Physiological Effects of Volume of Music on Heart Rate, Grip Strength, and Electromyography

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Abstract
For this study, the physiological effects of volume of music on the body were investigated. Previous studies have shown that aspects of music such as tempo and rhythm result in physiological responses within the body. However, little is known about the physiological effects of volume of music on the body. It was hypothesized that both loud (70-80 dB) and soft (45-55 dB) music would result in an increase in grip strength, electromyography (EMG), and heart rate as compared to baseline measurements where no music was present. It was also hypothesized that loud music would cause a greater increase in these measurements as compared to soft music exposure. To test this hypothesis, grip strength, EMG, and heart rate were measured in 50 research participants. The data showed that loud and soft music exposure both resulted in a significant increase in heart rate compared to no music exposure. There was a significant decrease in grip strength for the soft music exposure group compared to the no music exposure group. Lastly, loud music exposure resulted in a significant decrease in muscle stimulation. No significance was found for the other comparisons.

Introduction

Music is considered an ergogenic aid—a mechanical, nutritional, physiological, and psychological perceived advantage thought to increase energy production, use, or recovery (Levy et al., 2008). Many studies have investigated the ergogenic effect of music on sports performance, both before and during exertion, specifically as a psychological advantage. These studies have found that listening to music pre-exertion improves optimization of arousal, facilitation of task-relevant imagery, and performance in simple motor tasks (Levy et al., 2008). During exertion, music has been shown to enhance affect, reduce ratings of perceived exertion, improve energy efficiency, and lead to increased work output (Karageorghis & Priest, 2011).

Music has been shown to cause physiological changes and responses within the body. Current research has shown that music causes changes in blood pressure, heart rate, respiration, and EEG measurements (Myskja & Lindbaek, 2000). According to a study completed by Bernardi et al., the physiological changes depend on many factors related to music such as tempo, rhythm, and personal music preferences (2005). Their findings concluded that music with a fast tempo produces an arousing effect resulting in a significant increase in systolic and diastolic blood pressure, heart rate, and breathing rate (Bernardi, 2005). Conversely, music with
a slow tempo has a relaxing effect resulting in a significant decrease in heart rate (Bernardi, 2005). Many variables in music cause physiological changes within the body. This study expands on these findings and investigates a new variable in music, volume.

The autonomic nervous system controls many physiological responses of the body including heart rate, respiratory rate, and blood pressure (Gordon, 2015). Research has been completed to show that varying auditory stimulations can affect the two divisions of the autonomic nervous system, parasympathetic and sympathetic, antagonistically (Amaral et al., 2016). When the parasympathetic division is stimulated, the body will respond by lowering the heart rate, respiratory rate, and blood pressure (Gordon, 2015). When the sympathetic nervous system is stimulated, the body will respond by increasing heart rate, respiratory rate, and blood pressure (Gordon, 2015). Therefore, music with a relaxing effect will stimulate the parasympathetic division, while music with an arousing effect will stimulate the sympathetic division. In our experiment, we induce an arousing effect by utilizing music with a loud volume level which is expected to increase heart rate. With the sympathetic division stimulated, blood will flow to the skeletal muscles, and fast-contracting muscles will increase their strength of contraction (Feher, 2012). As a result, grip strength and electromyography (EMG) are expected to increase as a result of sympathetic nervous system stimulation.

In this study, we explore the physiological effects of the volume of music. Specifically, we investigated how music that stimulates the sympathetic nervous system affects grip strength, EMG, and heart rate. We hypothesized that participants exposed to loud music (70-80 dB) would show the largest increase in grip strength, EMG, and heart rate as compared to the baseline measurements in which no music was present. Next, we hypothesized that participants exposed to music played at a lower level (45-55 dB) would also show an increase in grip strength, EMG, and heart rate as compared to the baseline measurements but less dramatic than the loud music. To determine the relationship between volume of music and physiological responses, the results of loud music, softer music, and no music were compared to each other.

**Materials**
Three variables were measured to determine the physiological effects of two different volumes (70-80 dB and 45-55 dB) of electronic dance music on the human body: heart rate, grip strength, and EMG. Heart rate, measured in beats per minute (BPM), was determined via a pulse transducer (Model: SS4LA, Serial Number: 12107322; BIOPAC Systems, Inc. Goleta, California). Grip strength, measured in kilograms (kg), was determined via a hand dynamometer (Model: SS25LA; Serial Number: 1501004240; BIOPAC Systems, Inc. Goleta, California). Electromyography, measured in millivolts (mV) was determined via a lead set (Model: SS2L, Serial Number: 908A9635; BIOPAC Systems, Inc. Goleta, California). Additionally, this variable required pre-gelled disposable electrodes (Model: EL503; BIOPAC Systems, Inc. Goleta, California). All measurements of data were taken and recorded via BIOPAC Student Lab Systems utilizing BSL 4 Software (Model: BSLBSC; BIOPAC Systems, Inc. Goleta, California). Additional equipment to aid in the gathering of data were MP36 Data Acquisition Unit with USB Cable, DC Adapter (110V/60Hz), and electrode lead sets (Model: SS2LB) (BIOPAC Systems, Inc. Goleta, California). All calibration and equipment instructions were gathered from the BSL Laboratory Manual (Model: MANBSL4, ASIN:B01C6QCAYE; BIOPAC Systems, Inc. Goleta, California). The music was played utilizing a bēm speaker (Model: EXO-200) connected via Bluetooth to a standard iPhone 8. The decibel level of the music was measured utilizing the app, “Decibel: dB, dBA Sound Meter” made by the developer, Vlad Polyanskiy. “Levels” by Avicii was the song selected for this experiment. All apparati were connected and monitored via BIOPAC on one standard Dell computer.

Methods

Participants

The participants in this study included students (n=50) between the ages of 20 and 24 from the Physiology 435 course at the University of Wisconsin-Madison. The subjects voluntarily enrolled in the study and signed a consent form explaining confidentiality and any emotional or physical risks that may be present prior to engaging in the experimental activities.
Procedure

Participants were included in this study if they met the following criteria: between the ages of 20-24, enrolled in the Physiology 435 course at the University of Wisconsin-Madison, and if written consent to participate in the experiment was acquired. Participants were not excluded due to preexisting medical conditions. Prior to engaging in the study, participants completed a questionnaire which asked about workout regimens, music preferences, and volume preferences. Before the experiment, the BIOPAC system was set up with the pulse transducer, hand dynamometer, and lead set plugged into channels 1, 2, and 3, respectively. Before any experiments, the BIOPAC system was calibrated according to the instructions within the BSL Laboratory Manual. Measurements were taken in a private room with one administrator present to ensure proper data collection. The pulse transducer was attached to the index finger on the non-dominant hand of the participant, the lead set was attached to the forearm of the participant’s dominant hand according to the instructions within the BSL Laboratory Manual, and the hand dynamometer was held in the dominant hand. After participants had all BIOPAC equipment attached, they were instructed to sit upright with their feet flat on the floor for 1 minute while a baseline measurement for heart rate was taken in silence. After a minute elapsed, the proctor instructed the participant to squeeze the hand dynamometer as hard as they could for 5 seconds to measure grip strength and EMG. After these 5 seconds, participants were instructed to sit in the original position for another minute while the song “Levels” by Avicii played at a range of either 70-80 dB or 45-55 dB, and heart rate measurements were taken. The decibel level was measured utilizing the iPhone 8 app, “Decibel: dB, dBA Sound Meter.” Half of the participants (n=25) were played music at 70-80 dB, and the other half of participants (n=25) were played music at 45-55 dB. Participants were not told which volume of music they would be played. After 1 minute of sitting still with music playing, participants were again instructed to squeeze the hand dynamometer as hard as they could for 5 seconds while grip strength and EMG were measured. Afterwards, participants had all BIOPAC equipment removed as the experimentation reached completion. The average force of grip strength and maximum EMG were measured over the 5 seconds with and without music. Heart rate measurements were taken throughout the entirety of the experiment. The procedure is visually outlined in Figure 1.
Data Analysis

After the experiment, the data for heart rate (measured in BPM), EMG (measured in mV), and grip strength (measured in kg) were statistically analyzed to determine whether there was a significant difference between the baseline and experimental data measurements. The heart rate of each participant was measured over the course of the entire experiment. The baseline and experimental mean for heart rate of all participants was calculated during each phase of the experiment separately. A two-sample, two-tailed paired t-test was conducted to determine if the experimental mean significantly differed from the baseline mean. The mean grip strength data was calculated for each participant over the 5 seconds they squeezed both with and without music. Again, a two-sample, two-tailed paired t-test was used to compare the mean of the baseline data to the mean of the experimental data for grip strength. Electromyography was calculated similar to grip strength. The maximum EMG was calculated for each participant over the 5 seconds they squeezed both with and without music. The baseline and experimental mean were compared using a two sample, two-tailed paired t-test to compare silent baseline to the music stimulated response, and a two-tailed t-test to compare the loud and softer music stimulation to each other. Overall, the t-tests were used to determine if the baseline data gathered in silence significantly differed from the experimental data gathered with loud or softer music playing. Also, t-tests were used to determine if the loud music data significantly differed from the softer music. Data was considered statistically significant if $p < 0.05$. All t-tests were conducted with a 95% confidence interval.

Positive Control

In order to confirm that the BIOPAC equipment for this experiment was operating correctly, a series of positive control tests were conducted. Before taking measurements, all equipment was calibrated according to the instructions given within the BSL Laboratory Manual. First, heart rate was measured utilizing the SS4LA BIOPAC equipment. In order to ensure it was operating correctly, the subject’s heart rate was measured for 10 seconds while sitting down with a mean heart rate of 76.22 BPM. Next, the subject ran in place for 30 seconds, and their heart
rate was measured thereafter for 10 seconds with a mean heart rate of 112.89 BPM. This increase in heart rate after physical exertion ensures the functionality of the BIOPAC SS4LA equipment. Second, grip strength was measured utilizing the SS25LA BIOPAC equipment. The baseline measurement with no force applied was 0 kilograms. Afterwards, the subject clenched the bar for 2 seconds for a mean force of 17.03 kg. This testing ensured that the SS25LA equipment was working properly. While performing the positive control test for the BIOPAC SS25LA equipment, a positive control test for the SS2L Lead Set equipment was completed concurrently. When no clenching of the hand was occurring, the EMG was 0.00052 mV. When the clenching was occurring, the EMG increased to 0.01038 mV. As a result of all positive control testing, it can be concluded that the BIOPAC Systems equipment was working properly.

**Negative Control**

The negative controls within the experiment consisted of the phases in which no auditory stimulus was present. This ensured that any physiological responses after the addition of the auditory stimulus could accurately be compared to the data gathered without an auditory stimulus. Specifically, the first minute without music functioned as a negative control for pulse because no auditory stimulus was involved. In addition, the first grip strength and EMG measurements taken without auditory stimulus functioned as a negative control. As a result, the baseline could effectively be compared to the experimental data.

**Results**

The data for all variables was extracted from the Biopac Student Lab Program as seen in Figure 2. Each variable was measured *at rest* in the absence of music, with soft music, and with loud music. Additionally, each variable was measured *while gripping* the dynamometer in the absence of music, with soft music, and with loud music. The data for soft music was compared to no music (baseline), and loud music was compared to no music. The data for loud and soft music were also compared to each other.
Heart rate data was analyzed utilizing paired two-sample, two-tailed t-tests in order to
determine if heart rate in the absence of music significantly differed from heart rate in the
presence of music. First, for the loud music group (n=25) the data taken in silence during rest
was compared the the data taken during loud music at rest. There was an increase in heart rate
when loud music was played as compared to silence. The mean resting heart rate in silence was
79 BPM and the mean resting heart while loud music was playing was 84 BPM. This was an
increase of 5.7% when loud music was playing as compared to no music (Figure 3). This resulted
in a p-value of 0.0036, suggesting a significant increase in heart rate in the presence of loud
music, as compared to the baseline.

Next, a comparison between the heart rate while gripping in silence and the heart rate
gripping in the presence of loud music playing was analyzed. The mean heart rate while gripping
in silence was 88 BPM and the mean heart rate while gripping while loud music was playing was
91 BPM. This was a 3.4% increase in heart rate while loud music was playing as compared to no
music (Figure 3). Using a paired two-sample, two-tailed t-test a p-value of 0.029 was calculated.
Therefore the 3.4% increase in heart rate is significant for loud music while gripping.

Data was taken for the soft music group (n=23) to determine the heart rate during silence
and in the presence of soft music both at rest and during grip. There was an increase in heart rate
when soft music was playing. The mean heart rate at rest without music was 76 BPM and the
mean heart while soft music was playing was 80 BPM. This showed an increase of 5.8% (Figure
4). A paired two-sample, two-tailed t-test was used to compare the resting heart rate in silence to
the resting heart rate while soft music was playing, and this returned a p-value of 0.011. This
suggests a significant increase in heart rate when soft music was played.

Additionally, heart rate was measured for soft music and silence while the participants
were gripping. The mean heart rate during silence was 85 BPM and the mean heart rate while
soft music was playing was 86 BPM. This was an increase of 1.3%, and using a paired
two-sample, two-tailed t-test this increase gave p > 0.05 (Figure 4). This suggests that the
increase was not significant.

A cross trial analysis showed no difference in a comparison between the soft music silent
baseline and the loud music silent baseline. The average heart rate for the silent baseline of the
soft music trial at rest was 76 BPM whereas the average heart rate for the silent baseline of the loud music trial at rest was 79 BPM (Figure 5). In a two sample, two-tailed t-test, the p-value was $p > 0.05$. This data was similar for the silent baseline of the two trials during the clench, as the average heart rate for the silent baseline of the soft music trial during clench was 85 BPM and the silent baseline for the loud music trial during clench was 88 BPM (Figure 6). The two sample, two-tailed t-test resulted in a p-value of $p > 0.05$. In both cross trial comparisons, the difference in silent baseline values were therefore insignificant.

Additionally, the data for the music exposure to soft and loud music was compared. The average heart rate with music present for the soft music trial at rest was 80 BPM whereas the average heart rate at rest, with music present, for the loud music trial was 84 BPM (Figure 5). In a two sample, two-tailed t-test, the p-value was $p > 0.05$. Then, during clench, the average heart rate for the soft music trial was 86 BPM and the loud music trial average heart rate was 91 BPM (Figure 6). The two sample, two-tailed t-test resulted in a p-value of $p > 0.05$. Overall, in all cross trial comparisons between soft and loud music, the differences in baseline values as well as the differences in heart rate during the clench phase were insignificant.

Grip strength data showed a decrease in clench force when comparing the absence of music to soft music. The mean grip strength of the silent baseline during the soft music trials was 15 kg. The grip strength for the clench while soft music was present was 13 kg (Figure 7). Therefore, there was a 9% decrease in grip strength during the soft music clench trial, as compared to the baseline. The data was analyzed using paired two-sample, two-tailed t-tests. Comparing the soft music group (n=23) to the data taken in silence during rest, the two-sample, two-tailed t-test resulted in a p-value of 0.013, suggesting a significant decrease in grip strength in the presence of soft music.

Next, there was a decrease in grip strength during the loud music trial. During this trial, the mean grip strength of the baseline was 16 kg. In the presence of loud music, the mean grip strength was 16 kg (Figure 7). This produced a 0.30% decrease in mean grip strength in the presence of loud music as compared to the baseline. When analyzed with a paired two-sample, two-tailed t-tests, the resulting p-value was $p > 0.05$. Therefore the decrease in grip strength in the presence of loud music is was not significant.
When comparing the average mean grip strength of the silent baselines for both trials (loud and soft), there was no difference. The average mean grip strength for the silent baseline of the soft music trial was 15 kg, whereas the average mean grip strength for the silent baseline of the loud music trial was 16 kg (Figure 7). When compared in a two sample, the p-value was p > 0.05, making the difference between the grip strength of the baselines insignificant. Again, in a cross trial comparison of the average mean grip strength between the two trials there was no difference, even with music present. The average mean grip strength value of the soft music trial was 13 kg with soft music present. With loud music present in the loud music trial, the average mean grip strength value was 16 kg (Figure 7). Two sample, two-tailed t-tests were conducted to compare the grip strength between the loud music and soft music exposure groups. During the exposure to the two volume levels of music, the t-test resulted in a p-value of p > 0.05. Therefore, there was no significant change found between the groups such that louder or softer music was significantly different.

The last variable measured was average maximum electromyography (EMG). The data was analyzed using a paired two-sample, two-tailed t-test to determine if EMG in the absence of music differed from EMG in the presence of music. For the loud music group, the average maximum EMG with loud music present was 2.0 mV. The average maximum EMG for this group in the absence of music was 2.2 mV. This is a 10% decrease in average maximum EMG when loud music was playing as compared to silent (Figure 8). The t-test returned a p-value of 0.017, indicating a significant decrease.

Next the data taken for the soft music group was analyzed. The average maximum EMG in the absence of music was 2.1 mV and the average maximum EMG while soft music was playing was 1.5 mV. This is a 22% increase in average maximum EMG while soft music was playing compared to silence (Figure 8). A paired two-sample, two-tailed t-test was run and produced a p-value of p > 0.05 and thus the increase in EMG during the soft music trial was insignificant.

An analysis of EMG cross both baseline EMG and and EMG during the presence of music, respectively, was conducted. The baseline for the soft music trial produced an average maximum EMG of 1.2 mV whereas the EMG value for the baseline of the loud music trial was
2.1 mV (Figure 8). A paired two-sample, two-tailed t-test produced a p-value of p > 0.05. Therefore the difference in EMG value between the two baselines of the trials is insignificant. Additionally, the EMG values in the presence of music was analyzed. The EMG value from the soft music trial with music was 1.5 mV (Figure 8). The loud music trial EMG value was 2.0 mV (Figure 8). The paired two-sample, two-tailed t-test resulted in a p-value of p > 0.05. This difference in EMG values was again insignificant.

Of the individuals we tested, 32% stated that they did not enjoy electronic dance music while 68% stated that they did enjoy electronic dance music (Figure 9).

The results of this study provide interesting insight to the relationship between the volume of music and the physiological responses of the body. Regarding the significant findings within this experiment, there was a significant increase in heart rate after the addition of loud music during rest and the clench. In addition, there was a significant decrease in EMG after the exposure of loud music. Next, there was a significant increase in heart rate after the addition of soft music during rest. Also, the grip strength significantly decreased after exposure to soft music. Comparing the data extracted for both the loud and soft music exposure groups, no significant difference was found between heart rate, grip strength, or EMG during the silent or music exposure segments of the experiment. Also, there was no significant change in grip strength with the exposure of loud music. For the soft music exposure group, there was no significant difference in heart rate during the clench in silence or significant difference in EMG during the clench.

**Discussion**

Our findings suggest that exposure to different volumes of music results in an increase in heart rate. This discovery is in agreement with the findings of the Levy et al. (2008) study. Specifically, their study stated that music results in arousal. From our study, the sympathetic nervous system was stimulated resulting in arousal and therefore an increase in heart rate. This finding is also in agreement with findings of Myskja & Lindbaek (2000). The research completed by Myskja & Lindbaek (2000) showed that music can cause physiological changes in
the body such as changes in heart rate. In our study, we witnessed a significant increase in heart rate after the addition of music.

This experiment contained confounding variables that may have influenced the results of this study. First, there was a higher baseline heart rate for loud music participants than the baseline for soft music participants. The loud music participants were the first 25 participants of the study. The timing of this is correlated with a stressful time of semester and the beginning of a Physiology 435 project. It was also the beginning of the study, in which the protocol and equipment were still being regulated. The external stressors of the time could be a possible reason for the significant discrepancies in the baseline heart rate.

Next, there was a large margin of error in grip strength for the loud music group. This stems from the large chance of variation in participant on many bases. For example, if the fingers were not fully wrapped around the dynamometer before the start of the clench, the maximum clench force could be less as they spent more time reaching tension before moving into isotonic force. It is also important to note that there could be difference between genders. This should be considered in future studies.

Another variable could come from the sequence of the experiment. By completing two subsequent grip strengths, the participants may have become fatigued after the first grip and therefore could not perform at an optimal level for the second grip. The next experiment could be done in a two week period or with a greater recovery time between trials.

Next, the participant’s music choices varied which could have affected individual performance. Of the individuals we tested, 32% stated that they did not enjoy electronic dance music, while 68% stated that they did enjoy electronic dance music. This may have had an impact on our results since a large percentage of the participants did not enjoy electronic dance music. Additionally, feelings such as nervousness or discomfort due to the presence of experimenters could have affected the results.

In future experiments, the participant population should be expanded to become more representative of society as opposed to only individuals within Physiology 435 at the University of Wisconsin-Madison. An increase in the number of participants could also improve the significance and accuracy of the experiment. Additionally, this experiment could potentially
provide better insight if completed in two weeks rather than in one trial as the sequential grips may result in confounding fatigue. An aerobic exercise, rather than an anaerobic exercise, could also be investigated as to see how the physiological response changes over time. Lastly, it would be important to test whether participant preferences for EDM in conjugation to an experimentally set volume has an effect on the physiology of the participant. This experiment should be conducted again as a blind study, randomly selecting the soft or loud volume protocol, and analyzed on the basis of affinity for EDM music and also difference of gender.

Overall, music, long considered an ergogenic aid, has been studied in depth in its relation to rhythm and tempo with increased performance and mood, making it a common addition to workout routines. Our experiment supplemented the present research by looking into the relationship of volume on the physiological response by looking into this question-- does the perceived benefit of loud music have an effect on the body or is the benefit all psychological? According to our data, there are no significant increases to the physiologic responses of muscle stimulation and grip strength. However, there was an increase in heart rate when volume was present which further supplements the conclusion that music has an ergogenic effect.
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Figures and Legends

Figure 1. Sequence of Procedure.

Figure 2. Using the Biopac Student Lab system, a segment of Participant #3 data is presented during a clench with exposure to music.
Figure 3. This figure compares the average heart rate for silence to loud music exposure at rest and during clench. * Denotes significant change from baseline.

Figure 4. This figure compares the average heart rate for silence to soft music exposure at rest and during clench. * Denotes significant change from baseline.
Figure 5. This figure compares the average resting heart rate for the silent, soft, and loud music exposure groups. * Denotes significant change from baseline.

Figure 6. This figure compares the average heart rate during the clenching portion of the experiment during the silent, soft, and loud music exposure groups. * Denotes significant change from baseline.
**Figure 7.** This figure compares the average grip strength for the silent, soft, and loud music exposure groups. * Denotes significant change from baseline.

**Figure 8.** This figure compares the maximum EMG for the silent, soft, and loud music exposure groups. * Denotes significant change from baseline.
Figure 9. This graph depicts the number of participants that stated they enjoyed or did not enjoy electronic dance music in the pre-study questionnaire. 68% enjoyed electronic dance music, while 32% did not enjoy electronic dance music.