1 to 86% at Bb4. The markers placed on LLS and
DLI showed elongations by a few percent across all levels of pitch, whereas
those on ZYG and DAO showed shortening on average to 95% and 91%, re-
respectively.

**DISCUSSION**

The present findings confirmed that pre-attack setting of muscular activity
and accomplished skin movement were equivalent to those used during ac-
tual production of a tone at varied pitches and intensities. A sound error
commonly committed by brass players is unintended pitch at tone com-
mencement, known as an “off-pitch” tone attack. Successful tone production
at the intended pitch requires brass players to set their lip tension properly by
moving the lips toward their teeth. The proper lip tension is accomplished
mainly by contraction of the orbicular oris muscle, while pulling the lips lat-
erally using the groups of perioral facial muscles. This phenomenon can ex-
plain the clear pitch-related preparatory activations of the ZYG, DAO, DLI,
and RIS in the present study. Findings of a previous study (Fletcher & Tarno-
polsky 1999) indicated that the threshold of blowing pressure (BP) required
for tone commencement increased in proportion to the pitch. In the present
study, the facial kinematic analysis indicated that none of the muscles were
lengthened during preparation for tone production at a higher pitch. There-
forer, the pitch-related increase in facial muscle activity can also be explained
by pre-attack elevation of muscular tension in order to stiffen the wall of the
oral cavity to cope with preparatory increased BP. Related to the facial kine-
matics, the skin over the RIS was shortened in parallel with increased mus-
cular activation during the higher pitch preparation. The present study con-
forced that tone intensity is also a preparatory parameter of embouchure
muscles. The kinematic analysis of the facial markers further indicated no
intensity-related change for all muscles examined. Common problems associ-
ated with intensity control among less experienced players are production of
sound error, such as an unintended explosive attacking tone for an expected
soft tone, and a delayed tone commencement in a high-intensity range. These
Figure 3. The mean and SD (vertical bars) values of EMG for ZYG, DAO, and LLS at pp, mf, and ff for the pre-attack (□) and sustained (■) phases.

Figure 4. SPL-dependent changes in mean EMG for the RIS muscle. EMG values are shown in a logarithmic scale.

could occur if the prepared embouchure setting and the BP were mismatched. Isometric pre-attack muscular activity that was modulated with the level of BP was thus expected prior to tone commencement. In agreement with this hypothesis, all muscles examined in the present study showed an intensity-dependent change in pre-attack facial muscle activity.

Pitch and intensity independently influenced the level of muscular activity during the sound-sustained phase. There was also no pitch- or intensity-dependent modulation in the marker-to-marker distance, except for the RIS during pitch control, indicating that tone production at a higher pitch or louder intensity demands stronger isometric contraction of embouchure muscles. The level of isometric EMG activation has been known to be approximately proportional to tension developed in the muscles. Our data suggested that the relationship between tension developed in the perioral facial muscles and resonance frequency (RF) of the lips during the current sus-
tained tone production could also be proportional. According to Fletcher and Tarnopolsky (1999) the brass player’s lips act as an acoustic generator within a narrow frequency band quite close to their natural mechanical RF, which can be simulated fundamentally by a simple mass-spring model. The RF of the player’s lips may then be expressed by a simplified model as $RF = (MT/EM)^{1/2}$, where MT is tension of the lip and EM is effective (vibrating) mass. Elliott and Bowsher (1982) deduced that lip mass is inversely proportional to the vibrating frequency, by taking measurements of the mouthpiece pressure while producing various tones at different pitches, estimated average volume flows, and average opening of the lips. It can then be hypothesized that RF of the player’s lips is modulated in proportion to MT (Fletcher and Tarnoplosky 1999). The findings of the present study indicated that this relationship was reasonable within the range of tones examined. Intensity of a tone produced is adjusted by changing the rate of air volume blown into the instrument and a corresponding change in BP. The louder the tone is, therefore, the greater the airflow rate and BP at any pitch. Fletcher and Tarnoplosky (1999) demonstrated that the intensity-related increase in BP became stronger during the production of higher pitch, which was also the case in our EMG-SPL relationship (see RIS in Figure 4). Consequently, our EMG data suggests that embouchure muscular tension is also involved in the respiratory function required for the adjustment of tone intensity. Since the present kinematic data showed no intensity-related skin movement, it is most likely that the muscular tension is used for resisting increased BP in order to sustain a constant orofacial posture across all intensities.

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