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The Immediate Effects of Short-term Exercise on Diaphragmatic Breathing over Wind Instruments

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ABSTRACT

A strong diaphragm is critical to wind musicians because it helps produce a steady airstream needed for playing wind instruments. To strengthen the diaphragm, musicians use various methods. One method is exercise because it increases the breathing rate, forces the diaphragm to expand and contract, and allows for longer sustainment of breaths and greater endurance. This raises the question of whether exercise can affect the diaphragmatic breathing rate over wind instruments for wind musicians. The purpose of this research was to draw conclusions that could help rising and professional musicians improve their endurance through alternative means. The initial hypothesis was that as the duration of cardio exercise increases, there would be an increase in breath sustainment because the exercise would impel the diaphragm to expand and, subsequently, allow the lungs to fill to higher capacity. To determine this, human participants were gathered for three trials: no exercise, five minutes of exercise, and ten minutes of exercise. Each participant performed cardio exercises, after which they breathed into a breath builder. The amount of time they could sustain the ball in the air was measured as were the average times for each of the three groups of participants. The results of the ANOVA test demonstrated that $F(2, 5.07) = 0.0081$, $p<0.05$, indicating that the null hypothesis—that the mean durations of breath sustainment for the three trials were equivalent—could be rejected. The results demonstrated that exercise did not have the hypothesized immediate effect of increasing breath sustainment and diaphragmatic breathing.

Introduction

Professional musicians are able to deliver magnificent performances that amaze audiences because of their advanced control over their instruments. This ability to amaze often develops through much practice and through the development of endurance, the ability to tolerate an exercise for an extended period of time (Bubnis, 2020). Such endurance is critical to wind musicians as it is an essential skill that allows musicians to perform proficiently. Therefore, many wind musicians seek to improve their endurance through physical exercise or practicing their instruments often. However, the lack of exercise, the physical demand of playing an instrument, and the constant demand for air make wind musicians susceptible to injury. Some of these injuries include overload syndrome, hands and lips focal dystonia, and other muscular and neuromuscular origins (Gallego-Cerveró, C. et. al 2019). Studies recommend that programs for musicians-in-training include physical exercise because it can decrease the exertion musicians experience when playing for long periods of time (Ackermann et. al, 2002). In particular, cardio exercise has been recommended because it has been claimed that it will not only increase an individual's stamina but also train him or her to develop steady breathing patterns.

During exercise, breathing slowly allows for more oxygen to be absorbed into the body, creating more energy for use (Pilachowski, 2017). Diaphragmatic breathing, also known as belly breathing or abdominal breathing, in particular leads to a larger intake of air compared to shallow breathing. As a result, more energy is produced and available, allowing the individual to continue exercising for a longer period of time thereby building stamina. This type of breathing uses the diaphragm as the central muscle of breathing and, when utilized during rest, is associated

with increased relaxation and positive distraction (Mirgain et. al, 2020). Diaphragmatic breathing is essential for all wind musicians because they must use deep breathing and their diaphragms to maintain and manipulate their air supply to play their instruments. Wind musicians who lack this skill have more difficulty producing sound from their instruments as well as higher quality tone. Because exercise helps people build stamina and develop stronger diaphragms, it could help both developing and professional musicians strengthen their diaphragms enough to play their instruments without force. Without strong diaphragms, wind musicians will lack energy and stamina and not be able to give strong performances. It is also possible that even exercise, immediately before play, can lead to regulated breathing patterns that allow for better diaphragm control.

These studies point to the significance of this experiment because it tests the hypothesized impact of exercise on musical performance. The use of physical exercise could help advance performance skills for wind musicians. These findings and observations led to the research question: "How does the amount of exercise immediately affect the diaphragmatic breathing control of wind musicians." This research's findings would be informative to advanced wind musicians or any rising wind musician because if the hypothesis is true, exercise could help further improve playing abilities and endurance in a faster, more efficient way. Exercise, even short-term exercise immediately before performing, could strengthen diaphragms and help musicians to play longer portions of music without interrupting flow; this can make the performance more connected and melodious. Therefore, this research tested the hypothesis that as the duration of cardio exercise increases, there would be an immediate increase in breath sustainment because the musician's lungs are already expanded after participating in the experiment.

For this experiment, each participant was required to perform in three different trials: no exercise, five minutes of exercise, and ten minutes of exercise. Each trial took one day for the participants. Each activity in the five-minute trial was followed by 15 seconds of recovery time, while each activity in the ten-minute trial was followed by 30 seconds of recovery. Participants were directed to exhale into a breath builder and to sustain the ball within it for as long as they could after they had finished the exercises. A breath builder is a commonly used device that helps musicians practice the technique of inhaling and exhaling to prepare for long, extensive practices and performances. The sustainment of the ball was timed and recorded.

Literature Review

Endurance and Diaphragmatic Breathing

In order for rising musicians to enhance their skills, they must strengthen their endurance in order to sustain longer phrases of notes and improve performance. Endurance development is a major factor in playing a wind instrument because it allows for the musician to tolerate playing longer measures without breathing frequently; this can also help musicians play their instruments for longer periods of time. In *Strength or Endurance Training for Undergraduate Music Majors at a University*, Ackermann, Adams, and Marshall (2002) investigated how participation in different types of exercise programs can later affect performance and perceived exertion of play for each musician. The purpose of this study was to see how participation in an exercise regimen could help undergraduate music majors play their instruments for long periods of time with less exertion. This study highlights the high physical demand of musical performance. Because of the extensive practice and long hours of play they commit to everyday, musicians are often compared to athletes. Through the analysis of self-reported ratings of perceived exertion (RPEs) and field measurements (FM)—which can reflect the number of weights, repetition maximums for an exercise, or the number of exercises—by student-participants, the authors concluded that exercise over the long-term does have a significant impact on developing strength and endurance (Ackermann et. al., 2002).

Gallego-Cervero et. al (2019) provides a systematic overview of intervention studies on physical activity for musicians, revealing how musicians have experienced numerous physical health problems that have resulted in many musicians not performing at their usual level. Common health problems include temporomandibular disorders

(jaw muscle disorders), epicondylitis (pain from elbow to the wrist), and arthritis (swelling of one or more joints). Even though this source investigates and assesses the injuries suffered by musicians after performing for long periods of time, it highlights the benefits of physical activity interventions, supporting the conclusion that exercise can be beneficial to a musician's playing and physical condition (Gallego-Cerveró et. al, 2019).

There are two types of breathing: diaphragmatic breathing and thoracic (chest) breathing. Most rising musicians believe that all professionals use their chest in order to help support their airstream; however, this is not the correct method for breathing for musicians. Diaphragmatic breathing allows musicians to use their airstream more deeply, slowly, and effectively (Jevtic-Somlai, 2019; US Department of Veterans Affairs, 2020). By utilizing their diaphragms, musicians can intake more air while breathing, which helps support the intonation of the instrument. Poor airflow, on the other hand, can cause the musician's tone to go sharp or flat. In addition, without proper air support, musicians will face challenges and consequences during performances because musicians must be able to play long measures while breathing for air at only particular points in their performance pieces. Poorly chosen points for breathing can ruin the performance for the ensemble group. Using diaphragmatic breathing will help musicians give presentable performances. As musicians intentionally exercise their diaphragms and develop its capacity over time, their breathing control will advance and make it easier for musicians to sustain longer measures of music without breathing.

Respiratory System and Wind Musicians

Because wind instruments require proper air manipulation and musician respiration, musicians practice respiratory exercises (Antoniadou et. al, 2012). The respiratory system consists of blood vessels, tissues, the trachea, and muscles of the diaphragm and chest wall. The process of respiration begins with the inhalation of oxygen and the release of the waste gas, carbon dioxide, out of the body. Oxygen and carbon dioxide enters and exits through numerous airways, including the mouth, nose, and trachea (National Heart, Lung, and Blood Institute, 2020). The diaphragm and lungs assist in the inhalation and exhalation of air, adapting to meet the demands of active muscles that are used to play a wind instrument. Exercise helps develop stronger diaphragms due to the breathing patterns that are utilized during workouts, such as running (Pilachowski, 2017).

In the assessment of the impact of yoga on respiratory regulation, Beutler et. al (2016) investigated whether there were different respiratory responses between yogic subjects and non-yogic subjects with similar physical activity levels. Yoga, it was found, did not improve exercise capacity but rather led to the development of a different breathing pattern. It also found that yoga had a significant impact on the breathing patterns of people during rest rather than after exercises and that it reduced ventilatory responses. Though the study found no significant differences in lung function or capacity, the study did not assess diaphragm function. It is possible that developing respiratory regulations through exercise could help wind musicians strengthen their diaphragm muscles to change breathing patterns and improve their tonality and produce fuller sounds.

Summary

Although these studies demonstrate how exercise can benefit a person's long-term endurance and breathing patterns, gaps exist in the literature. Previous studies do not focus on how cardio exercise can immediately impact a person's breathing pattern, endurance, and diaphragm muscles. In addition, other studies do not experiment with the use of a breath builder to gauge how long musicians can exhale from their diaphragm into the builder. Other studies, however, have investigated how exercise can benefit wind musicians, which helps fill the gaps. What is still unknown is whether exercise can immediately induce diaphragmatic breathing useful in building endurance for wind musicians.

Materials

- Timer
- Breath Builder (amazon.com)
- Diaphragm breathing video
- Microtube cleaning brushes
- Human participants (high school students)

Methods

Before starting the experiment, each participant was required to fill out an informed human consent form in order to participate. It was ensured that each of the 32 participants had a form completed before experimentation. For this experiment, there were three different trials: no exercise (control), five minutes of exercise, and ten minutes of exercise. For the control, none of the participants had to engage in any exercises. These trials served as reference trials to which the exercise trial measurements were compared. Each participant was shown a video tutorial on how to produce diaphragmatic breathing and asked to follow the directions. A small demonstration was also shown to the participants in order to ensure that they understood what diaphragmatic breathing was. A study by Mirgain et. al (2020) found that people can learn how to perform diaphragmatic breathing through observation and instructions. Then, each participant breathed into a breath builder using their diaphragms and blew into the builder for as long as they could. As each of the participants blew into the builder, the amount of time the participant kept the ball sustained in the air was recorded. The data from the trials for which the treatment "exercise" had been applied were then compared to those from the control trial in which there was no treatment in order to determine if the treatment "exercise" caused a change in the time of breath sustainment.

Figure 1. Image of Breath Builder

Figure 1 is the image of the breath builder that was used during experimentation. Inside the device is the ball that the participant was required to sustain in the air. Participants exhaled into the device using the clear tube. The breath builder was used in order to measure the endurance that participants had before and after exercise. The next day, the participants performed the five-minute exercise trial. All participants were given two minutes of recovery time at the end for this trial. A recovery point was added to allow the participants to return back to their resting state, but the time was not prolonged so that the results would more directly reflect the participant's ability to use his or her expanded diaphragm previously induced by exercise. Each participant was required to participate in the following exercises:

1. 30 seconds of jumping jacks
2. 15 seconds of recovery
3. 30 seconds of running in place
4. 15 seconds of recovery
5. 30 seconds of jumping
6. 15 seconds of recovery
7. 30 seconds of mountain climbers
8. 15 seconds of recovery
9. 30 seconds of high knees
10. 15 seconds of recovery
11. 30 seconds of jumping jacks
12. 15 seconds of recovery
13. 30 seconds of burpees
14. 2 minutes of recovery

During the two-minute recovery period, the participants were asked to inhale through their nose and exhale through their mouths because the action would be most similar to how participants would later exhale into the breath builder. After recovery, all participants exhaled into the breath builder, trying to sustain the ball for as long as they could. Similar to the methods that Ackermann and Adams (2002) used to gauge how different exercises impacts the strength and endurance of musicians, this research measured the amount of time each participant sustained the ball in their exhaled air. The purpose of the experiment was to first strengthen the diaphragm after exercise to see how exercise can immediately help musicians advance their breathing sustainment. On the next day, the same individuals participated in the ten-minute exercise trial. This trial included a three-minute recovery time at the end to prevent overexertion and lightheadedness. The recovery time was increased in order to allow recovery to a state similar to that in the five-minute trial since this trial used more extensive and draining exercises. The participants performed the following exercises:

1. 30 seconds of jumping jacks
2. 30 seconds of recovery
3. 30 seconds of running in place
4. 30 seconds of recovery
5. 30 seconds of jumping
6. 30 seconds of recovery
7. 30 seconds of mountain climbers
8. 30 seconds of recovery
9. 30 seconds of high knees
10. 30 seconds of recovery
11. 30 seconds of jumping jacks
12. 30 seconds of recovery
13. 30 seconds of running in place

14. 30 seconds of recovery
15. 30 seconds of jump roping
16. 30 second of recovery
17. 30 seconds of mountain climbers
18. 30 seconds of recovery
19. 30 seconds of burpees
20. 3 minutes of recovery

During the three-minute recovery, the participants were again directed to breathe in through their nose and exhale through their mouths. Then, each participant was required to expire into the breath builder again. The amount of time that the ball was sustained in the air was timed and recorded. All participants had a choice of wearing their masks or taking them off for the exercises because a study has proven that the different types of masks, such as cloth masks and disposable masks, did not have an effect on heart rate or fatigue (Harvard Health Publishing, 2021). For the study, a sample of high school students were used since they would represent a good mixture of both experienced and inexperienced musicians. In contrast to the study done by Ackermann and Adams (2002), this research used a mixture of wind musicians and typical high school students, representing experienced musicians and new, developing musicians.

Figure 2. Experimental Design Diagram

Title of the Experiment The effect of the amount of short-term exercise affects the diaphragmatic breathing control of wind musicians.
Hypothesis If the amount of cardio exercise increases, there will be an increase in breath sustainment because exercise helps increase an individual's heart rate, which also expands a person's lungs and diaphragm. This will allow people to hold their breaths longer and musicians to be able to sustain notes longer during performances.
Independent Variable The amount of exercise (minutes): No exercise, 5 minutes of exercise, 10 minutes of exercise Number of observations: 32 observations for each group
Dependent Variable The amount of time the participants sustained the ball in the breath builder up in the air (seconds).
Control Group The control group is the trial with no exercise for the participants.
Constants The type of breath builder, the weight of the ball inside the builder, the number of observations per group, the type of breathing, and the type of ball inside the builder.

Results

The research consists of numerous data points, which are shown in Table 1, Table 2, and the Appendix. After all data was collected for each participant, the averages (means) for each group trial were calculated. Table 1 provides the mean, median, and standard deviations of the three different group trials. For the control trial, the mean time of exhalation sustainment was 3.91s with a standard deviation of 1.25s (the median was 3.98s). The mean time of exha-

lation in the five-minute trial was lower (mean = 3.35s, median = 3.25s, and s.d. = 0.97s) than that of the control. The mean time for the ten-minute trial was found to be even lower (mean = 3.08s, median = 3.07s, and s.d. = 0.95s). The results reveal that with more exercise, the mean time of exhalation decreases.

Table 1. Average Time (seconds) for Each Exercise Trial

	Control	5-Minute Trial	10-Minute Trial
M	3.91	3.35	3.08
Median	3.98	3.25	3.07
s	1.25	0.97	0.95

Note: Table 1 demonstrates the averaged times for each trial. As more exercise was performed, the average times decreased. Compared to the control, each of the times have a smaller average.

The bar graph (Figure 3) reveals the average duration in the sustainment of exhalation for each trial. The control had the highest average with an approximate value of 4 seconds. The five-minute trial had the second highest average with an approximate value of 3.5 seconds. The ten-minute trial had the lowest average of approximately 3.0 seconds. Among the three trials, the control had the highest average.

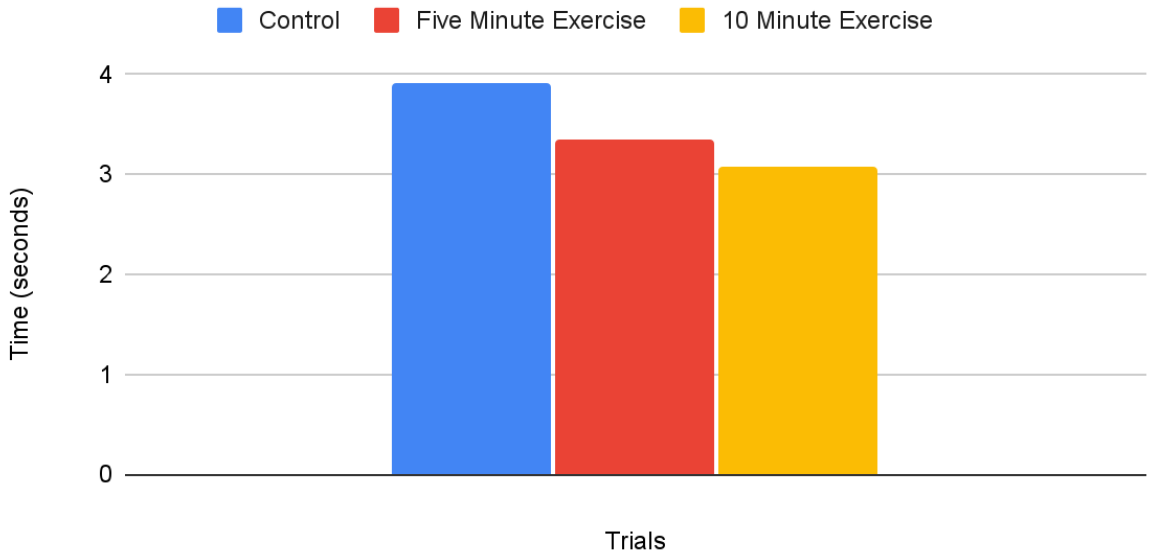

Figure 3. Bar Graph of the Average Times of the Exhalation Sustainment of the Participants for Each Trial
Ho: Mean 1 = Mean 2 = Mean 3

Note: Figure 3 is a bar graph of the duration in the sustainment of exhalation for each trial. As exercise was added, the average time decreased.

For this experiment, an ANOVA test was utilized in order to determine whether the exercises had a statistically significant impact on the duration of exhalation sustainment. This test was used in order to compare the means of the trials. Table 2 demonstrates that the exercises had a significant impact because the F-statistic was $F(2, 5.07) = 0.0081$, $p<0.05$. Based on the results, the null hypothesis that the means of the three different trials were equal was

rejected, meaning that the means were statistically different. However, instead of increasing exhalation sustainment, additional exercise was found to lower exhalation sustainment (lower mean) and therefore did not have the hypothesized effect of increasing diaphragmatic breathing.

Table 2. ANOVA Test

Source	SS	df	MS	F	P-value	F crit
Between Groups	11.5154	2	5.7577	5.07	0.00815	3.09434
Within Groups	105.6581	93	1.13611			
Total	117.17350	95				

Note: Table 2 demonstrates the effect exercise had on the duration of exhalation sustainment of the participants, such that $f(2, 5.07) = 0.0081$, $p<0.05$. The results reveal that the p-value is less than the alpha value (0.05), which makes the results significant.

Discussions

As novice wind musicians enter the music world, their weak endurance presents multiple challenges in producing sound out of a wind instrument. However, the use of exercise to strengthen the respiratory system and build endurance allows musicians to create dulcet music and overcome the challenges of producing sound in a wind instrument. Musicians are even compared to athletes because both groups need exercise in order to persist through long practices during the day. Due to this, physical exercise is commonly advocated for musicians (Ackermann et. al, 2002). Exercise is seen as an important form of training for musicians because it serves to improve their musicality and endurance.

This leads to the purpose of this research which was to help rising and professional wind musicians improve their endurance through faster means. This research is significant because it provides guidance to current wind musicians who want to improve their endurance in performing in long concerts and in demanding musical pieces. This research also provides guidance on reducing injuries musicians face during their long, demanding practices, pointing to findings in literature that promote the importance of exercise for musicians. This project was conducted to determine if increase in exercise can immediately affect the duration of breath sustainment of participants. The experiment did not support the hypothesis that an increase in cardio exercise would lead to an immediate increase in the duration of breath sustainment of the participants. The results demonstrate a decrease in time as more exercises were performed. As Table 1 demonstrates, the results present a statistically significant decrease in the averages, disproving our original hypothesis. This decrease reveals that the exercises caused the participants to be more exhausted, with immediate post-exercise weakening of the diaphragm, causing them to have lower times for breath sustainment. Figure 1 also reveals a larger difference between the control and the five-minute trial, which reveals that the participants were not able to accomplish steady respiration for as long as they could due to the exercises. As more exercises were added, the average time continued to decrease because the participants began to be out of breath.

Table 2 demonstrates an ANOVA test on the times of breath sustainment of the participants. An ANOVA was used for this experiment because this experiment contained two treatments: no exercise (control), five-minute exercise trial, and ten-minute exercise trial. Because the p-value of 0.00815 is less than the alpha value 0.05, the data is statistically significant. Therefore, the null hypothesis that the means of the three trials were equivalent was rejected. The treatment trials with exercise had statistically different means; however, they showed a decrease in

breath sustainment. Therefore, this research's initial hypothesis that exercise would have an immediate impact of increasing breath sustainment because of improved diaphragm activity was found to be incorrect.

Based on these results, it is likely that the increase in short-term exercise did not immediately increase the time of breath sustainment of the participants due to the participants' lack of energy at the end of the trials. Because of this, the average times have shown reductions between trials in which exercise was performed. This means that short-term exercises before immediately playing a wind instrument will not be beneficial due to the musician's lack of energy. This shows that short-term exercise does not immediately strengthen the diaphragm. Even though exercises are beneficial to a person's endurance and lung capacity in the long-term, exercising immediately before blowing into an instrument can lead to shortness of breath. Therefore, long-term exercise in building up capacity over time is more effective and beneficial for wind musicians. The findings of this research in conjunction with those evaluating the impact of exercise on musical performance imply that long-term exercise is more effective than short-term exercise immediately before play. It also reveals that endurance is developed over a long period of time. Time is needed in order for the diaphragm muscles to slowly strengthen.

One important limitation of this study is the assurance of proper diaphragmatic breathing: some participants could have utilized chest breathing instead of diaphragmatic breathing for the trials. Chest breathing can result in lower times of breath sustainment. Another limitation relates to the performance of the participants during the exercise trials. This experiment could not control the level of effort that participants put into each of the trials. A third limitation is that the sample population was limited to high school students, which is unrepresentative of all musicians who range in age. Young and old musicians might have had weaker diaphragms and unregulated breathing compared to those of high school students. Their inclusion would have most likely changed the data.

Sources of error include the time of day in which the participants performed the exercises: some participated in the exercise trials after lunch. Fuller stomachs of participants could have resulted in less oxygen intake through the body. Less energy would be produced from the body because of the reduction in oxygen consumption, leading to tiredness or laziness. Another source of major uncertainty was that some participants were athletes, who are in better physical condition and may therefore feel less tired than other participants immediately after exercise. Because athletes are more adjusted to exercising frequently, they may have experienced less energy loss at the end of the exercises compared to non-athletic participants. A third source of uncertainty is experimenter drift because there were a few participants who were not as motivated as other participants during the exercise trials. As a result, there could be inconsistency in the data.

An important improvement that could address the first limitation would be to spend more time teaching the participants diaphragmatic breathing through various activities, including breathing exercises, videos, and models. In order to address one source of error, all participants should perform the exercises at the same time of day. The participants should also be screened so that the control and treatment groups include either only athletes or only non-athletes so as to properly control for prior conditioning to exercise.

Future research could investigate the impact of long-term exercises, potentially having participants exercise over a longer period of time: three to four weeks. This would allow their diaphragms and endurance to strengthen and increase over time as well as allow them to develop breathing patterns. Additionally, future research may focus on one exercise, such as running, and on breathing patterns to focus more on the development of endurance. Particular attention could be given to how exercise strengthens the participants' diaphragm muscles, which in turn assists in manipulating airflows for better performance on wind instruments.

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