Fall 2015

# Music and Medicine

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## Recommended Citation

Zink, Thomas, "Music and Medicine" (2015). *WWU Honors Program Senior Projects*. 24.
https://cedar.wwu.edu/wwu_honors/24

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WWU Honors Program Senior Project

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## Preface

Music is an extremely powerful modality. It has the ability to produce chills, motivate a crowd, induce trance or even bring us to tears. It is something that we all have experience with, save for those who are hearing impaired. For me, music has been an incredible journey. I started at a young age tinkering on the piano, then switched to saxophone, and finally trombone, which has carried me to university, and will hopefully be a part of my life for some time to come.

As I became better at playing trombone, I found my self practicing more and more, until finally trombone had started to define who I was; who I am today. It is like the old saying one of my coaches used to say, “There are people who play football, and then there are football players.” This describes the phenomena that at some point, an activity ceases to be something one simply does, and begins to intertwine into one’s life, becoming an extension of self. However, that does not mean the activity dictates every decision we make. When I arrived at college, I found a new interest in health sciences and delved into a different realm of study. While this usually leads to an abandonment of musical performance, trombone was so much a part of who I was, such a passion, that I continued play. At this point my life seems to have split. Part of me was devoted to several ensembles, while the other part was in vigorous pursuit of a new found dream: to become a physician. This split in my life continued to exist until recently, when I was asked about how I, a person who was passionate about music, would incorporate music in my future medical practice. To this I had no answer. I had never entertained the idea that two very separate parts of my life could somehow be integrated. As I thought about the question, the more apparent it became that I needed to find some answers. I needed to totally reexamine how I saw my self, how I looked at music and at medicine.

I continued to ponder the question, and came to the realization that just talking about music or playing it in the waiting room was not good enough. There had to be more. As someone who is fascinated in physiology, I came to the conclusion that physiology must have the answer. If I could see how music is used in the clinic, and understand it at the deepest level, then maybe I could come to a satisfactory answer to my question. Thus, my project was born.

As my project progressed, my advisor recommended that I do an experiment to illustrate some of the physiological effects I had found in my research. With a lack of experience in experimental research, I was reluctant; however, I realized that my inexperience was just the reason to do an experiment. What better way to build experience? As I began to think about my experiment, I became more and more excited. It seemed like it would all come together very smoothly. However, there was one part I had not foreseen. Because my study involved human subjects, I needed ethics board approval before I could run any trials, and because my project was an independent study project, it did not meet the criteria for a waiver of review. Thus, I started the arduous process of transforming my proposal into an official protocol, which includes an extensive breakdown of parameters not always discussed in a simple proposal, including methods to maintain confidentiality and a complete consent form. Additionally, I needed to become NIH certified in Protecting Human Study Participants. Not one to give up, I continued to work on the project, got approval, and was able to carry out the study.

Fortunately for me, even though my results did not come out crystal clear and my experimental design ended up being less sound than I had anticipated, the experience I gained from carrying out the project has proven invaluable. Foremost, the experience writing a protocol and working with an IRB is extremely useful. It is a preferred qualification for many entry level clinical research jobs, and this experience, along with my NIH training, my help me gain employment that would be very significant on a medical school application. Along the same lines, research experience, particularly with human subjects, is also extremely valuable in the clinical research field and on medical school applications. Further, by integrating my two areas of interest, I have developed a better sense of my self and my future, which will hopefully translate to depth of character and maturity.

In discussing what I have gained from this project, I would be remised not to mention all I have learned in terms of the clinical applications of music. From my research, it is clear that music can be used as an effective intervention in many different cases including cognitive disorders, disorders effecting gait such as Parkinson's, rehabilitation for traumatic brain injuries, and managing anxiety and pain. In particular, the possibility that music may be used instead of drugs to augment pain and anxiety is extremely attractive, because music is much more cost effective and carries no adverse side effects. With all of these potential uses in mind, I will incorporate music into my practice by providing playlists and and recommending the use of music for patients facing surgery or dealing with chronic pain or anxiety.

Fundamental to the acceptance of music as a clinically significant analgesic is an understanding of the underlying physiological mechanisms. I believe that much of the resistance to using music by allopaths stems from a general disregard for any treatment that does not have an established physiological basis. This disregard, or dismissal rather, is directly related to the relationship between science and medicine, and a wiriness of too-good-too be true natural remedies that are generally ineffective. The former relates to the roots of modern medicine in biology. Physicians are not just practitioners. They are both clinicians *and* biologists – and they often think like biologists. For the most part, this is effective. It has brought modern medicine to the highly effective force it is today. No longer do healers use mercury or blood letting to treat a common cold. Instead, most treatments have been developed in a laboratory with critical empirical evidence supporting their efficacy and a general understanding of the underlying mechanisms. This serves to protect the patient and maintain medical practices that are highly evidence based. Of course, there is innate bias in this system. The tools and techniques employed in molecular biology and chemistry are far more advanced than the tools and techniques used to measure the effectiveness of other modalities. Thus, it is easy to prove the effectiveness and mechanism of action of a drug. As such, allopathic medicine focuses on pharmacology. However, for other modalities, such as music, the lack of sophisticated equipment and understanding of related physiology (such as an understanding of the nervous system) limits the ability to generate empirical evidence that supports their use, and they are generally ignored despite a wealth of anecdotal evidence and personal experiences with the modality. (In the case of music, instrumental performances have been used in hospital wards for centuries to calm patients and help them heal, yet music is still considered an alternative therapy. Further, we have all experienced the power of music to effect our mood. Despite physicians wait for empirical evidence.) So, to effectively integrate music into the clinic for the management of pain and anxiety, both of which can be managed with prescription drugs, it is imperative to develop an understanding of its mechanism of action.

Luckily, through this project I uncovered a wealth of studies that illuminate the mechanisms of music's effects on anxiety and pain. Anxiety seems mostly related to the ability of music to stimulate the parasympathetic nervous system, which helps calm people down. This is likely done through stimulation and entrainment of the limbic system, and a resultant entrainment of nervous impulses transmitted through the vagus nerve and the hypothalamic-hypophyseal tract. The amygdala, which is implemented in sensations of fear and anger, may also be inhibited, allowing music to block negative feelings. Analgesia also appears to be produced through musical stimulation of the limbic system, but in contrast to anxiety, the major effect is inhibition of nociception through dopamine and opioid release, not parasympathetic activation. While some studies discuss the possibility that music induced analgesia works through the gate theory of pain modulation, I believe these assertions come from a fundamental misunderstanding of the theory by the authors who cite it. The theory, which states that non-noxious stimuli limit the amount of noxious stimuli that reach the brain, thus limiting pain perception, includes a deeper element. The effect does not occur due to a simple limit on stimuli that the brain can process similar to a maxing out CPUs on a computer, but rather works by inhibition of nociception action potential transmission by other sensory receptors, which trigger a release of inhibitory neurotransmitters that hyperpolarize the ascending nociception neuron. This occurs in the spinal cord, not in the brain. Thus, sound stimuli, which is transmitted through the third cranial nerve directly to the thalamus of the brain, would likely not be able to to produce such an effect, as auditory tracts do not synapse with the inhibitory interneurons in the spinal cord. As you can see, these mechanisms are complex, and may not necessarily be understood by a patient. However, when discussing my practice with other doctors or admissions panels, knowing these mechanisms will allow me to passionately defend my use of music using ever-so-important empirical evidence.

With that all in mind, I come away with this project with a wealth of experience, new found knowledge, and a sense of accomplishment. As I look toward a career in medicine, I will continue to play trombone and follow research on music, with the peace of mind that comes from fully integrating my interests. I am grateful for all of the help and advisement I have received on the project, but am also proud of the independence I demonstrated in my self-motivated work. I am also thankful for have had the financial support of the Adam's Honors Scholarship and an Honors Department Tuition Waiver. I hope that this project helps to educate others on the use of music and demonstrate some of the key findings in the field.

Sincerely,

Tom Zink

# The Effect of Music on Exercise Recovery

## Introduction

Music therapy is not a new concept, although its acceptance by the medical community as a clinical modality is just beginning to grow. This newfound acceptance is the result of recently emerging empirical evidence supporting the efficacy of music in a range of applications. Using music to aid learning, either in recovery from brain damage or to overcome neurological disorders is widely accepted. For instance, music has been used to help patients learn to speak after traumatic brain injury (Schlaug, 2009). Much of these music learning programs are based off the Tomatis method that uses specifically adapted music tracks to stimulate cerebral blood flow and facilitate the formation of new neural pathways (Thompson, 2000). Music therapy is also used regularly to treat anxiety. These applications are easily accepted as nearly everyone has grown up with intimate musical experiences; music's power to affect mood and set a tone are well recognized because it is a part of daily life.

The medical potential of music is not isolated to neuropsychology. Music has also been shown to have profound effects in the medical clinic. In particular, evidence suggests that music used prior to, during, and after surgery reduces patient anxiety, pain, and sedative/analgesic requirements (Ayoub, 2005; Ganigdali 2005; Good, 2001; LePlage, 2001; MacDonald, 2003; Moris 2012, Nilsson, 2003). The physiological basis of these results is currently under investigation, although evidence supports several theories. First, music appears capable of stimulating the parasympathetic nervous system, as exposure to deactivating music (calm, >120BPM) has been shown to cause decreases in BP, HR, and RR; responses that are consistent with parasympathetic activation (Bergstrom-Isacsson, 2007; Chan, 2008, Moris, 2012). It has also been suggested that music may activate the dopaminergic systems in the limbic system or opioid release in the periaqueductal grey (Hseih, 2014; Garza-Villarreal, 2014). Further, it has been suggested that music analgesia may function through modulation of pain gaits in the CNS by occupying part of total afferent input capacity and inhibiting nociception transduction, effectively closing down pain pathway transmission (Whitehead-Pleaux, 2007). A placebo effect does not seem to be at play (Hseih, 2014). Regardless of explanation, the potential of music as an adjunct to analgesics in pain management is promising, and could have significant implications in reducing medication costs and drug side effects, as music is both inexpensive and bears no side effects.

**Commented [RD1]:** FGates?

Music has also been studied in athletic settings. As anyone who has worked out with headphones has realized, listening to music during exercise improves performance and decreases rater-perceived exertion, allowing for longer, more intense workouts. Music can also be used in race settings, such as cycling, where higher tempos are correlated with higher athlete paces (Waterson, 2010). Given the similarities between post-operative, stress, and post-exercise states (increased pain, potentially elevated BP, HR, RR), it is logical to question whether the same recovery effects observed from music in clinical settings may also apply to exercise recovery. Few studies have been done to answer this question, although the effects of music do appear to cross over into exercise recovery, likely because the same physiological responses are being elicited, in particular parasympathetic activation. A study by Desai, Thaker, Patel, and Parmer (2015) found that listening to slow music significantly decreased recovery times (return to resting HR and BP) after a 3 min step-test. Another study by Savitha, Reddy, and Rao (2010) also found that slow music aided recovery times, while a study by Eliakim and Colleagues (2010) found that music during recovery enhanced lactate clearance. Due to the relatively limited study of music in exercise recovery, further study is justified to corroborate or disprove results and provide further insight into the analgesic effects of music. Approval for this study was granted by the Western Washington University Institutional Review Board.

## Methods

Seven college-aged subjects with varying musical backgrounds and physical activity levels participated in the study. Prior to testing, the subjects self-reported their height, weight, age, physical activity levels, and musical background. Their resting HR, SDP, and DBP were then measured using a pulse oximeter and an automated blood pressure cuff placed on opposite arms according to equipment uses protocols. The subjects were also asked to rank their perception of fatigue (RPF) and pain (RPP) on 0-10 scales (Figure 1).

Following pre-testing the subjects were guided through a dynamic warm-up as outlined by the NSCA (2008) and instructed to run 600m around a standard outdoor track as fast as possible. Immediately following the run, the subjects' HR, BP, RPF and RPP were measured, and were continually measured every 2 min for 16 min. After a minimum of 24 hrs, the subjects repeated the procedure. On the first day of testing 4 subjects were slow, familiar music to listen to during recovery. On the second day of testing, these subjects were not provided music, while the other three subjects that did not listen to music on the first test day were provided music to listen to. Thus, each subject recovered under the influence of music and no music. The music was chosen by the subjects and screened by the investigator to ensure the tracks were below 120 bpm. Music was listened to through over ear headphones.

## Calculations

Mean decrease of the test measures from 0-2 min, 0-4 min, 0-8 min, and 0-16 min was calculated using the following equation:

$$MD = \frac{1}{n}\sum([x0 - x_t]1 + \cdots + [x_0 - x_t]\mathrm{n})$$

A mean maximum decrease was also calculated using the highest and lowest values found for each measure for each subject, regardless of time of occurrence. Single variable ANOVA was implemented for statistical analyses using Microsoft Excel.

## Results

Subject characteristics and demographics are summarized in Tables 1 and 2. Environmental conditions were generally cold and dry, although one subject did run in the rain.

Table 1. Subject Characteristics

| | |
|---|---|
| Age (yrs) | 21.3±1.8 |
| Height (in) | 69±2 |
| Weight (lbs) | 168±19 |
| HR (bpm) | 72.6±10.2 |
| SBP (mmHg) | 130±17 |
| DBP (mmHg) | 85±21 |
| Run Time (sec) | 144.1±21.8 |

Table 2. Subject Demographics

| | |
|---|---|
| Subjects | 7 |
| Males | 5 |
| Females | 2 |
| Music Background | 5 |
| Physically Active | 4 |

RPP decreased rapidly over the first 6 min and then leveled out (Figure 2). RPF also decreased more rapidly over the first 6 min, but then continued to slowly decline for the remainder of the recovery period (Figure 2). HR declined extremely rapidly over the first 2 min and then continued a slow decline (Figure 2). SBP declined slowly for 8 min and then showed a slight upward trend while DBP tended to undulate up and down through out the recovery period (Figure 2).

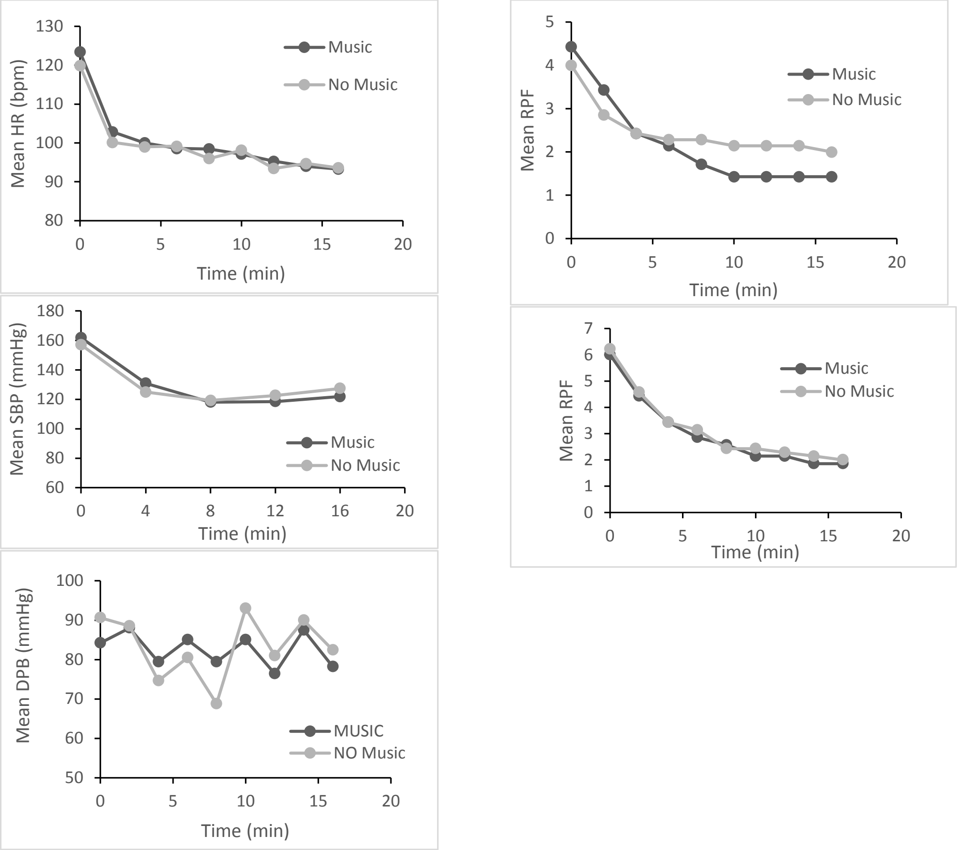

**Figure 2.** Mean HR, SBP, DBP, RPP, and RPF during a 16 min recovery period following a 600m run.

The music treatment displayed greater mean decreases in HR, SPB, and RPP compared to the no music treatment over all time intervals while RPF and DBP showed greater mean decreases during the no music treatment over all time intervals (Figure 3). However, there was no statistically significant differences between either treatment for any test measure.

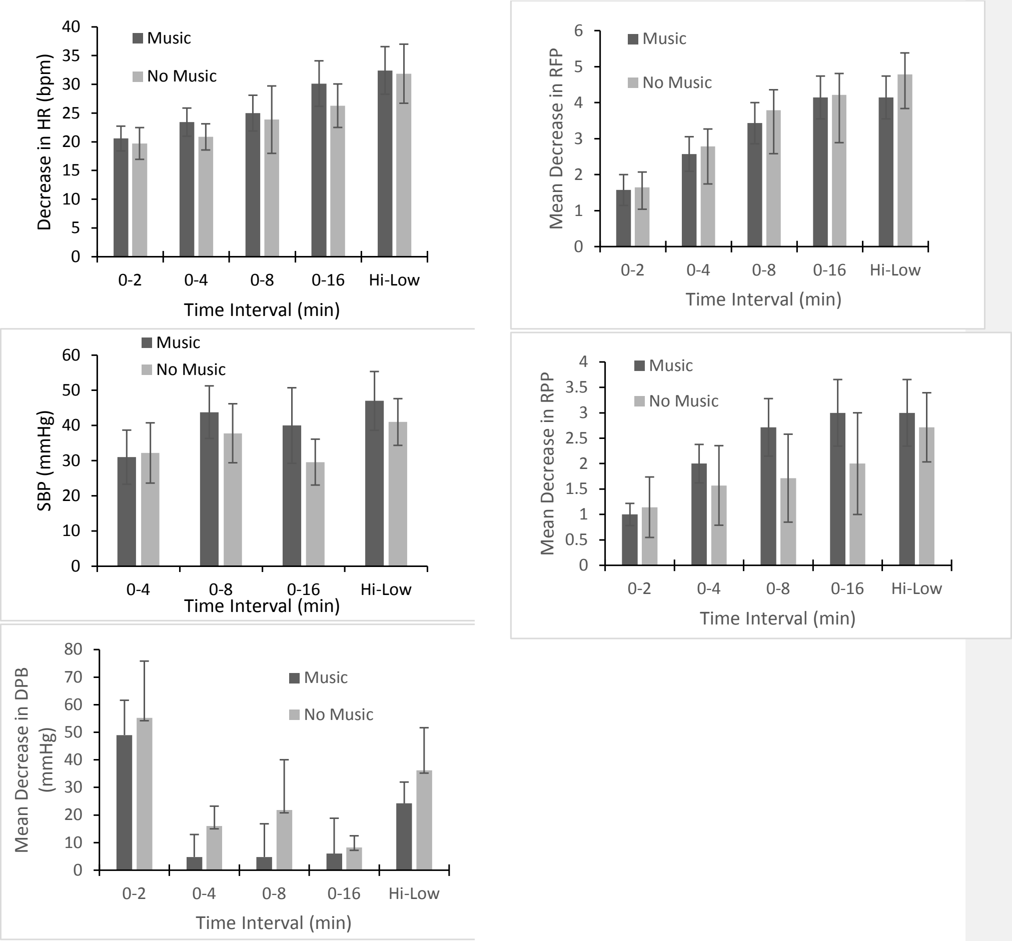

**Figure 3.** Mean decreases from 0-2 min, 0-4 min, 0-8 min, 0-16 min, and highest to lowest recorded values for HR, SBP, DBP, RPF, and RPP during 16 min of exercise recovery with an without music following a 600 m run.

## Discussion

The trends of recovery over time for HR and BP were consistent with established understanding of HR and BP during and after exercise. HR dropped of quickly, which is expected, as HR is easily controlled and responds quickly to changes in conditions. SBP decreased slower, but in a similar fashion, reflecting the delayed physiological control of SBP in comparison to HR. It is likely these decreases are the result of parasympathetic activation and sympathetic withdrawal at the cessation of exercise. The lack of a declining trend in DBP reflects the established understanding the DBP is not greatly effected by exercise. Since the run was of a relatively short duration, DBP likely did not rise significantly, and therefore would not have room to recover. Ratings of RPP and RPF decreased over time, as is expected with recovery.

The observed greater decreases in HR, SBP, and RPP that resulted under the music condition were consistent other studies (Desai, 2015; Savitha, 2010). Greater decreases in HR and SBP are likely the result of increased parasympathetic activation mediated by musical stimulation of the limbic system, as has been observed in other studies (Bergstrom-Isacsson, 2007; Chan, 2008, Moris, 2012). In contrast, the analgesic effect observed in this study is more likely related to the disruption of nociception stimuli from the leg muscles resultant from dopamine and endogenous opioid release from the ventral tegmental area and nucleus accumbens, respectively, as music has been shown to increase the activity of these areas of the brain (Hseih, 2014; Garza-Villarreal, 2014, Menon, 2005). Greater decreases in RPF is contradictory to other findings. However, while it was predicted that music would help ease perceptions of exhaustion, it may be that the calming effect of slow music resulted in a perception of decreased arousal relative to the no music state, which subjects may have indicated with a higher RPF rating. Thus, this observation finding still supports the use of slow music for relaxation purposes, as it illustrates music producing a deactivating effect. Greater mean decreases in DBP under the no music treatment are likely due to error and natural variability, as it is inconsistent with other studies.

The lack of statistical significance in this study is most likely due to the small sample size, not a lack of a music effect. Experimental design could have also affected results. For instance, running out side in the cold could have limited physiological responses to exercise, and potentially attenuated subsequent physiological responses, as there would not be as much room for recovery. The exercise stress chosen may not have been strenuous enough to elicit strong physiological responses, which again could limit the degree to which music could affect recovery. Similarly, subjects may not have run at full speed for each trial, and inconsistencies between days could have added variation to the data not accounted for in analysis. To improve on this experiment, it would be better to perform the tests indoors using an exercise modality where workload can be precisely controlled, such as a stationary bike or treadmill.

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