Spring 5-2-2023

Effect of motivational music on peak knee torque, perceived exertion, and enjoyment in college-aged individuals

Arianna Cole
Binghamton University--SUNY, acole11@binghamton.edu

EFFECT OF MOTIVATIONAL MUSIC ON PEAK KNEE TORQUE, PERCEIVED EXERTION, AND ENJOYMENT IN COLLEGE-AGED INDIVIDUALS

Honors Thesis

Integrative Neuroscience

Spring 2023

BY

ARIANNA COLE

Department of Psychology

Binghamton University

State University of New York (SUNY)

Vipul Lugade, Ph.D.

Sung Joo Lim, Ph.D.

Emily Zale, Ph.D.

Acknowledgments

I would like to express my gratitude to my honors committee chair: Dr. Vipul Lugade for supporting my interest in research, encouraging me to complete an honors thesis, and always making himself available to answer any questions I have regarding the scope and methodology of my research and analysis. This project simply would not have happened without his suggestion and support.

I would also like to thank committee members; Dr. Sung Joo Lim and Dr. Emily Zale for supporting my work throughout its completion and for providing feedback and professional insight on its contents. Recruitment through the SONA Psychology Pool on campus would not have been possible without their support.

I am also grateful to graduate student, Dr. Molly Torbitt for providing me with professional insight in the field of physical therapy and for always being available and willing to provide me with editing help, feedback sessions via appointment, and moral support.

Finally, I would be remiss in not mentioning my family, especially my parents. Their belief in me has kept my spirits and motivation high during this process.

Abstract

There is a general consensus in previous and current literature that the incorporation of music in exercise has the potential to benefit performance (Karageorghis 2020; Terry et al. 2019). Research on the potential benefits of music in rehabilitative exercise has become more prevalent but has mainly focused on music and the rehabilitation of neurological conditions such as Parkinson's disease or stroke (Craig et al. 2015; De Bartolo et al. 2020; Grau-Sánchez et al. 2022; Katlen da Silva et al. 2021; Särkämö 2018). Research in a more general rehabilitative setting has not been explored as widely and this is the aim of the current study. A total of 28 college-aged individuals were randomly assigned into two groups, a music or a no-music group, and asked to participate in rehabilitative exercises with or without motivational music (a rhythm of 120 bpm or more; Karageorghis 2020). Peak knee extensor and flexor torque were measured and analyzed between groups (Biodex® Quick Set Dynamometer System 3). The effects of music were evaluated across three speeds in isokinetic testing: 60, 180, and 300 degrees per second to see if music had an effect across different speeds. If music produces higher values of peak torque, clinicians may be able to increase strength output simply with the addition of music. This study additionally attempted to take a more interdisciplinary approach by also including a psychophysical measure of perceived exertion and a psychological measure of enjoyment. No significance was found between groups for measurements of peak torque, perceived exertion, and enjoyment. However, as more research is revealed about the potential benefits of music on exercise and rehabilitation, future research is encouraged and may reveal differing results.

Introduction

Humans have a musical footprint of over 43,000 years (Karageorghis, 2020) and music has been culturally ingrained in societies worldwide (Damasio et al 2018; Karageorghis 2020; Maes et al, 2014). Humans have a genetic predisposition to physiologically respond to music (such as through changes in respiration, heart rate, skin conductance, motor patterns, neuroendocrine response, and immunological function) and synchronize motor activity to rhythm (Terry et al 2019). The ability to recognize, interpret, and respond to music is even observed in infants aged 3-10 months (Damasio et al. 2018; Mazokopaki and Kugiumutzakis, 2009). Thus, it is not surprising that music has been adapted to many modern aspects of life including exercise.

At the gym, music plays over the speaker and people often listen to music via headphones during exercise; runners listen to music during roadside treks, and music is also played at many sporting events to evoke “improved feeling and enjoyment” (Terry et al. 2019). However, the researched effects of music on exercise and performance are ongoing and controversial. Music has previously been shown to prime movement (Karageorghis 2020; Maes et al. 2014) and there is more recent evidence suggesting that music does have ergogenic or exercise-enhancing effects (Ballmann et al. 2021; Biagini et al. 2012; Cox et al 2020; English, Mavros, & Jay 2019; Karow et al. 2020; Stork et al. 2019; Thakare, Mehrotra, & Singh 2017; Terry 2019). However, some studies have demonstrated only a small to moderate increase in exercise parameters such as the rate of perceived exertion (RPE) or levels of maximal oxygen consumption due to music (Karow et al. 2020; Terry 2019) or the number of repetitions on a strength-based repetition to failure protocol in resistance exercise (Moss, Enright, and Cushman 2018).

Other studies have no significant results and have observed no ergogenic effects with the addition of music (Aton 2018; Castañeda-Babarro et al. 2020; Moss, Enright, & Cushman 2018; Pujol et al 1999). Disadvantageous effects of music were found for peak velocity production on the bench press. However, this could be due to a fatigue effect and a lack of counterbalancing, since all participants completed the bench press after power and strength squat tests (Moss, Enright, and Cushman 2018). Nevertheless, there is a consensus that music has at least some benefits on exercise whether it be physical, psychological, psychophysical, or physiological (Ballmann et al. 2021; Castañeda-Babarro et al. 2020; Cox et al. 2020; English, Mavros, & Jay 2019; Moss, Enright, & Cushman 2018; Stork, Karageorghis 2020, and Martin 2019; Thakare, Mehrotra, & Singh 2017; Terry 2019).

The type of music can also influence exercise performance and response. Research on pace (beats per minute (bpm)), genre, and participant self-selected versus researcher-selected music show that there must be some level of music preference by participants for there to be significant differences in exercise performance and/or psychological and psychophysical-related parameters (Ballmann 2021; English, Mavros, & Jay 2019; Karageorghis 2020; Karow et al. 2020; Terry et al 2019). *Preferred music* may refer to a particular tempo and rhythm (Karageorghis 2020; Terry et al. 2019), a particular or preferred genre (Ballmann 2021; Karageorghis 2020; Moss, Enright, and Cushman 2018), a particular key (major vs minor depending on cultural background (Karageorghis 2020), or music familiarity (Terry et al. 2019). Many studies in the domain of music and exercise with ergogenic findings use self-selected music as it realizes many of the preferred music guidelines for each participant (Ballmann 2021; Ballmann et al. 2021; English, Mavros, & Jay 2019). However, in certain settings, using self-selected music is unrealistic such as community gym speakers and clinical and rehabilitative settings. In these situations, motivational music: music with 120+ beats per minute and/or characterized with a strong rhythm (Karageorghis 2020) is favored.

The use of music in physical therapy and rehabilitation has also revealed some encouraging results, particularly in the treatment of neurological disorders such as Parkinson's disease (Craig et al. 2015; De Bartolo et al. 2020; Fritz et al. 2013; Grau-Sánchez et al. 2022; Katlen da Silva et al. 2021; Särkämö 2018). However, the effects of music in a more general rehabilitative (more diverse population of individuals with varying types and degrees of physical injury) setting has not been as widely considered (Grau-Sánchez et al. 2022).

Isokinetic testing allows one to test for *torque*: "the ability of a force to cause rotation on a lever" (Duarte et al. 2018, p. 2), exerted by muscles during the range of motion of a joint at a predetermined velocity. Isokinetic testing is, therefore, a reliable and valuable tool in physical therapy, athletic training, and rehabilitation to test for strength with a controlled velocity factor (Dragicevic et al. 2015; Duarte et al. 2018). Godwin et al. 2014 investigated the effect of an instrumental version of the song "Eye of the Tiger" on 19 healthy college-aged students' peak torque generation in knee flexion/extension, but this study did not find significant effects. However, "Eye of the Tiger" has a rhythm of 109 beats per minute which is not considered motivational (Godwin et al. 2014; Karageorghis 2020). Furthermore, this study only analyzed peak torque at 60 degrees per second and did not measure any other variables to indicate the potential benefits of music. The effect of music on faster speeds (180 degrees per second and/or 300 degrees per second) could have been analyzed aside from just 60 degrees per second. Additionally, the rate of perceived exertion could have been analyzed to indicate whether those in the music group displayed a "reduced exercise consciousness" (Terry et al 2019) associated with music whereas maximum torque would be produced with less feeling of fatigue. The effects of music on psychological factors such as overall enjoyment could also be measured to see if music has an interdisciplinary impact.

The primary purpose of this study was to examine the effects of motivational music on isokinetic testing for peak torque across three different speeds in a unilateral (dominant leg) knee flexion/extension exercise in healthy college-aged individuals. A psychophysical measure of perceived exertion and a psychological measure of enjoyment were also analyzed to take a more interdisciplinary approach to analysis. It was hypothesized that participants in the music condition would have a higher peak torque across all speeds. However, because there is less resistance to movement at higher speeds, a decreased peak torque value for isokinetic testing was expected at increasing speeds across both groups. Secondary hypotheses included a lower rating of perceived exertion in the music group as well as a higher enjoyment of isokinetic testing.

Materials and Methods

Participants

A sample size of n= 28 was determined based on an effect size of d = 0.5, alpha level of 0.05, power of 0.80, and correlation among repeated measures of 0.7 for a repeated measure two-way ANOVA, with differences in velocity (60, 180, and 300 deg/sec) as the within-subjects factor and group (music and no music) as the between-subjects factor (G*Power 3.1.9.7). Because there is not enough research on isokinetic testing between 2 separate groups for a repeated measures ANOVA, the common standard effect size (d=0.5) was used in determining the sample size. Young adult participants, 18-34 years of age, were recruited from Binghamton University, State

University of New York. Most individuals received course credit for volunteering via the SONA psychology research pool whereas 3 individuals were a part of the Pre-Physical Therapy and Occupational Therapy Club on campus and participated out of interest and to receive a tour of the Motion Analysis Research Laboratory. Exclusion criteria across all individuals included any current or previous (within the last 6 months) lower-body injury, cardiovascular, metabolic, or pulmonary disease, auditory diagnoses/limitations, or any contraindications (i.e. doctor's notes) to participating in exercise. Individuals were also encouraged to refrain from any fatigue-inducing exercise of the lower extremities on the day of testing prior to their appointment time to reduce the possibility of muscle fatigue during testing. This study was conducted in Binghamton University's Motion Analysis Research Laboratory. All participants provided written informed consent as approved by the university's Institutional Review Board prior to enrolling in the study (STUDY00003981).

Procedure

Participants were randomly assigned a number from 1-28 via a random number picker wheel after signing up for the experiment. Participants were randomized into either the music group or the no-music control using a random sequence generator from Google, where column 1 was deemed the music group (n=14) and column 2 was deemed the no-music control (n=14) (Figure 1). Participants were blinded as to which group they were assigned to and information regarding the addition of music was withheld. A debriefing process was held at the end of the study to inform individuals of this information and Binghamton University's Institutional Review Board approved all procedures.

Here is your sequence:

7	10
27	18
4	14
20	25
21	23
2	19
24	1
12	11
22	9
26	8
28	6
16	13
3	15
5	17

Timestamp: 2022-10-30 18:10:34 UTC

Again! Go Back

Figure 1. Randomly generated group assignments. Column 1 indicates the music group whereas column 2 indicates the no-music group

Upon entry to the laboratory, individuals were tested for leg dominance where participants were asked “If you were asked to shoot a ball on a target, which leg would you use to shoot the ball?” Self-report responses to this question yielded 100% agreement in observance to physically kicking a ball in both men and women (van Melic et al 2017). After determining dominance, individuals were weighed using a scale present in the lab. Individuals then were guided to the Biodex where they were seated and secured to the chair of the dynamometer. The non-dominant leg for the trial run was situated such that the lateral epicondyle of the femur aligned with the dynamometer (Figure 2). The two buckles going across the chest were not placed across the individual as previous use of the Biodex revealed that they were unable to fit across all individuals of different weight values.

Figure 2. Biodex knee flexion/extension setup. Individuals were seated and strapped to the equipment as pictured above. The two buckles going across the chest were not placed across the individual. The lateral epicondyle of the knee was lined up with the dynamometer

Participants were then coached through the isometric knee flexion/extension task to find their maximum torque value. They were told that the dynamometer would hold their knee in place and they would have to push as hard as they could away from the dynamometer for 5 seconds (extension), get 30 seconds of rest, and push as hard as they could against the dynamometer for 5 seconds (flexion) during the task. Participants were then allowed 4 minutes of rest while they were informed about the isokinetic unilateral leg flexion/extension task. They were told that during the experiment, they were going to complete three tests of forward and backward knee movement with increasing speeds and repetitions with each trial. The first trial would be at the slowest speed with 5 repetitions, the second faster trial had 10 repetitions, and the final trial was the fastest with 15 repetitions. They were also told to push as hard as they can no matter the speed. The participant then completed the three-speed exercise on their non-dominant knee to get a feel for what they would be doing during the test set and was encouraged to notify the investigator if they felt any discomfort or if they had any questions. After the test set, the dynamometer was switched to perform the data collection of isometric and isokinetic peak torque on the dominant knee. The participant performed the isometric task as mentioned for the non-dominant leg. After the first 2 minutes of rest between isometric and isokinetic tasks, participants were again informed about the unilateral leg flexion/extension task protocol and were told again that they were going to complete three tests of forward and backward knee movement with increasing speeds and repetitions with each trial. The participant was also told that they would be asked to fill out 2 surveys rating their level of exertion and enjoyment based on their experience with the equipment after testing. The participant then went on to complete the task after the rest period subsided. Music was played for participants in the music group at the start of the first isokinetic test at 60 deg/sec immediately prior to gathering the range of motion limits via the Biodex software.

At the conclusion of the third exercise, participants were asked to respond to the rating of perceived exertion (Appendix 1), unstrapped from the dynamometer, and guided to a nearby table where they were asked to fill out the rating of enjoyment survey (Appendix 2). After the completion of these surveys, individuals were debriefed on the true purpose of this experiment and why information about music was withheld.

Variables

Music (Independent Variable)

Motivational music is defined as music with a tempo of 120+ beats per minute "and/or [is] characterized by pronounced rhythmical features" (Karageorghis 2020, p. 944). The music chosen for this experiment was a 140 bpm best hits workout mix found on YouTube (Fitness & Music, 2018). This playlist was selected for its easy availability (any individual could find this playlist on YouTube), strong emphasis on the motivational beat (rhythm section throughout the track), and its hour-long duration to ensure no disruption of the music during participant exercise. The music was played for the music group over a speaker (JBL charge 4) at a sound level that was normalized to a set amplitude using Audacity® software, had a fade-in of 20 seconds (Audacity®), and played averaging around 63.5db ± 0.417db as measured via the Sound Meter (Android) version 1.6 app by Smart Tools co. Sound levels playing through the speaker were measured seated in the Biodex around 20-30 minutes prior to the appointment time of each participant in the music group. This app was deemed the most accurate Android app for environmental noise sound determination in a study by Murphy and King in 2016. A measurement of ± 3.5db was determined to be the average differential of the true noise level given by the app (Murphy and King, 2016).

Peak Torque (Dependent Variable)

Measurements of peak torque (defined as the highest torque output of the joint produced by muscular contraction as a limb moves through its range of motion; Morrissey, M.C. 1987) were achieved through the use of the Biodex® Quick Set Dynamometer System 3. Peak Torque values were then normalized to body weight to give a peak torque (foot/lbs)/body weight (lbs) ratio in foot/lbs. A trained investigator performed all data collection. All participants had a familiarization session with the equipment where they performed the experimental protocol on their non-dominant knee before switching to the dominant knee. Prior to isokinetic testing, an isometric test for maximum torque was performed to achieve a baseline maximum torque per individual as a value of comparison to isokinetic testing. The isokinetic test was a unilateral (dominant leg) quadriceps/hamstrings 3-speed evaluation of knee flexion/extension. Participants' peak torque was measured at 3 different controlled velocities (60 deg, 180 deg, and 300 deg/sec). This test is commonly used bilaterally in athletic training and physical therapy to compare an injured knee's peak torque to an uninjured knee's peak torque (Andrews et al.); however, comparing bilateral torque values is not necessary for this study. Therefore, the dominant leg (for consistency between participants) was evaluated for peak torque in a unilateral evaluation. The unilateral Biodex test for peak torque was only tested across one session given the limited timespan of this research. However, the reproducibility of isokinetic peak torque in knee flexion/extension has been found within subjects after 2 test sessions a week apart (Duarte et al 2018).

Rate of Perceived Exertion (Dependent Variable)

To measure perceived exertion, Borg's Rating of Perceived Exertion (RPE) Category-Ratio Scale was used (Borg 1998). This assessment was given immediately following the assessment of peak torque (Appendix 1). Participants rate their level of exertion from the previous analysis of peak torque from 0 (*nothing at all*) to 10 (*extremely strong; "maximal"*).

Enjoyment (Dependent Variable)

Enjoyment was measured via the Interest/Enjoyment subscale of the Intrinsic Motivation Inventory (Cox et al. 2020; Ryan 1982). This test was administered after perceived exertion as a reflection of overall experience (Appendix 2). Participants rated how true a set of 7 statements pertaining to the enjoyment of the task were from 1 (*not true at all*) to 7 (*very true*). Examples of statements include: *I enjoyed doing this activity very much* and *This activity was fun to do.*

Analyses

Since measured variables (peak torque, rate of perceived exertion, and enjoyment) were of different domains (physical, psychophysical, and psychological), they were analyzed separately. A repeated measures ANOVA was run with isokinetic peak torque data whereas differences in velocity (60, 180, and 300 deg/sec) were the within-subjects factor, and group (music and no music) was the between-subjects factor. An independent sample t-test was run for isometric peak torque between gender as a part of the demographics to see if there were differences in maximum torque between gender. Independent sample t-tests were also run for the rate of perceived exertion and enjoyment data between music and no music. SPSS software was used for all analyses. Isokinetic peak torque data were normalized to body weight whereas peak torque values were divided by body weight (significance for all tests at $p < 0.05$). Analyzing the peak torque values in terms of a peak torque/body weight ratio allows the value of torque produced by each individual to be more comparable between individuals of different gender and weight.

Results

Demographics

Table 1 includes the descriptive statistics, mean, and standard deviations of all individuals in total as well as categorized by music and no music group. There was a higher number of females than males participating in the study. Overall there were 18 females and 10 males participating in this research. The mean age of individuals participating was 18.7 years (Table 1). 26 out of 28 individuals were right-leg dominant and one individual in the music group and one individual in the no-music group were left-leg dominant. The average weight for individuals was 147.2 lbs (table 1). Between males and females, males generally had a higher maximum (isometric) peak torque output than females. An Independent samples t-test between Isometric Peak Torque values in males vs females revealed a significant difference between mean values of both flexion and extension ($F_{flexion}$=6.725, p=0.015; $F_{extension}$=5.847, p=0.023).

Peak Torque

Peak Torque was normalized to body weight to give a peak torque/body weight ratio in foot/lbs. Lavene's Test for Equality of Variance revealed p-values greater than 0.05 across all speeds for both flexion and extension, thus, the homogeneity assumption of the variance is met. There were no significant differences between music and no music groups for peak torque values at any speed (Tables 3 and 4). There was also no significance between the 3 different speeds for flexion. At 180 degrees per second for flexion values, there was an increase in the value of peak torque in the music group. In the no-music group, there was a rise in the value of peak torque at 300 degrees per second (Figure 3). With that being said, there were no significant differences found between values of flexion at differing speeds in general (Table 3). The only significant value found was between the 3 different speeds of extension across both music and no-music groups (Table 3).

Perceived Exertion

No Significance was found in measures of perceived exertion between music and no music groups (Table 5). A Box plot was created comparing the means and general trends of the data (Figure 5). Overall, there was a little more variation in reported Perceived Exertion scores in the music group. Additionally, both groups reported lower levels of perceived exertion with mean values of 2.179 and 2.714 out of 10 for the no music and music groups respectively (Table 5).

Enjoyment

There was no significance in the measure of enjoyment between groups as well (Table 6). While there was not much of a difference in mean values, there was a little more variation in the no-music group whereas individuals tended to report a wider variety of scores (more scores in the twenties and mid to lower thirties) out of 49 while individuals in the music group consistently tended to report mainly higher scores (upper thirties to forties) except for 2 individuals (Figure 6).

Discussion

Clinical Implications

1. **Peak Torque**

Just as in the study by Godwin et al. in 2014, there were no significant differences between music and no music groups at 60 degrees per second. Furthermore, this study demonstrated no significant differences between groups at higher speeds (180 and 300 degrees per second) as well. However, while no significance was found, there were still some intriguing trends established in the graphical data. Overall, the music group still did have higher values of peak torque in comparison to the group without music (Figure 3 and Figure 4). However, generally as speed increases, peak torque values of extension and flexion should decrease due to less resistance. For peak torque values of flexion, there was an increase in the value of peak torque at 180 degrees per second in the music group. Similarly, in the no-music group, there was a rise in the value of peak torque at 300 degrees per second (Figure 3). With that being said, there were no significant differences found between values of flexion at differing speeds in general (Table 3). Thus, this result may be something corrected with a larger sample size. Contrary to the results in flexion, extension values did follow this trend of decreasing peak torque at increasing speeds for both music and no music groups (Figure 4), and significance was found between values of extension at different speeds (Table 4). The music group, although also insignificant, had higher values of extension compared to the no-music group (Figure 4). However, the difference between values of peak torque in the music and no music group got closer together as speed increased. Thus, if music was influencing values of peak torque in extensor values even slightly, it appears to have less of an effect as speed increases. Previous research in the field of music and exercise has conflicting results on whether music has a beneficial effect at different intensities. Some research suggests that at higher intensities, individuals tend to hone in on psychological and internal cues and, thus, music does not have as much of an effect (Hardy and Rajeski 1989; Thakare et al. 2017), while others suggest that music increases motivation and performance at higher intensities (Ballmann, 2021). At increased speeds, there is less resistance to movement in isokinetic exercise, so individuals could have had higher motivation in the music group because of higher resistance similar to the research mentioned in the article by Ballmann, 2021. However, at higher speeds, individuals also had to complete more repetitions; therefore, it could also be perceived as higher intensity from an endurance perspective. In viewing higher speeds from this perspective, music produced less of an effect between groups similar to the research of Hardy and Rajeski (1989) and the suggestion of Thakare et al. (2017).

2. Perceived Exertion and Enjoyment

No significance was observed between values of perceived exertion and enjoyment between groups. Overall, individuals across both groups reported lower values of perceived exertion (Table 5, Figure 5). With that said, there appeared to be a discrepancy in the amount of motivation to perform among individuals regardless of the group they were in. Although encouraged to work to their highest potential during isokinetic testing during the trial session on the non-dominant leg, it was observed that many individuals were not as motivated to perform as compared to a select few that challenged themselves to perform at their maximal effort. As a researcher, I did not feel as though I had the right to intervene in testing on the dominant leg to encourage a little more effort as music had the potential to be a motivator on its own. Nevertheless, music did not appear to have as much of an impact on the scores of perceived exertion, and motivation to perform may very likely have had more of an effect. There was, generally, a little bit more variation in ratings of perceived exertion in the music group (Table 5, Figure 5); however, this could be due to variation between individuals as well as variation in the amount of motivation.

Overall, individuals reported higher values of enjoyment with mean values in both groups in the high thirties out of 49 (Table 6, figure 6). Enjoyment means were only off by about a factor of 1.00 and unsurprisingly not significant. Individuals seemed to enjoy isokinetic testing regardless of the presence of music or not. With that said, this enjoyment may have been due to the sample of subjects taking part in this study. Most individuals were participating in the study as a research requirement for an introductory psychology course (i.e. General Psychology or Psychological Statistics). Many individuals noted that they chose to participate in this study because they thought it sounded interesting. Furthermore, as a degree in the sciences requires individuals to be familiar with and in some cases take part in research, individuals could have just been more excited or intrigued about the idea of participating in research. This could have been reflected more in the higher rating across both groups. The remaining 3 individuals not present in the psychology pool were from the Pre-Occupational and Physical Therapy club on campus and showed interest in the lab which could have resulted in higher values of enjoyment overall. Be as it may, the presence or lack of music thereof did not have much of an influence on enjoyment scores.

Limitations and Future Research

The particular sample and sample size had the potential to bias results. Since the sample was from a group of students from a specific age range (18-21) who likely had a particular interest in research and/or the sciences, enjoyment ratings could have been skewed towards higher values. A difference in motivation across individuals was also observed in individuals. This had the potential to skew the results of peak torque and perceived exertion. During testing, music had the potential to be a motivator, encouraging individuals to perform harder during testing did not seem plausible. Future research may want to try to include a more motivated sample. In the rehabilitative setting, individuals likely would be more motivated to, ultimately, improve motor quality and work towards individual goals. In general, future research in a rehabilitative setting may be of interest. However, regarding the scope of this study, future research may want to bilaterally collect isokinetic data and encourage individuals to work towards increasing their non-dominant and/or weaker limb to the potential of their dominant and/or stronger limb to have a larger potential of increasing motivation. In this way, a goal similar to the goal of rehabilitation is established for participants.

The sample size for this study, although calculated using the standard value for effect size (d = 0.5) via the G*Power 3.1.9.7, is not backed by research in the field of isokinetic testing as there is not any research including power analysis found on isokinetic testing using a repeated measure two-way ANOVA. In evaluating peak torque values for flexion across both groups, there were different trends than what one would expect between speeds. Further study with a larger sample size may correct this trend since there were no significant differences outlined between peak torque values of flexion across speeds.

With a larger sample size, gender differences could be evaluated between groups as well. This study had a larger number of females (n=18) than males (n=10). Biological sex differences may be something interesting to look at, but because the sample size was so small for males in particular between groups (5 males per group), the power would be very low between groups of biological sex. Because of the low number of individuals between groups, gender was not controlled for within this study. However, there was a difference in normalized isometric strength values (normalized by calculating the peak torque/body weight ratio) between males and females (Table 2) suggesting that males produced overall more torque even after normalization to body weight. Furthermore, there is research in music and exercise that has shown differences in musical evaluation between males and females. Females have shown a greater ability to evaluate rhythmic quality and have higher levels of tempo entrainment (Buhmann et al. 2018; Karageorghis, 2020). In a comparison of preference for music, males tend to enjoy "heavier" music such as rock (Terry et al. 2019). However, music preference (preferred stimuli) has been shown to affect females more than males (Buhmann et al. 2018). Thus, future research may want to examine biological sex differences between rehabilitative exercise, strength, and music.

This study used a researcher-selected playlist from YouTube with a set rhythm of 140 beats per minute. Since music preference has been shown in many studies involving music and exercise to have more of an ergogenic effect on participants (Ballmann 2021; Ballmann et al. 2021; English, Mavros, & Jay 2019; Karageorghis 2020; Terry et al. 2019), researching and finding ways to incorporate more of a participant-selected music genre in rehabilitative exercise may also be a point of interest of future research. Playlists with different genres and similar rhythms could be used and participants could be asked which genre they prefer, for example. Furthermore, there has been research completed by Fritz et al. 2013 and Fritz et al. 2018 in which music has been able to enhance mood and enjoyment in exercise respectively. However, both studies involved a music group that had a synchronization aspect to them in which music was synchronized with weight-training equipment such that "fitness machines created sounds that could be interactively combined into a holistic musical piece at a constant tempo of 130 bpm" (Fritz et al. 2013 p. 3). Synchronization compared to no-synchronization enhanced mood (Fritz et al. 2013) and increased pain tolerance to a cold-pressor test immediately following exercise (Fritz et al 2018). With that being said, future research regarding the synchronization of music in exercise and rehabilitation may be an interesting point of study.

One last point of interest includes an analysis of isometric peak torque in comparison to isokinetic peak torque. This study also took into account a possible correlation between isometric and isokinetic peak torque. Theoretically, if isometric peak torque is the maximum torque that one can generate, then isokinetic torque should not be a larger value than the isometric value. Thus, it was considered to analyze the simple difference between isometric peak torque values at 60 degrees per second and isokinetic peak torque at each individual speed between music and no music groups (i.e. isometric peak torque-isokinetic peak torque at 60 degrees per second; isometric peak torque-isokinetic peak torque at 180 degrees per second; and isometric peak torque-isokinetic peak torque at 300 degrees per second). The idea was that the closer the individual was to their maximum, or the smaller the difference between isometric and isokinetic values, the more effort and force they were putting into isokinetic movement in comparison to isometric testing. However, as this method has not been found to be used in research, normalizing data to body weight was opted for instead. With that being said, a secondary analysis was run using this data (Figures 7 and 8). For these analyses, there was also no significance found ($F_{flexion}$= 2.235, $p_{flexion}$= 0.126; $F_{Extension}$= 0.635, $p_{extension}$=0.538). With that being said, the trends were completely different compared to the data normalized to body weight. Figures 7 and 8 show that the music group produced a higher isometric-isokinetic difference than the no-music group, indicating that they on average performed further from their isometric value of maximum torque than the no-music group during isokinetic testing. This trend may suggest that music may have actually decreased peak torque output in some way in isokinetic testing compared to isometric testing. However, as the results were not significant, there is no way to tell for sure. That said, the limitations mentioned above still apply to this case as well and further research with a larger sample size could still be explored.

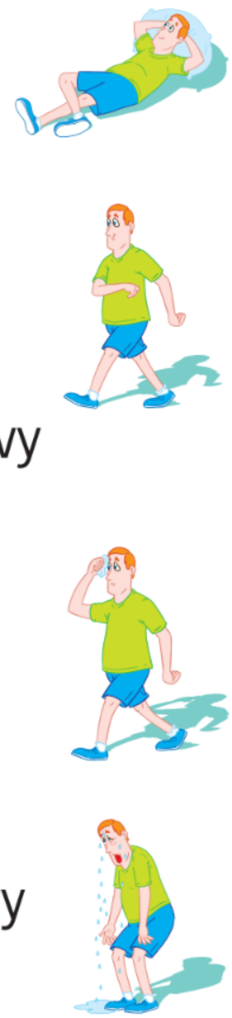
Conclusion

Research on music in rehabilitative exercise is still recent and ongoing. The potential effects of music (of different genres, tempo, rhythm, etc.) on many different physical, psychological, psychophysical, and physiological measures in rehabilitation have yet to be explored. Furthermore, Grau-Sánchez et al. (2022) mention that there are methodological challenges to investigating music-based neurological rehabilitation in a paper published just this past year. They describe the need for a uniform and empirical approach as there have been several disparities in the quality of research being presented on music and rehabilitation. An empirical approach to research music-based rehabilitative intervention is then outlined as a reference for future research (Grau-Sánchez et al. 2022). Thus, there is still a lot to be explored when it comes to the potential benefits of music in rehabilitative exercise. All in all, the results of this study, although insignificant, hope to provide a ground for future research in the field of music intervention in rehabilitation and to make an effort to improve overall patient performance and satisfaction.

Appendix 1

HOW HARD IS THE ACTIVITY?

0	Nothing at all
0.5	Just noticeable
1	Very light
2	Light
3	Moderate
4	Somewhat heavy
5	Heavy
6	
7	Very heavy
8	
9	
10	Very, very heavy
* *	Maximal



Appendix 2

THE POST-EXPERIMENTAL INTRINSIC MOTIVATION INVENTORY

For each of the following statements, please circle a number to indicate how true it is for you, using the following scale:

1	2	3	4	5	6	7
Not at all true			somewhat true			very true

1. I enjoyed doing this activity very much

   1 2 3 4 5 6 7
2. This activity was fun to do

   1 2 3 4 5 6 7
3. I thought this was a boring activity

   1 2 3 4 5 6 7
4. This activity did not hold my attention at all

   1 2 3 4 5 6 7
5. I would describe this activity as very interesting.

   1 2 3 4 5 6 7
6. I thought this activity was quite enjoyable.

   1 2 3 4 5 6 7
7. While I was doing this activity, I was thinking about how much I enjoyed it.

   1 2 3 4 5 6 7

Tables and Figures

Table 1. Demographic Data

	n (%)	mean (sd)
Female	18 (64.3)	
Music	9 (64.3)	
No Music	9 (64.3)	
Right Leg Dominant	26 (92.9)	
Music	13 (92.9)	
No Music	13 (92.9)	
Age		18.7 (0.82)
Music		18.7 (0.73)
No Music		18.6 (0.93)
Weight (lbs)		147.2 (29.7)
Music		145.3 (24.3)
No Music		149.1 (35.2)

Table 2. Peak Isometric Torque Values Between Biological Sex. Values are normalized by calculating a peak torque/body weight ratio (ft/lbs). (*indicates significance (p=<0.05))

	Male (Mean (sd))	Female (Mean (sd))	F value (p-value)
Body Mass Ratio of Flexion for 60 degrees	0.336 (0.132)	0.219 (0.064)	6.725 (0.015)*
Body Mass Ratio of Extension for 60 degrees	0.603 (0.212)	0.426 (0.102)	5.847 (0.023)*

Table 3. Peak Torque Values for Flexion. Values are normalized by calculating a peak torque/body weight ratio (ft/lbs). (*indicates significance (p=<0.05))

	No Music (Mean (sd))	Music (Mean (sd))	F value (p-value)
Body Mass Ratio of Flexion for 60 deg/sec	0.136 (0.094)	0.166 (0.127)	
Body Mass Ratio of Flexion for 180 deg/sec	0.135 (0.084)	0.177 (0.116)	
Body Mass Ratio of Flexion for 300 deg/sec	0.149 (0.084)	0.168 (0.092)	
Multivariate Statistics for Flexion between the 3 different speeds for both groups			0.082 (0.921)
Multivariate Statistics for Flexion between 3 different speeds between groups			1.728 (0.199)
Internal (Within-Subjects Effects) for Flexion between groups (Greenhouse-Geisser)			0.572(0.484)

Table 4. Peak Torque Values for Extension Values are normalized by calculating a peak torque/body weight ratio (ft/lbs). (*indicates significance (p=<0.05))

	No Music (Mean (sd))	Music (Mean (sd))	F value (p-value)
Body Mass Ratio of Extension for 60 deg/sec	0.289 (0.160)	0.353 (0.261)	
Body Mass Ratio of Extension for 180 deg/sec	0.284 (0.158)	0.328 (0.235)	
Body Mass Ratio of Extension for 300 deg/sec	0.209 (0.103)	0.214 (0.124)	
Multivariate Statistics for Extension between the 3 different speeds for both groups			8.796 (0.001)*
Multivariate Statistics for Extension between 3 different speeds between groups			0.590 (0.562)
Internal (Within-Subjects Effects) for Flexion between groups (Greenhouse-Geisser)			0.954 (0.370)

Table 5. Perceived Exertion Values. Borg's Scale was used where participants rate their level of exertion from the previous analysis of peak torque from 0 (*nothing at all)* to 10 (*extremely strong; "maximal"*). (*indicates significance (p=<0.05))

	No Music (Mean (sd))	Music (Mean (sd))	F value (p-value)
Measure of Perceived Exertion (Borg's Scale measuring from 0-10)	2.179 (1.648)	2.714 (2.190)	1.374 (0.252)

Table 6. Enjoyment was measured via the Intrinsic Motivational Inventory where individuals rated how true a set of 7 statements regarding enjoyment were to them on a scale from 1 to 7. Scores were out of 49 where a higher score meant the individual enjoyed the task more. (*indicates significance (p=<0.05))

	No Music (Mean (sd))	Music (Mean (sd))	F value (p-value)
Enjoyment	37.930 (8.704)	38.640 (8.454)	0.136 (0.716)

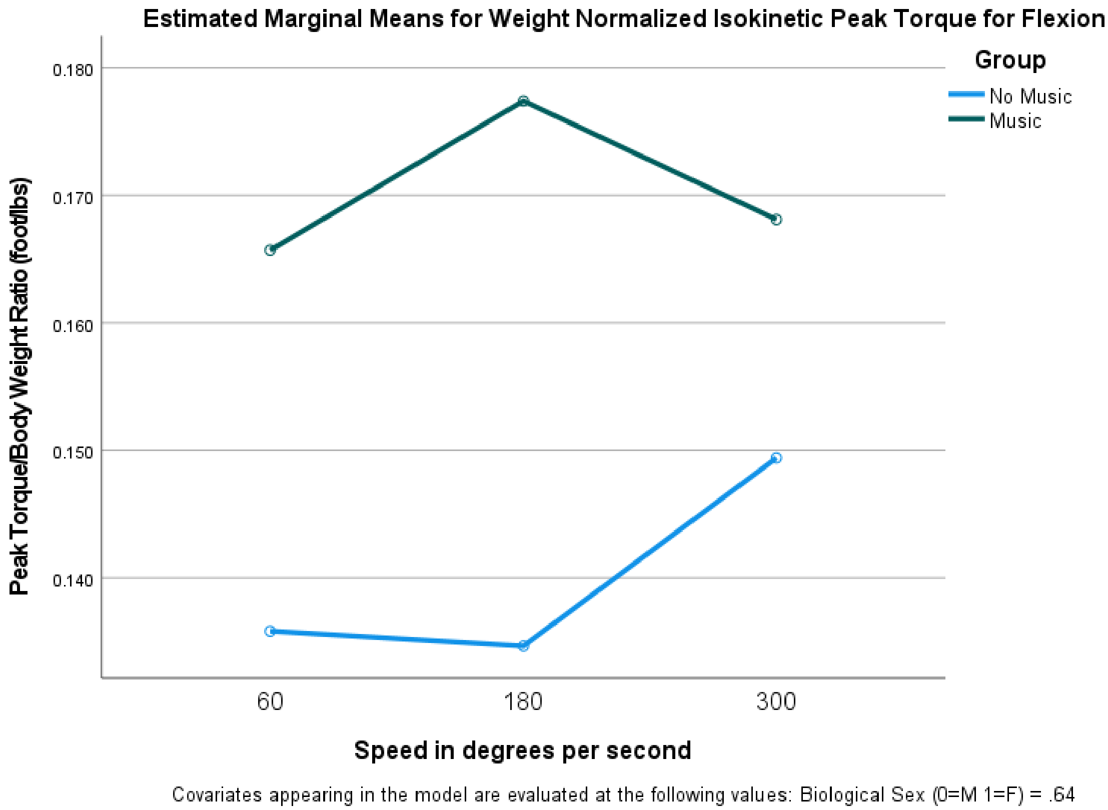


Figure 3. Isokinetic Peak Torque Flexion Values across Speeds. Peak Torque was Normalized to produce a Peak Torque/Body Weight Ratio (ft/lbs). Speed was in degrees per second of movement. No Significance was found between music and no-music groups and no significance was found between flexion values within groups at different speeds.

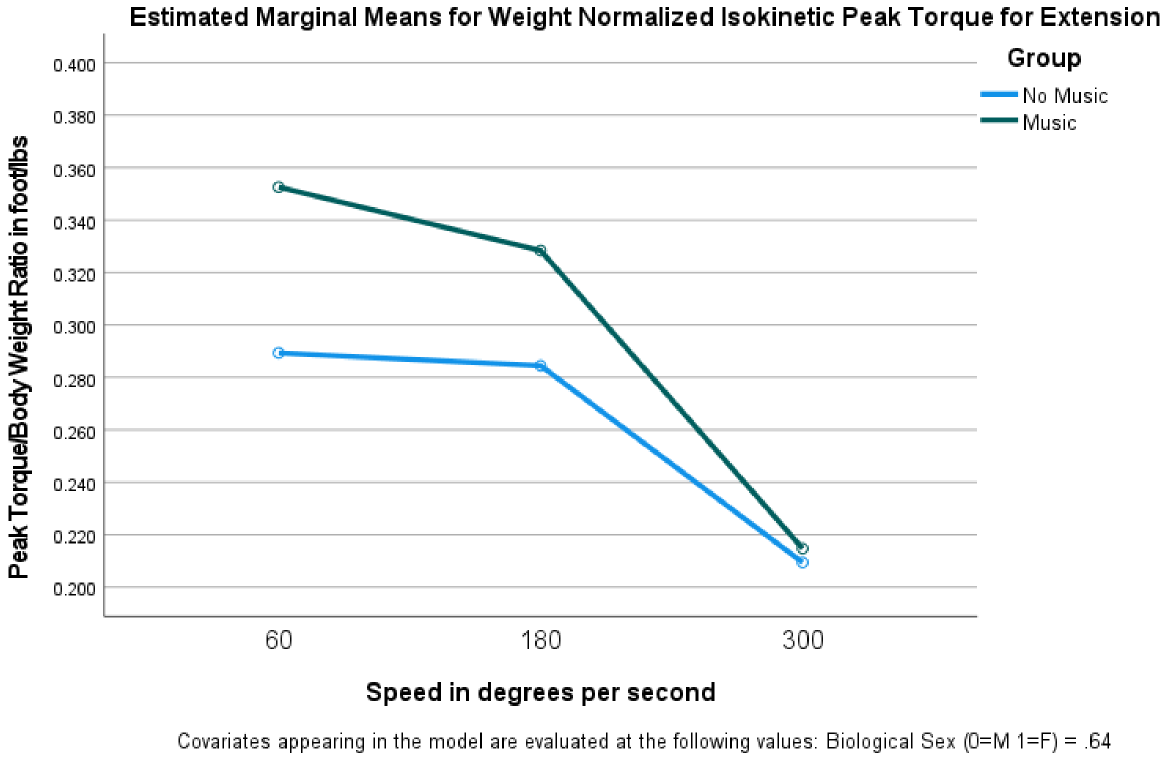


Figure 4. Isokinetic Peak Torque Extension Values across Speeds. Peak Torque was Normalized to produce a Peak Torque/Body Weight Ratio (ft/lbs). Speed was in degrees per second of movement. No Significance was found between music and no-music groups.

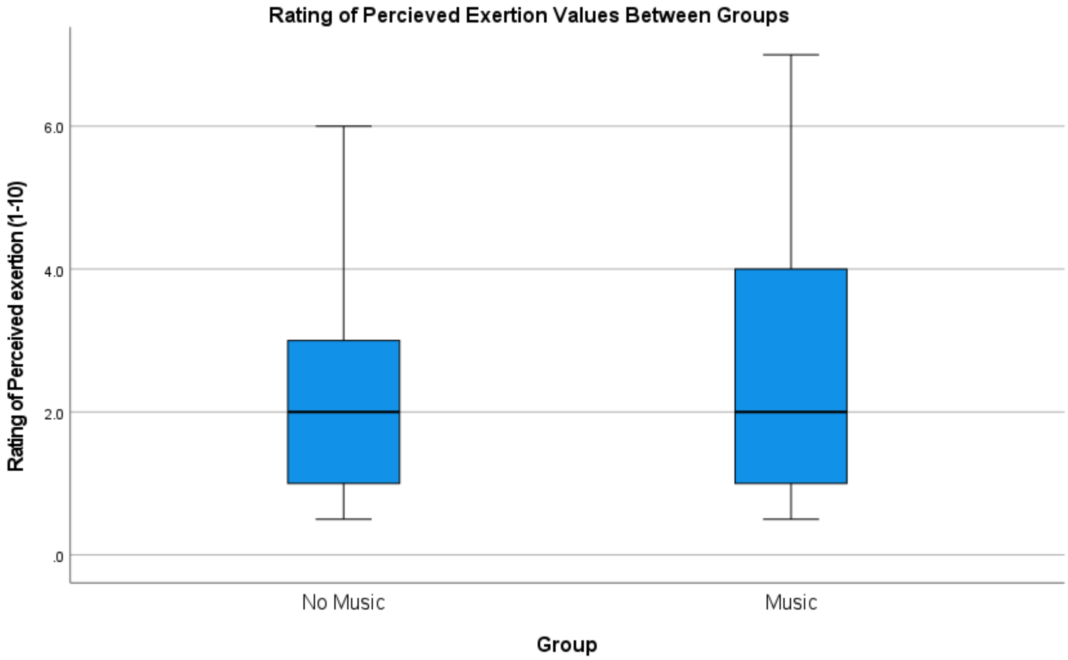


Figure 5. Rating of Perceived Exertion Between Groups. Borg's Rating of Perceived Exertion (RPE) Category-Ratio Scale was used (Borg 1998) and individuals rated exertion on a scale from 0 (*nothing at all*) to 10 *(extremely strong; "maximal")*. No SIgnificance was found between groups.

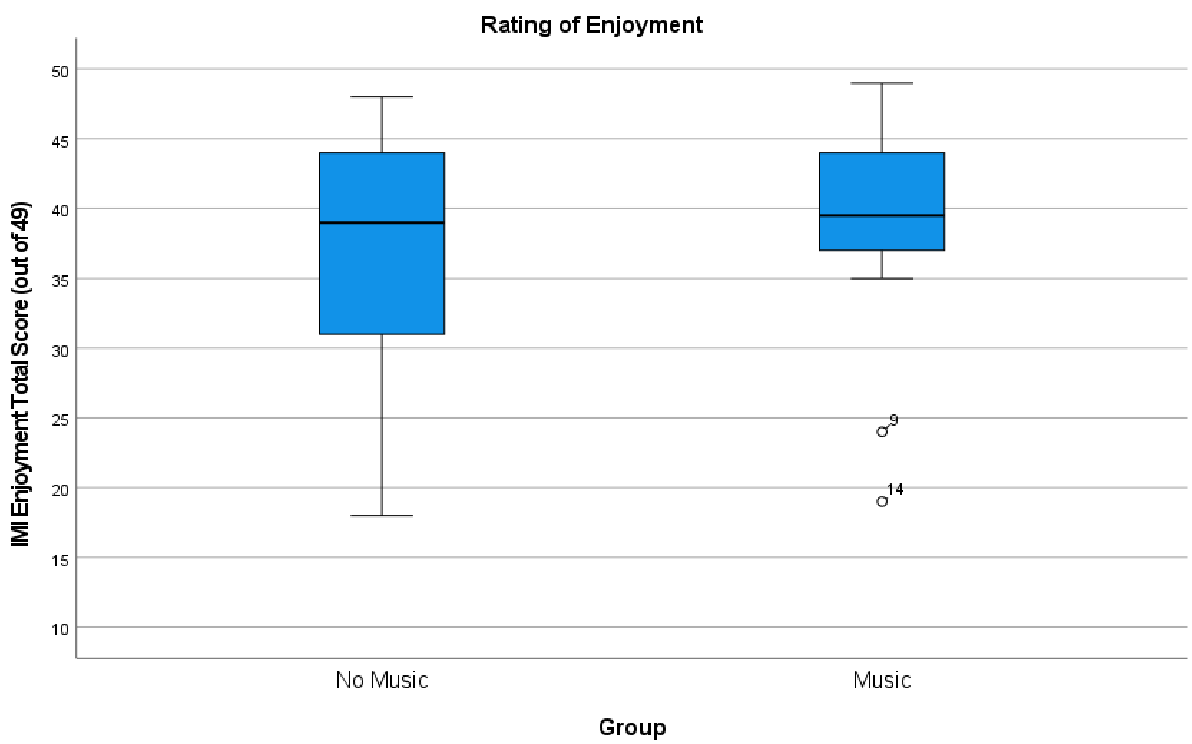


Figure 6. Enjoyment Ratings Between Groups. The Interest/Enjoyment subscale of the Intrinsic Motivation Inventory (Cox et al. 2020; Ryan 1982) was used. Total scores were out of 49 whereas a higher score indicated higher levels of enjoyment. No Significance was found between groups.

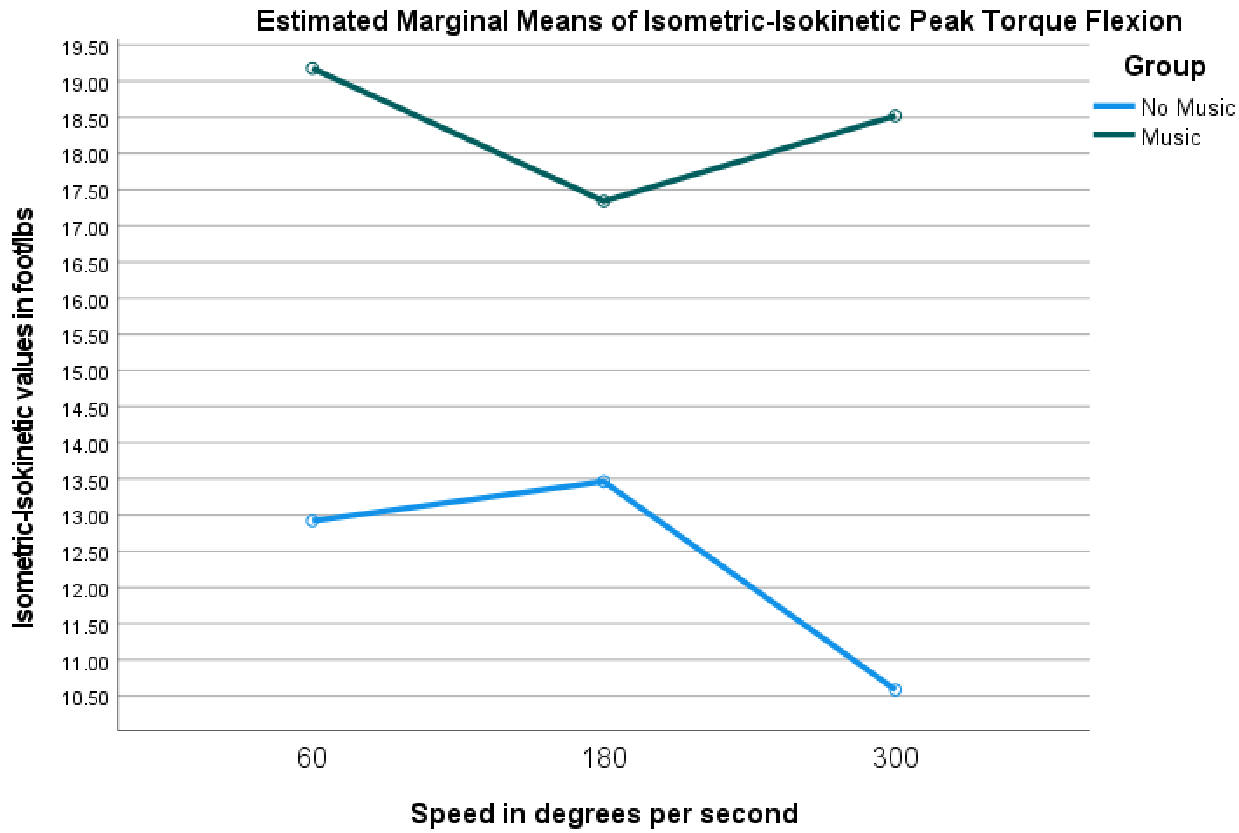


Figure 7. Isokinetic Peak Torque Flexion Values across Speeds. Peak Torque was normalized by analyzing the difference between isometric and isokinetic peak torque. This was a secondary analysis out of interest. The difference between isometric and isokinetic values has not been explored in research. Speed was in degrees per second of movement. No Significance was found between music and no-music groups.

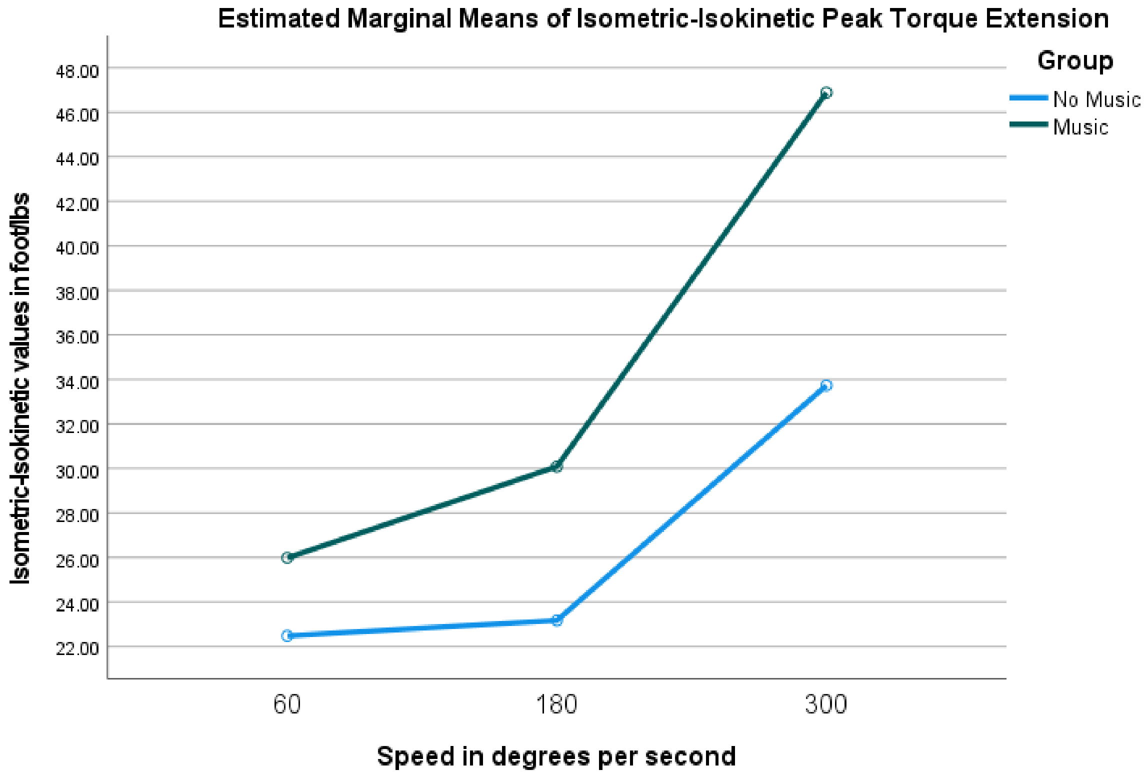


Figure 8. Isokinetic Peak Torque Extension Values across Speeds. Peak Torque was normalized by analyzing the difference between isometric and isokinetic peak torque. This was a secondary analysis out of interest. The difference between isometric and isokinetic values has not been explored in research. Speed was in degrees per second of movement. No Significance was found between music and no-music groups.

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