Article

Effect of Expiratory Muscle Strength Training on the Performance of Professional Male Trumpet Players

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BACKGROUND: Many trumpet players use breathing training devices in addition to their daily practice routine. Playing a brass instrument requires, besides many other skills, a controlled air stream to generate the necessary air pressures. On the trumpet, high intraoral pressures are needed, especially during high and loud notes. Therefore, it is not uncommon in trumpet pedagogy to teach that the use of breathing training devices enhances physical strength so that the required pressures can be produced with less effort. However, to date, no systematic assessment of the use of breathing training devices among trumpet players exists and their effect on playing performance is still unclear. **METHODS:** In this a pre-post, within-subject repeated measure study, we investigated the influence of a 5-week expiratory muscle strength training (EMST) upon trumpet performance. Twenty-four male professional trumpet players were allocated to either a control or intervention group. The intervention group (n =13) trained with an EMST device against a set resistance of 55% of their maximum expiratory pressure (MEP) for 5 weeks on 5 days per week. The control group (n =11) did no intervention. All participants underwent the same measures (MEP and rate of perceived exertion [RPE]) and played the same tasks (maximum long note, maximum high note, maximum dynamics and phrasing in high register) prior to and after the 5 weeks. **RESULTS:** After EMST, MEP increased significantly (13%, p = 0.049) in the intervention group, whereas no significant change was found in the control group. Performance parameters did not change in either of the groups, also after EMST. Despite the increase in MEP, we found no evidence that EMST has an influence on trumpet performance. **CONCLUSION:** We conclude that EMST seems unnecessary for the enhancement of trumpet playing, at least in a population of male professionals who already demonstrate excellent respiratory condition and control. *Med Probl Perform Art* 2024;39(1):18–26.

KEYWORDS: expiratory muscle strength training, music, music physiology, trumpet, wind instrument

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THE TRUMPET is considered a low-airflow / high-pressure instrument with high intraoral and intrapleural pressures during high and loud notes and a generally low airflow (1,2). In trumpet pedagogy, the relation between airflow and pressure to produce a sound is discussed extensively. Many teachers recommend specific breathing exercises for wind-instrumentalists in their lessons, but at the same time there is not much evidence that these exercises are effective (3).

Respiratory function among wind instrumentalists has been investigated for several decades, however, with inconclusive results (4–7). The interrelation between airflow and pressure has been studied extensively by Bouhuys in the 1960s. Further research has been conducted by Fuks and Sundberg (1996) (8), Fletcher and Tarnopolsky (1999) (9), Schwab and Schultze-Florey (2004) (1), Huber (2007) (2), Fréour et al. (2010) (10), and Fréour (2013) (11). Mean playing pressure and maximum pressure among the different wind instruments can be measured in different playing tasks (1). However, due to variable conditions during playing, studies on flow and pressure report inconsistent results even for one individual instrument. Despite varying results, researchers agree on the increase of flow and pressure with rising dynamics and pitch. This applies to all wind instruments except the clarinet, where pressure rises in the low register compared to higher notes (12).

On the trumpet, intraoral pressure can reach a maximum of up to 254 cmH_2O [~24 kPa] (9) and 258 cmH_2O [~25 kPA] (1). Trumpet players need many years of practice to develop an effective technique to produce these pressures. Without an optimal control, sound quality may be unprofessional with a high range restricted, which may also lead to lip and muscle fatigue (13).

Breathing training devices are commonly used in musical communities to enhance breathing. Originally developed for patients with pulmonary or neurodegenerative diseases, exercising with a breathing training device can improve inspiration, expiration, airflow, and strength of respiratory muscles (14). Trumpet players use different kinds of breathing training devices to enhance the above-mentioned factors. However, the type of device, training regimens, intensity and resistance have only been evaluated for patients and athletes so far (15–17). Some studies have described the effect of expiratory muscle strength training (EMST) on maximum expiratory pressure (MEP) among wind instrumentalists (18–20), but only two of them investigated the direct relation of EMST to playing performance (19,20). Woodberry et al. (19) only found a significant impact of EMST on loudness in high and low tone production in general. Dries et al. (20) found changes in flow rates, which led to changes in timbre and sound. However, in Woodberry at al. (19), only one participant played the trumpet and Dries et al. (20) focused on saxophone players. Therefore, these results cannot be used to answer our research question regarding the effect of EMST on professional trumpet players' performance.

In order to play at a professional top level, trumpet players need to control the constant high pressure required to produce the desired sound in a reliable, reproducible, and consistent way. We hypothesized that a specific breathing training (EMST) can improve the players' MEP as well as their performance, measured as length of a given note, highest possible note played, loudest possible dynamic played, and rate of perceived exertion (RPE) in a given phrase.

METHODS

Participants

Twenty-four male trumpet players between the ages of 20 and 45 years took part in the study. Because of the "high-end-performance" playing tasks, only professional or very advanced players were included. In order to have a group with comparable physiological factors, age was restricted to 20 to 45 years. Lung volumes and measures of breathing parameters clearly differ in different phases of life, so that values of a 20-year-old person cannot be compared to those of a 60-year-old (21–23).

Exclusion criteria were untreated chronic respiratory diseases, acute respiratory problems, high blood pressure, structural abnormalities of the heart, structural changes of the lung, high eye pressure, hernia, disc prolapse, neurological disorders that worsen due to high pressure and deep breathing, vertigo, esophagus fold insufficiency, current surgery, regular intake of blood-thinning medication, and use of other breathing devices during the time of the study.

Gender was limited to male gender as respiratory values differ considerably between men and women (21). Investigating both male and female players without having a similar percentage of each gender would have resulted in improper matching in and between groups. While the tradition of the instrument still results in a rather low percentage of professional female trumpet players, in order to report on both genders equitably, another study will be conducted with female players in the future.

TABLE 1. Descriptive Values of Study Participants (*n*=24).

	Intervention	Control
No. in groups	13	11
Age (yrs)		
Mean (SD)	27.2 (7.7)	26.3 (6.9)
Min – max	20 – 45	20 – 40
Height (cm), mean (SD)	183.5 (6.6)	179.9 (5.6)
Weight (kg), mean (SD)	91.5 (21.9)	76.6 (10.7)
BMI, mean (SD)	27.1 (6.2)	23.6 (3.0)
Vital capacity (L), mean (SD)	5.7 (0.7)	5.3 (0.5)

All participants were high-level male trumpet professionals.

Ethical approval was given by the ethics committee of the University of Music and Performing Arts Vienna (case no. 02/2016). All participants received thorough information about the procedures in this study and gave their written consent.

A priori sample size was calculated with 24 participants, using G* Power, an effect size of 0.3, α err prob of 0.05, power (1–β err prob) of 0.08 and ANOVA repeated measures, within-between interaction. Participants' allocation to intervention or control group was calculated with statistical program R 3.5.0 GUI 1.70. There were no drop-outs among the participants. Participants' characteristics in and between the two groups are presented in Table 1.

Study Design and Outcome Measures

The study was designed as a pre-post, within-subject repeated measure study. Initial measures of all outcomes for both groups were taken at the beginning of the study. This initial measurement was followed by a 5-week intervention (EMST) for the intervention group and no intervention for the control group. After 5 weeks, all outcomes were measured again in both groups in a final measurement.

During both the initial and final measurements, the following outcomes were collected: length of tone (L), pitch (P), sound pressure level/intensity (SPL), rate of perceived exertion (RPE), and maximum expiratory pressure (MEP). Vital capacity (VC) was only measured at the final measurement. Except for MEP and VC, all outcomes were collected while the participants played standardized tasks. Of all outcomes, MEP was the only one to be measured every week, whereby these weekly measurements were used to adjust the training resistance for the EMST at 55-60% of each participant current MEP value.

A player's form, which can vary over time, significantly impacts the performance especially in tasks at a "high-end" level. Therefore, great care was taken that the final measurements took place at the same time of the day (morning, afternoon or evening) as the initial measure-

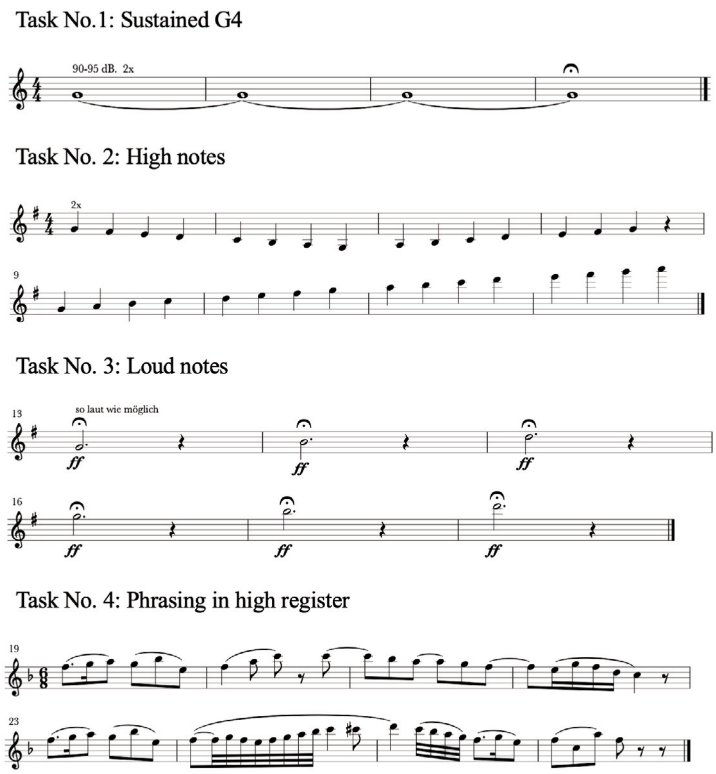

FIGURE 1. Four tasks were played for the performance tests pre and post the intervention training: 1) a sustained note to be played as long as possible; 2) a G major scale up to the maximal note that can be played; 3) notes to be played as loud as possible (*ff-ffff*); 4) a difficult transposed theme of the Haydn trumpet concerto.

ments. The participants also had to play standing during all tasks and measurements (24). Furthermore, it was important that participants followed the same schedule with the same amount of playing (or no playing) both on the days of the final and the initial measurements.

Blinding of participants and researcher was not possible. The participants of the intervention group were informed that they were performing a breathing training. To increase adherence and ensure that practice habits did not change during the time of the study, all participants of both groups filled out a daily practice diary.

Experimental Setup

Assessment tools included Audacity software version 2.1 for recording of sound parameters (L, P and SPL/intensity), Borg scale for RPE, and a calibrated portable desktop spirometer (model PONY FX MIP/MEP by Cosmed Srl [Rome, Italy] with accompanying Omnia© software ver. 1.4.2) for lung function measurements MEP and VC. All playing tasks were recorded with a Røde NT USB microphone (Røde Microphones, Silverwater, NSW, Australia) and Audacity software at the same gain level for all measurements.

Playing Tasks and Sound Recording Analyses

Before starting the playing tasks, all participants had the opportunity to warm up according to their individual warm-up habits. All participants played the tasks on their own trumpet and mouthpiece.

The subjects performed the following playing tasks: a long *mf* G4 (task no. 1), a G major scale up to the individually highest possible note (task no. 2), loudest possible note (task no. 3), and a melody in the upper register (task no. 4) (Fig. 1).

Recordings of playing tasks no. 1–3 were analyzed with the software Praat, version 6.0.29. Praat was developed for scientific analyses of speech, but can also be used for analyses of sound, as it shows the exact pitch and dynamics of tones as well as their spectrums. Tones had to be stable in terms of intonation and tone spectrum in order to be included in the analysis. Fluctuations of more than a quarter tone in intonation and lack of overtones are well visible in Praat, so that tones with these characteristics were not used for the analyses, as they would also not be labeled "musically useful" in classical music. The researcher, who is also a professional musician, listened to the tones and included only those tones which met the objective criteria made visible by Praat.

For task no. 1, subjects were told to play a G4 (392 Hz) as long as possible while keeping the dynamics between 90 and 95 dB(A), which they could monitor on the SPL meter display. A G4 at 90 to 95 dB(A) on the SPL meter sounded *mf* in the examination room. For a professional trumpet player, playing a *mf* G4 is comfortable. The goal of this task was to check the players' airflow and embouchure control, i.e., how they used their air in order to play as long and as stable as possible.

For task no. 2, subjects were asked to play a non-legato G-major scale starting from G4 down to G3 and then up to as high as possible. The goal was to determine the highest note the player could play on that day.

For task no. 3, subjects were told to play the individual tones of a G-major triad (G4 392 Hz, B4 494 Hz, D5 587 Hz, G5 784 Hz, B5 988 Hz, and D6 1175 Hz) as loud as possible for 3 to 4 seconds. The goal was to determine the highest intensity (measured in dB(A)), i.e., the loudest the player could play on that day.

For task no. 4, subjects were asked to play the first eight bars of a well-known score among professional trumpet players, the second movement of Haydn's trumpet concerto, transposed an octave higher. The goal of this task was to investigate the subjective level of effort or RPE during musical playing by using the Borg scale. The Borg scale was chosen for its reliability to measure fatigue (25) and its ability to indicate physical load (26). On a scale from 6 to 20, represented in colors, words and numbers, participants rated their subjective effort of playing task no. 4.

MEP Measurements

MEP and VC were measured with a desktop calibrated spirometer in compliance with the guidelines of the American Thoracic Society (ATS) and the European Respiratory Society (ERS) (27). To obtain MEP, subjects inhaled to total lung capacity and then exhaled into the device against the resistance of the pressure transducer as forcefully as possible. The maximum push had to be held for 1 to 2 seconds in order to count. Three repetitions, with breaks of 30 to 60 seconds between maneuvers, were executed. The highest value was taken for statistics. VC was collected to ensure that no participant showed abnormal values in comparison to reference values regarding gender, age, height and weight.

Intervention

The intervention consisted of a strength training of the expiratory muscles (EMST), executed with the EMST150© device (Aspire Products LLC, Cedar Point, NC, USA). The EMST150© is a calibrated, one-way, spring-loaded valve in which the participant blows into as hard as possible (28). All participants received their own EMST150© device and trained individually at home five times a week for 5 weeks. The days with no training were chosen individually by each of the participants and this was documented in their practice and exercise diary.

Based on previous studies (14), the resistance of the EMST150© device was set at 55-60% of MEP and 25 repetitions in five sets of five repetitions, with a break of 15 seconds between repetitions and a break of 1 minute between sets. The resistance level was chosen in order to train in a way that is as close as possible to blowing into the trumpet, which considers the aspect of specificity of training (28). Furthermore, the resistance level had to be in accordance with the general rules of strength training to lead to an increase in power and hypertrophy of the muscles trained (29).

The resistance of the EMST150© device was adjusted weekly to the measured at MEP, so the targeted 55–60% of MEP would be reached during the following individual training sessions. At the weekly appointments, the researcher also controlled that EMST was executed correctly.

Practice and Exercise Diary

All participants filled out a daily practice and exercise diary to document the daily amount of practice in hours, the type of instrumental exercises that had been practiced and whether the subjects of the intervention group did their breathing training or not.

Data Analysis

Data from the pre- and post-intervention measurements were analyzed. Changes over time (pre vs post) were calculated with 2-factor ANOVA. Differences between groups at T1 and at T6 were calculated with *t*-test. Data were metric per definition and normally distributed. Significance was set at $p < 0.05$. Statistical program R 3.5.0 GUI 1.70 was used.

RESULTS

Demographics and Adherence

The 11 participants of the control group (A) had a mean age of 26.3 yrs (SD 6.9) compared to the 13 participants in the intervention group (B) with a mean age of 27.2 yrs (7.7). Adherence to EMST in the intervention group was 100% with an average number of training sessions of 23 times. For both groups, the adherence to measurement appointments was 100% for pre- and post-intervention measurements and 92% for the weekly measurements. There were no dropouts.

No significant difference was detected in the amount of time the members of each of the two groups spent playing their instrument ($p = 0.381$). Participants of the control group (A) played for a total of mean 80.3 hrs (29.2), whereas participants of the intervention group (B) played for a total of mean 93.5 hrs (40.9) during the 5 weeks of the study. This is an average playing time of approximately 2.3 – 2.7 hours per day.

MEP

MEP values from pre- and post-intervention within and between groups were used. MEP measurements of Group A (control) at pre-intervention were mean 212 cmH_2O (SD 37), while group B (intervention) participants' measures were mean 213 cmH_2O (35), showing no significant difference ($p = 0.965$) between the two groups. The comparison

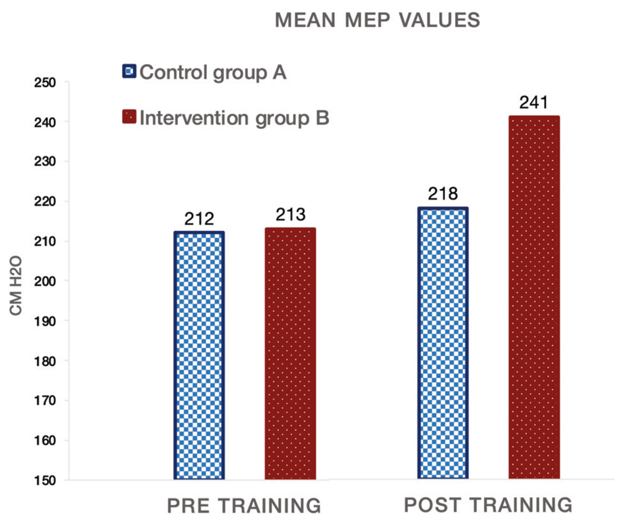

FIGURE 2. Mean values of MEP in groups A (control) and B (intervention) pre and post 5 weeks of EMST.

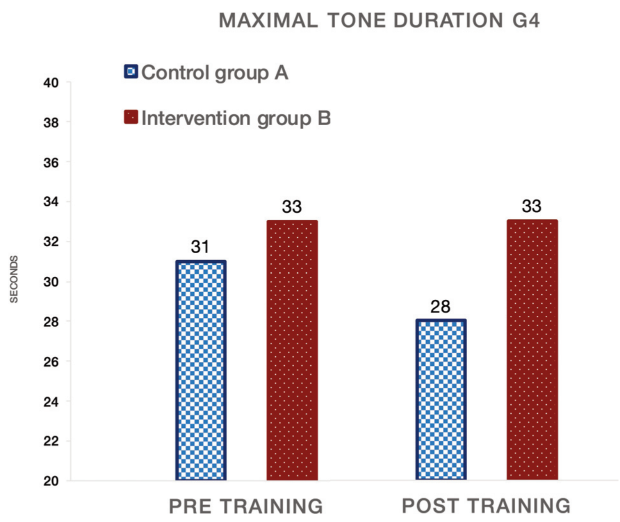

FIGURE 3. Mean of the maximal length in seconds to play a G4 in *mf* (90–95 dB(A) in 50 cm distance) pre and post 5 weeks of EMST.

between the two groups after the intervention was also not significant (p=0.115). After EMST, control group A reached a mean 218 cmH_2O (34) with no significant change (p = 0.697) to pre-EMST, whereas group B increased their MEP significantly to mean 241 cmH_2O (34) (p = 0.049) (Fig. 2).

Performance

Length of G4

Participants of the intervention group B maintained the same maximal length when playing a G4 after the 5 weeks, while for the control group A, the mean length decreased by 3 seconds. Group A pre: mean length 31.34 sec (SD 5.68), Cl. mean 3.82. Group A post: mean length 28.13 sec (5.23), Cl. mean 3.51, p = 0.1845. Group B pre: mean length 33.00 sec (8.21), Cl. mean 4.96. Group B post: mean length 32.84 sec (7.08), Cl. mean 4.28, p= 0.9506 (Fig. 3).

Maximal Intensities (Loud Notes) of G4, B4, D5, G5, B5 and D6

Mean values of the maximal intensity (how loud one can play in dB(A)) of the six selected isolated notes (G4 392 Hz, B4 494Hz, D5 587 Hz, G5 784 Hz, B5 988 Hz, and D6 1175 Hz) did not change significantly over time, in or between groups. Differences, if existent, were plus or minus 1 decibel maximum, which is within measuring tolerance and cannot be accounted as an actual difference in dynamics.

Group A pre: PowG4 mean 81.49 dB (SD 1.62), Cl. mean 1.09. PowB4 mean 82.22 dB (1.43), Cl. mean 0.06. PowD5 mean 82.52 dB (1.29), Cl. mean 0.87. PowG5 mean 83.17 dB (1.30), Cl. mean 0.87. PowB5 mean 81.68 dB (2.07), Cl. mean 1.39. PowD6 mean 81.71 dB (2.63), Cl. mean 1.77.

Group A post: PowG4 mean 80.59 dB (SD 1.39), Cl. mean 0.93. PowB4 mean 81.15 dB (1.87), Cl. mean 1.26. PowD5 mean 81.69 dB (1.39), Cl. mean 0.94. PowG5 mean 83.15 dB (1.80), Cl. mean 1.21. PowB5 mean 81.05 dB (2.20), Cl. mean 1.48. PowD6 mean 81.08 dB (2.68), Cl. mean 1.80.

p-Values group A: G4 p = 0.1762, B4 p = 0.1446, D5 p = 0.1623, G5 p = 0.9775, B5 p = 0.4931, D6 p = 0.5828.

Group B pre: PowG4 mean 81.41 dB (SD 2.01), Cl. mean 1.22. PowB4 mean 82.22 dB (2.26), Cl. mean 1.36. PowD5 mean 82.22 dB (1.37), Cl. mean 0.83. PowG5 mean 83.06 dB (1.47), Cl. mean 0.83. PowB5 mean 82.51 dB (2.41), Cl. mean 1.46. PowD6 mean 83.24 dB (2.87), Cl. mean 1.74.

Group B post: PowG4 mean 81.50 dB (SD 0.92), Cl. mean 0.56. PowB4 mean 81.94 dB (0.78), Cl. mean 0.47. PowD5 mean 81.67 dB (1.23), Cl. mean 0.74. PowG5 mean 83.49 dB (1.51), Cl. mean 0.91. PowB5 mean 81.64 dB (2.29), Cl. mean 1.38. PowD6 mean 81.56 dB (2.89), Cl. mean 1.74. p-Values group B: G4 p = 0.8768, B4 p = 0.6768, D5 p = 0.2905, G5 p = 0.4672, B5 p = 0.3513, D6 p = 0.1496.

Pitch of Highest Tone (Playing Range)

The ability to play higher tones did not change significantly in any of the groups. In average, the highest tone that subjects of both groups were able to play was an E6 (1319 Hz) or MIDI 68 (Fig. 4). After the 5 weeks, the mean highest tone of the players of the control group A decreased slightly to a D#6 (1245 Hz, MIDI 67). Subjects of intervention group B maintained the same mean highest tone pre and post training.

Group A pre: mean pitch MIDI 68 (SD 2.44), Cl. mean 1.64. Group A post: mean pitch MIDI 67 (2.70), Cl. mean 1.81, p = 0.3328. Group B pre: mean pitch MIDI 68 (2.07), Cl. mean 1.25. Group B post: mean pitch MIDI 67.84 (1.67), Cl. mean 1.01, p = 0.6812.

RPE

RPE stayed the same pre and post training in both groups. The difference between groups was also not significant

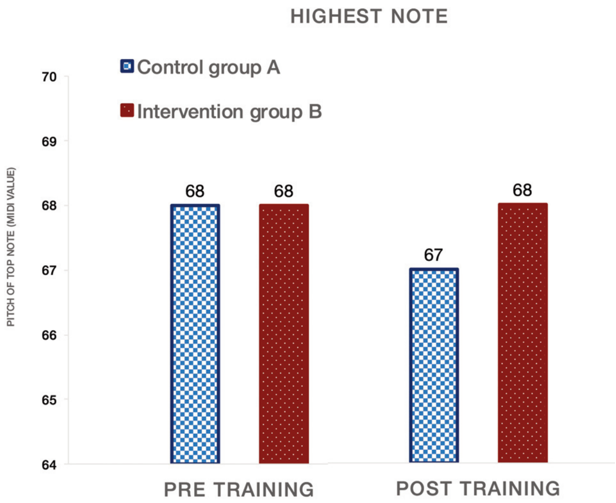

FIGURE 4. Mean values of the highest tone (pitch as MIDI value; E6 = midi 68) pre and post 5 weeks of EMST.

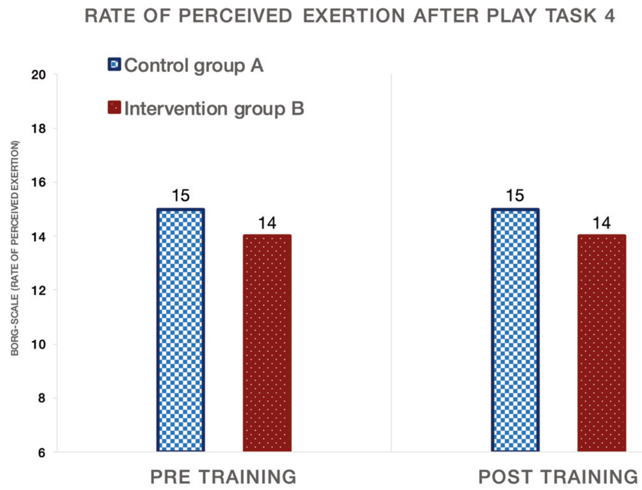

FIGURE 5. Mean values of RPE to play a phrase in a high register in groups A (control) and B (intervention group) pre and post 5 weeks of EMST.

(Fig. 5). Group A pre: mean Borg 15.27 (SD 1.55), Cl. mean 1.04. Group A post: mean Borg 14.72 (1.34), Cl. mean 0.90, $p = 0.3899$. Group B pre: mean Borg 13.69 (1.97), Cl. mean 1.19. Group B post: mean Borg 14.38 (2.95), Cl. mean 1.78, $p = 0.4896$.

DISCUSSION

Prior work has documented the effectiveness of EMST on MEP, both in healthy and diseased populations. In healthy populations, including athletes, high-risk voice users and wind instrument musicians, MEP also increases significantly after EMST (17–19,20,30).

In this study, where the effect of EMST on MEP, RPE, and performance (maxima of sound intensity and tone duration as well as the highest possible tone played) was tested in professional trumpet players, it was found that MEP had increased significantly after EMST, whereas RPE and performance parameters had not changed significantly or had even remained unchanged.

Change in MEP

The increase of MEP in the intervention group is in general agreement with previous EMST studies and was somehow predictable, as the EMST intervention followed the general principles of strength training. However, the percentage of MEP post-intervention rise differs widely among published studies, some of which report no increase of MEP after EMST. In this study, MEP significantly increased by 13% ($p = 0.049$). Other studies investigating healthy subjects of similar age and gender surpass this result with rises of 25% (31), 30% (32), 45% (18), and 68% (19). These results stand in contradiction to Wells et al. (30) and Griffiths and McConnell (17), who could not find a rise of MEP after EMST.

A rise of 13% in MEP might not seem very high at first, but considering the initial high level at 212 and 213 cmH_2O, this percentage can be interpreted as understandable indeed. When starting below normal values, as in Woodberry et al. (19) with 125 cmH_2O, a rise of 68% up to 211 cmH_2O is possibly easier to attain. On the other hand, enhancing something that is already above normal expected values might require more effort than improving something under normal expected values.

American Thoracic Society (ATS) and European Respiratory Society (ERS) suggest predicted normal MEP values of 140–150 cmH_2O for males (20). Wilson et al. (33) reported a prediction equation for normal MEP values that goes as follows: $180 - (0.91 \times \text{age})$. According to this equation, the predicted MEP would be 156 cmH_2O for the population of this study with an average age of 26.8 years. As mentioned above, the subjects of this study started at 136% of their predicted MEP (212 and 213 cmH_2O) and finished respectively at 140% and 155% of predicted MEP (218 and 241 cmH_2O).

Seen from a mere physical point of view, high pre-intervention MEP values imply small post-intervention increase due to typical plateau reaching during training. As regards the control group, the MEP small rise (from 212 to 218 cmH_2O) could result from a learning effect.

Impact on Performance

Although participants increased their MEP, the performance of the participants from the intervention group did not seem to benefit from this strength gain. These results are similar to those of previous studies investigating the effect of EMST on performance in athletes and wind instrument musicians, where no impact of an increased MEP on performance was found so far (19,30,32).

The lack of evidence of expiratory muscle strength gains on performance is surprising insofar as studies investigating inspiratory muscle strength training (IMST) hasve shown that athletes of different disciplines had improved their performance outcomes after IMST (17,34–36). Studies on the effect of interventions including EMST, IMST and combined EMST/IMST in the same population reported that the effects of IMST on performance seem to surpass those of EMST or the ones of combined EMST/IMST (Dries et al., 20). Dries et al. (20) documented changes in sound after saxophone players had executed combined EMST/IMST. This is analogous to Illi et al. (37), who demonstrated that combined EMST/IMST impacted more performance than EMST or IMST alone.

For the authors it remains unclear, why EMST does not seem to induce a performance enhancement in the way IMST does. Similar to their MEP values, it could be assumed that participants of this study had reached a performance plateau or at least a very high-end level in their playing, which cannot be easily enhanced further. It would have to be investigated in more detail though, whether this plateau is already reached in normal healthy populations or only in high-end performers such as athletes or wind instrument musicians.

Two hypotheses of this study were that trumpet players could play louder and higher after EMST. This was not the case, as highest pitch remained the same and dynamics either stayed the same, or in- or decreased only by 1 dB. According to Bertsch (13), intention includes what the player wants to play, whereas realization is characterized by motivation, concentration and frame of mind. Arnold Jacobs (in Stewart, 38) went as far as to state that: “The important thing is not what you sound like, it’s what you want to sound like.” Although participants were told to play as loud and high as possible and to give their very best, they might not have been mentally as focused as they would have been in a concert situation. However, for mental preparation, there is no scientific foundation for this assumption, but this example emphasizes the complexity of tone production and also the limitations of the study setting.

Implications for Pedagogical Practice

Although participants showed a higher MEP and therefore increased strength in their expiratory muscles after EMST, they were not able to use this strength gain to enhance their playing. This finding requires deeper investigation into some factors of trumpet playing and sound production.

According to Bertsch (13), the trumpet sound depends on 58 different variables, from which lung function and constitution of participating muscle groups are only two. All variables depend more or less on each other, which means that, for example, the strength of the expiratory muscles can only be used efficiently for playing if other directly related parameters, such as the strength of facial muscles or the coordination of embouchure are trained at a similar level. If facial muscles are too weak in relation to expiratory muscles, a high intraoral pressure cannot be built up despite strong expiratory muscles because the lips will open to the sides and air will leak out. Therefore, players and pedagogues should always focus on a broad spectrum of exercises that synchronously enhances all variables or at least the ones related directly to each other. If additional breathing exercises are applied in trumpet lessons, care should be taken that related factors are practiced as well.

Limitations

One of the challenges with EMST studies is the lack of gold standard. Although many studies were conducted with a load of 75% of MEP, a total duration of 5 weeks and a training frequency of 25 repetitions five times per week, other training regimens of shorter time, lower intensity of different frequency also produced successful results. This, plus other studies investigating mixed wind instruments with a different pressure and airflow situation, make comparison of studies difficult.

Conclusion

EMST increases MEP. As high and loud notes on the trumpet require high intraoral pressure, an increase in MEP ought, in theory, subsequently facilitate the playing of higher and louder tones. In order to verify if systematic EMST has an impact on performance, this study tested whether the intervention influenced playing performance and physiological factors. After 5 weeks of EMST, MEP increased significantly by 13% in the intervention group ($p = 0.049$). In the control group, no significant change of MEP was found. Performance parameters had not changed in any of the groups. Regardless of their group, participants did not play significantly louder, higher, or longer in the final measurement compared to the initial measurement. Furthermore, RPE did not change after the 5 weeks.

Therefore, recommendations for EMST have to be cautious, at least for a population of professional male trumpet players with a well-trained respiratory system, for whom EMST might not be the most efficient strategy to improve performance. That being said, EMST could be beneficial and an interesting addition to instrumental practice for other populations with naturally (still) lower MEPs, such as women, adolescents, or amateurs who might want to increase their current MEP values. However, this assumption has to be investigated in the future.

If trumpet players—regardless of their playing level, age or gender—want to perform EMST, they should be aware of the high pressures that can occur during training and should never ignore warning signs of their bodies such as dizziness or headache.

Based on the results of this study, the authors regard EMST as not necessary for professional male trumpet players possessing excellent lung function, as the effects of EMST on playing performance do not seem to surpass the effect of practicing alone.

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Data availability: The sound files and further data that support the findings of this study are available on request from the corresponding author [ATE]. The data are not publicly available due to their nature that could compromise the privacy of research participants.

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