Cardiff School of Sport

DISSERTATION ASSESSMENT PROFORMA:

Empirical [1]

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Dissertation title: The Effects of Music on Physiological Responses in Sub Maximal Arm Crank Ergometry.	
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Comments	Section
	Title and Abstract Title to include: A concise indication of the research question/problem. Abstract to include: A concise summary of the empirical study undertaken.
	Introduction and literature review To include: outline of context (theoretical/conceptual/applied) for the question; analysis of findings of previous related research including gaps in the literature and relevant contributions; logical flow to, and clear presentation of the research problem/ question; an indication of any research expectations, (i.e., hypotheses if applicable).
	Methods and Research Design To include: details of the research design and justification for the methods applied; participant details; comprehensive replicable protocol.
	Results and Analysis [2] To include: description and justification of data treatment/ data analysis procedures; appropriate presentation of analysed data within text and in tables or figures; description of critical findings.
	Discussion and Conclusions [2] To include: collation of information and ideas and evaluation of those ideas relative to the extant literature/concept/theory and research question/problem; adoption of a personal position on the study by linking and combining different elements of the data reported; discussion of the real-life impact of your research findings for coaches and/or practitioners (i.e. practical implications); discussion of the limitations and a critical reflection of the approach/process adopted; and indication of potential improvements and future developments building on the study; and a conclusion which summarises the relationship between the research question and the major findings.
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CARDIFF METROPOLITAN UNIVERSITY
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CARDIFF SCHOOL OF SPORT

DEGREE OF BACHELOR OF SCIENCE (HONOURS)

SPORT & PHYSICAL EDUCATION

The Effects of Music on Physiological Responses in Sub Maximal Arm Crank Ergometry.

(Dissertation submitted under the discipline of Physiology and Health)

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THE EFFECTS OF MUSIC ON PHYSIOLOGICAL RESPONSES IN SUB MAXIMAL ARM CRANK ERGOMETRY

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ABSTRACT

Previous research has provided mixed results in regards to the use of music as an ergogenic aid. Some studies have found a positive impact of music on performance, whereas others have found none. This study focused on using a music intervention in sub maximal upper body exercise that had a major element of anaerobic work. Specifically, the aim was to monitor variations. Six physically active, but non-specifically-trained, men volunteered to participate. Their mean age, height and mass were 20.3 s = 0.8 years, 177 s = 0.07 cm and 70.3 s = 5.7 kg respectively. Initially, the participants completed a peak power protocol to determine 80% of their peak power as a wattage, whilst maintaining an imposed crank rate of 80 rev·min^{-1}. The participants then completed two tests to exhaustion at 80% of their relative peak power, using a self-selected crank rate. The first test was completed under a control condition whilst the other test was completed in a music condition. During the music condition, the participants listened to a selection of songs through headphones at full volume. The songs were roughly 140 b·min^{-1} as suggested by Karageorghis et al. (2011). A gas analysis system was attached to each participant during both test conditions and respiratory values were recorded, along with mean crank rate, heart rate and the rating of perceived exertion. Statistical analysis revealed no significant differences ($P > 0.05$) between the time to exhaustion, crank rate and peak values of heart rate, the volume of oxygen consumed, the volume of carbon dioxide produced, pulmonary ventilation, the rating of perceived exertion and the respiratory exchange ratio in either test conditions. The peak values for the volume of oxygen consumed and heart rate for the control condition were 2393.5 s = 226.3 ml·min-1 and 183 s = 8 b·min^{-1} respectively. Similarly, the peak values for the volume of oxygen consumed and heart rate were 2235.8 s = 384.6 ml·min^{-1} and 184 s = 11 b·min^{-1} respectively within the music condition. Analysis of the findings demonstrated that music did not enhance physiological responses during sub maximal arm crank ergometry and there was no increase in performance. However, there was some evidence to support previously published theories regarding synchronisation of movement patterns to music.

This research can be beneficial for coaches to manipulate the tempo of a piece of music to enforce a set intensity during training in preparation for competition. This research also argued that a music intervention may not be as beneficial during short duration, anaerobic exercise compared to longer, aerobic exercise. In relation to future research, there is potential scope to study the impact of different genres of music or personal preferences in music on sub maximal arm crank ergometry.

CHAPTER ONE

INTRODUCTION

With the development of newer, more compact music devices, for example MP3 players and iPods, music has become more accessible and convenient, allowing people the capability to listen to music throughout any type of exercise (Brooks & Brooks, 2010). However, research by Bernatsky, Bernatsky, Hesse, Staffen and Ladurner (2004) indicated that there were mixed results in relation to investigating the effects of music on exercise performance. A study conducted by Barney, Gust and Liguori (2012) instructed 184 undergraduate students to complete a questionnaire and found that music was most commonly used during free weights (27.2%), treadmill running (26%), machine weights (19.6%) and the use of an elliptical trainer (17.4%). If used during exercise, it appeared that music selection was normally down to personal preference. This was supported by Hagen et al. (2013) who suggests that it was the individuals' belief in their selected music that aided in an improvement in performance. However, further results from the aforementioned study by Barney et al. (2012) found that the most popular music genres were hip hop (27.7%), rock (24%), pop (20.3%) and country (12.7%).

The intention of the literature review was to develop an understanding of the current research that studied the effects of music on aerobic and anaerobic performance and to identify areas that previous research had not yet established. The research highlighted that music can have positive effects when used in conjunction with aerobic exercise. However, research into anaerobic exercise provided mixed results, with some studies finding positive effects on performance and others finding no difference. Within the literature, a small proportion of studies have highlighted that there are various mechanisms that the body can utilise in the presence of music that can help increase performance. These studies concluded that music could reduce the perception of fatigue (Yamashita, Iwai, Akimoto, Sugawara & Kono, 2006), increase arousal (Karageorghis & Terry, 1997), increase relaxation (Copeland & Franks, 1991) or cement synchronisation of movement patterns with the music tempo (Simpson & Karageorghis, 2006). However, in relation to increased arousal, it has not been made clear whether this effect was psychological or physiological.

A major proportion of the available literature has studied the effects of music on lower body protocols, for example treadmill running or cycling. This limits the application of the research in sporting contexts to leg dominated sports. Therefore, due to the lack of research on music and how it impacts upon upper body exercise, future research should address this issue. Therefore, the aims of this research were to use a music intervention during sub maximal arm crank ergometry to identify if there were any benefits in regards to performance and the associated physiological responses. Due to the lack of research into the effects of music on upper body, a rationale is provided for the current study. The null hypothesis constructed in relation to this study stated that the intervention of music would have no effect upon performance (time to exhaustion) or the related physiological responses compared to the control (no music) condition. The results could be used to enhance both a coaches' and an athlete's understanding of music on performance, especially in events such as swimming, kayaking and a variety of disability sports where individuals do not have the habitual use of their lower extremities. Also, if the results of this study conclude music can enhance performance, it provides a cheap and legal method of increasing performance.

CHAPTER TWO

LITERATURE REVIEW

Currently available is a vast body of research concluding that the presence of music can enhance performance (Eliakim, Eliakim, Meckel & Nemet, 2007; Rendi, Szabo & Szabo, 2008; Adnan, Haluk & Turchian, 2009; Brooks & Brooks, 2010). For example, Adnan, Haluk and Turchian (2009) found significant differences between a control condition and music condition in maximal exercise. In contrast, several studies have opposed these findings and highlighted no benefits of listening to music during exercise (Pujol & Langenfeld, 1999; Yamamoto et al., 2003; Hagen et al. 2013). This was supported by Copeland and Franks (1991) who found that loud and fast music did not enhance physiological and psychological responses in treadmill endurance exercise, which was contrary to other findings.

2.1 - The Effects of Music on Aerobic Performance

A majority of the literature available has studied the impact of music upon aerobic performance. Initially, Copeland and Franks (1991) required 24 volunteers to complete a multi stage treadmill walk and run to exhaustion under three conditions: no music; loud, fast, exciting music; soft, slow, easy listening music. Throughout the test, heart rate (HR) and rating of perceived exertion (RPE) was collected along with the time to exhaustion. It was found that HR was lower during the soft, slow, easy listening music in minutes one and six, yet peak HR was also higher with the soft, slow, easy listening music. Time to exhaustion was longer and RPE was lower with soft, slow, easy listening music. Consequently, this study suggested that soft, slow, easy listening music reduced arousal and, therefore, increased endurance performance. Atkinson, Wilson and Eubank (2004) reported similar findings whilst researching cycling performance. They observed the power output of 16 volunteers during a 10-km cycling time trial in two conditions, music and no music. The music was selected at the discretion of the researchers but remained roughly 140 $b \cdot min^{-1}$. They identified that the RPE remained fairly consistent in both conditions, although time to completion was shorter in the music condition as opposed to the control (1030 s = 79-s and 1052 s = 77-s respectively). They were also able to identify that the largest music-induced responses occurred within the first 3-km (cycling speed and heart rate). These results suggested that whilst working aerobically, the increase in performance occurred towards the beginning of performance and then maintained throughout. These results followed the trend in suggesting that music can act as an ergogenic aid to performance. The next study was conducted by Elliott, Carr and Orme (2005) who observed the impact of music on aerobic performance. Similar to Atkinson et al. (2004), this study also regarded cycling as the test protocol. A 20-min sub maximal cycle task was completed by 18 participants in three conditions: no music, non-motivational music and motivational music. The study discovered that both music types led to an increased amount of work completed, however there were no differences between music types or gender. Mohammadzadeh, Tartibiyan and Ahmadi (2008) investigated the impact of music on the rating of perceived exertion and performance during progressive exercise. However, unlike other studies, this study also attempted to identify if fitness levels had an impact upon the effectiveness of a music intervention on performance. There were 24 participants split into two equal groups, a trained group and an untrained group. All participants completed the Bruce Test on two occasions, either listening to music or no music. The music selection for the test was a series of songs with a fast rhythm. However, there was no research to support this selection and thus presented a weakness within this research. The results reported significant differences in RPE and time to exhaustion between the test conditions. In regards to the level of fitness, music had a greater effect on RPE in the untrained group than the trained group; however there was no significant difference in time to exhaustion to report between the two groups. These results suggested that the presence of music can aid performance irrespective of fitness level.

Despite a numerous amount of studies highlighting the benefits of a music intervention on performance, some studies have reported adverse results. For example, Birnbaum, Boone and Huschle (2009) compared the cardiovascular responses in three different music conditions (control, slow music and fast music) during a 15-min steady state jog at 8.85 $km \cdot h^{-1}$. The volunteers were six males and five females. During the fast music condition, increases in oxygen consumption (VO_2), cardiac output, stroke volume, pulmonary ventilation (VE) and frequency of breaths were experienced compared to the other conditions. These findings suggested that in the presence of fast music, the acute physical responses could in fact inhibit performance due to the same work being able to be completed by the participants in the control and slow music condition with a lower stroke volume, cardiac output and VO_2. These results conform with the earlier study by Copeland and Franks (1991) suggesting that for endurance based events, fast music could illicit responses that might hinder performance, making slower music or no music ideal to maximise performance. Hagen et al. (2013) also reported contradictory findings. They investigated the impact of a music intervention on 18 specifically trained participants (nine male, nine female) during a 10-km cycling time trial. Each participant completed four trials, two habitual and two randomly ordered experimental trials. The music choice was left to the participants and what they perceived to be motivational for them. During all the trials, there was no significant difference between performance time, mean power output, HR_{max}, peak blood lactate and peak RPE. These results suggested that self-selected music does not enhance some physiological parameters during a 10-km cycling performance that involves predominantly aerobic work.

Of the aforementioned studies, conclusions can be drawn regarding the impact of music on performance by suggesting that the right music choice can act as a physiological ergogenic aid. However, if the music tempo is too fast, it could potentially produce acute physiological and maybe psychological responses that may hinder performance.

2.2 - The Effects of Music on Anaerobic Performance

Initially, Pujol and Langenfeld (1999) recruited 12 men and three women to randomly complete the Wingate test in two, randomly selected conditions, a music and non-music condition. Each visit saw the participants' complete three tests, with 30-s rest in between. However, the last test was to continued and completed voluntary exhaustion. An Analysis of Variance (ANOVA) statistical test was performed on time to fatigue in the third trial compared to the other conditions and no significant differences were indicated. This suggested that performance did not increase with the presence of music. Support for this was shown by Yamamoto et al. (2003) who tested six male participants. The participants listened to 20-min of either slow or fast tempo music before completing a 45-s supra maximal cycle. Results indicated that there was no increase in power output with either music condition. However, this study used a small sample size and did not have a control condition, making it difficult to compare the data collected. The previous two studies, both of which considered anaerobic cycling, highlighted no significant differences in performance in the presence of music. Conversely, Rendi et al. (2008) used a different mode of exercise as they tested rowing. They investigated the impact of fast and slow tempo music on anaerobic performance, a 500-m sprint rowing effort. They observed 22 rowers in three conditions: slow music, fast music and no music. The variables measured were the time to completion, stroke rate in strokes per minute (SPM) and RPE. The results showed there was no difference in RPE between the two music conditions and the time to completion was shorter in the fast music condition. The fast music condition also encouraged a higher SPM rate. This study indicated that music could potentially enhance anaerobic performance, although an inadequate number of variables were measured to allow a definite conclusion. The increase in stroke rate in the fast music condition could have been linked to synchronisation of stroke rate in time with the tempo of the music which was previously proposed by Simpson & Karageorghis (2006). A subsequent study by Adnan et al. (2009) employed the Wingate test. This study exposed a sample of 20 physically fit college students to complete a Wingate test in three different conditions (slow music, fast music and no music). Music selection was open to the preference of the participants and allowed them to select a genre of music that motivated them personally and not a prescribed genre they may not have enjoyed. Furthermore, this study measured a number of variables, possibly due to the smaller sample size engaged. Peak power, mean power output, maximum power output, minimum power output and fatigue index were all measured. The results obtained showed significant differences between slow music and no music conditions and fast music and no music conditions. However, no significant difference between slow and fast music conditions was identified. This study suggested that any music type specific to the individuals' preference can enhance performance. These findings opposed the previous studies, suggesting that no performance increase was observed during a Wingate test.

This was supported in a succeeding study by Brooks and Brooks (2010) who applied the Wingate test to a larger sample. They recruited 71 participants to take part in a music and a no music condition. However, this time music selection was made using the Brunel Music Rating Inventory (BMRI) scale. In order to provide a measure to allow consistency in music selection in scientific studies, the BMRI scale was devised by Karageorghis, Terry and Lane (1999). At a later date, a study by Karageorghis et al. (2011) suggested that the optimum music tempo for young adults fell between 125-140 beats·min^{-1}. Peak power, average power and power drop were the variables measured. Employing music as motivation, significant differences of the previously mentioned variables were experienced between the two conditions. This suggested that music could potentially improve anaerobic performance and was similar to the study by Adnan et al. (2009), which implied that music could act as an ergogenic aid.

A handful of studies have looked to see if the use of music in a warm up before anaerobic exercise can be beneficial for performance. Initially, Eliakim et al. (2007) observed the effects of music during a warm up and the subsequent effects on performance in a Wingate test. The results gathered from the study were more beneficial for competing and recreational athletes, as most athletes are unable to listen to music whilst competing but listen to it beforehand in a warm up. This reasoning also related to the sample used as it consisted of elite volleyball players, compared to other samples tested that recruited students. The warm up consisted of pedalling at 60 rev·min^{-1} on a stationary cycle ergometer with a load of 1-kg. Music selection was a popular collection of three spinning tracks at 140 b·min^{-1}, which fell into the bracket later identified by Karageorghis et al. (2011). After the warm up the participants completed a Wingate test, measuring maximal power output, mean power output, minimal power output and fatigue index. The results of the study showed a higher heart rate during the warm up in the presence of music and that there were no significant differences in genders. This study was able to conclude that music can have a positive effect during warm up, which could then have transitional effects during performance.

More recently, Jarraya et al. (2012) also studied the use of music during a warm up prior to supra maximal anaerobic exercise. The researchers recruited 12 young, highly trained male participants' to complete two wingate tests with a recovery of at least 48 h in between tests. Prior to the tests commencing, the participants completed a 10-min warm up at 60 W either with or without music. The music selection was high tempo music that was roughly 120 to 140 $b{\cdot}min^{-1}$. Statistical analysis of the results indicated no significant difference in heart rate, RPE and the fatigue index between warm up conditions. However, there was a significant difference in power output between warm up conditions suggesting that music can be beneficial during a warm up prior to supra maximal lower body exercise. More recent research by Eliakim, Meckel, Gotlieb, Nemet and Eliakim (2012) tested a sample of 12 national league basketball players on their repeated sprint ability under two conditions, a control condition and a motivational music condition. The music selection was made using the BMRI scale. The music selection decided upon was around 120 $b{\cdot}min^{-1}$. The test protocol involved the participants completing 12x20 m sprints that begun every 20 s. The results indicated no significant difference in performance between conditions. However, when comparing each sprint, the last two sprints were faster in the music condition than the control. These results suggested that during repeated, intense exercise, music had a beneficial impact on the aerobic element towards the end of exercise. Atan (2013) studied the impact of two different music interventions on power output, heart rate and blood lactate concentration. There were 28 male participants recruited and they had to complete both a Running-based Anaerobic Sprint Test (RAST) and a Wingate test under the control condition, slow music and fast music. The tempos of the slow and fast music were 70 $b{\cdot}min^{-1}$ and 200 $b{\cdot}min^{-1}$ respectively. However, there was no research to support the choice in music tempo, highlighting a weakness of this research. Statistical analysis of the results highlighted no significant differences in anaerobic power, heart rate or blood lactate between the three conditions in either test.

Drawing upon the previously reviewed literature, there were mixed results when considering the use of music as an ergogenic aid for anaerobic performance. Certain studies have observed beneficial effects on performance, whereas others have found contrasting results. Earlier studies were unable to identify beneficial impacts on performance whilst listening to motivational music. However, more recent studies have been able to identify improvements in performance, but only related to performance of a physical task rather than the associated physiological responses. Therefore, this leaves an opportunity for future research to closely monitor physiological responses during exercise. The 30-s Wingate test has been used extensively and could therefore present an opportunity for an alternative mode of testing using a different exercise, for example, running or arm ergometry.

2.3 - Arm Crank Ergometry

Arm crank ergometry is the use of an upper limb cycle against resistance in a synchronous or asynchronous rhythm. The effect of music on arm ergometry is an area that lacks research. Therefore, future research can prove useful for a wide range of athletes that use an upper body cycling motion, notably kayakers, canoeists and wheelchair athletes. Studies have looked at the influence of varied tempo music on wheelchair mechanical efficiency (Goosey-Tolfrey, West, Lenton & Tolfrey, 2011) which recruited a similar movement pattern. 22 abled-bodied participants completed a 4-min steady state bout of exercise at 1.1 $m \cdot s^{-1}$ followed by a VO_2 peak test. The variables measured were push frequency, gross efficiency, heart rate, RPE, force application and temporal characteristics. After the initial tests, the participants completed a three week practice period, listening to either low tempo music (125 $b \cdot min^{-1}$) or high tempo music (170 $b \cdot min^{-1}$) or as a control group. The test was then repeated by the participants. Results found that gross efficiency was higher in the low tempo group than the control group (6.6% and 6.1% respectively). When comparing the high tempo music against the control group or the low tempo music group, the researchers suggested that the differences were trivial and only the low tempo music group experienced an increase in gross efficiency. The researchers also highlighted favourable effects on RPE, work per cycle and push and cycle time in divergence to the control group.

Glaser, Sakwa, Brune and Wilde (1980) studied physiological responses to maximal effort wheelchair and arm crank ergometry. There were 16 participants (10 able bodied and 6 wheelchair dependent) who completed each mode of exercise maximally to physical exhaustion. During testing, physical work capacity (PWC), peak VO_2, VE_{max}, HR_{max} and maximal blood lactate concentration (LA_{max}) was measured. No significant differences were found between PW, peak VO_2, VE_{max} and HR_{max}. In the wheelchair ergometer, responses in PWC, HR_{max} and LA_{max} were significantly lower (36%, 7% and 26% respectively) than the arm crank ergometer yet peak VO_2 and VE_{max} remained similar in both exercise modes. Although none of the studies have directly considered the impact of music on performance, their very existence provides a rationale for this study.

2.4 - Reasons for Performance Increase

Within the available literature, a number of studies have tried to identify the reasoning behind music and exactly how it impacts performance when beneficial responses occur. Initially, Copeland & Franks (1991) suggested that listening to music during exercise increased relaxation and this was how performance improved. Following on, Karageorghis & Terry (1997) later proposed that increased levels of arousal before and during exercise were the reason as to why performance increased. At a later date, Yamashita et al. (2006) suggested that music led to a reduced perception of fatigue that caused increases in performance. Finally, Simpson & Karageorghis (2006) suggested music encouraged motor co-ordination or synchronisation of movement patterns in time with the tempo of the music.

2.5 - Synopsis

Research into anaerobic exercise, running, rowing and particularly the Wingate test, has been exhausted. Although originally the results were contrasting, during recent times, more studies have supported the use of music as an ergogenic aid. However, there is a lack of research observing the effects of music on upper body exercise. A thorough search of the available literature proved inconclusive, therefore identifying an area for potential research. As a result, the aim of this study was to observe and analyse the effects of music on physiological responses during heavy sub maximal arm crank ergometry where a considerable anaerobic contribution to energy turnover was evident.

2.6 - Hypothesis

Having identified the direction in which this study will follow, the null hypothesis constructed stated that the intervention of music would have no effect upon performance (time to exhaustion) or the related physiological responses compared to the control (no music) condition.

CHAPTER THREE

METHOD

Having concluded that music can enhance aerobic performance; this study looked to see if music could also enhance anaerobic performance.

3.1 - Participants

The participants recruited for the study were 6 active, yet not specifically trained, males, age 20.33 s = 0.81years, height 176.67 s = 7.31cm and body mass 70.25 s = 5.72kg, from Cardiff Metropolitan University. The study had gained institutional ethical approval and all participants were drafted with informed consent. Before testing commenced, a Physical Activity Readiness Questionnaire (PAR-Q) was completed to ensure the participants health and safety was of paramount importance. The results revealed that everyone was healthy enough to participate despite one participant having a history of a shoulder injury. The participant was advised to stop if the testing procedures aggravated the injury at any point.

3.2 - Study Design

The design of the study was a crossover repeated measures study that ran over a three week period. In week one, participants were introduced to the aims of the study. Mass (SECA, 770, Hamburg, Germany) and height were measured as this information was required to calibrate the Oxycon system (Oxycon, CPX, Warwick, England). Participants then undertook the peak power protocol to determine the relative intensities they would work at for the main test protocol. After testing, participants were randomly assigned an order in which they would complete the remaining two tests. Weeks two and three operated as the main testing sessions. The participants arrived and followed the ethically approved, main protocol. Participants either completed the test in the no music condition or the music condition in the first week then completed it in the other condition the following week.

3.3 - Peak Power Exercise Protocol

A preliminary staged VO_2 peak test was completed by all participants. The protocol required participants to complete an initial power output of 50 W for 2-min, which acted as an integrated warm up, on an arm ergometer (Lode Arm Ergometer, Groningen, Netherlands). Thereafter, external power increased by 20 W every 2-min until the point of volitional exhaustion. Throughout the test, participants were required to maintain an imposed crank rate of 80 $rev \cdot min^{-1}$; fatigue was deemed to have occurred when the participant could no longer maintain a crank rate of 75 $rev \cdot min^{-1}$. This preliminary test served two purposes: firstly, to establish peak physiological responses and secondly, to determine peak aerobic power that would subsequently be used to individually prescribe a relative, submaximal exercise intensity.

3.4 - Sub Maximal Exercise Protocol

Initially, the participants were attached to a wireless heart rate monitor (Polar Electro, RS4000, Kemple, Finland) and a gas mask that was attached to a calibrated Oxycon CPX gas analysis system. After 3-mins of rest, in which data was being collected, the participant began to arm cycle at 50 W for 1-min as a warm up to prevent injury. Thereafter, the participant increased their work to 80% of their relative peak power. This intensity was maintained for as long as possible and the test finished when the participant was unable to continue at 80% peak power and aborted the test. To measure the effectiveness of the intervention, the pace ($rev \cdot min^{-1}$) the participant worked at was self-selected and the work (watts) was kept constant. When the test was completed under the music condition, the same playlist consisting of songs between 125 - 140 $beats \cdot min^{-1}$ (Karageorghis et al. 2011) were played on an iPad (Version 6.1, Apple, California) through headphones (Goji, England) at full volume from the start of the rest period and throughout the duration of the test.

To ensure consistency throughout testing, the same selection of songs was played for each participant in the same order. During the no music (control) condition, the participant sat in silence for the rest period and when the test began, they received continual verbal encouragement throughout.

3.5 - Pilot Studies

The aims of the pilot studies were to familiarise the researcher with the equipment and the initial protocols. The peak power protocol and the control protocol were both subject to vigorous testing. It allowed the researcher to familiarise himself with the timing of the data collection during the test. It was found that the original 3-min warm up participants had to complete at 50 W, proved to be quite intense and too long. Therefore, the warm up was shortened to 1-min. Also, due to the untrained nature of the participants, the original plan to work at 85% of their peak power was deemed to be too difficult. As a result, the test was changed to 80% peak power and the test was repeated again. This adaption to the test was successful and resulted in a more suitable protocol where the participants were still working anaerobically.

3.6 - Physiological Measurements

The dependent variables collected during both tests included volume of oxygen consumed (VO_2), volume of carbon dioxide produced (VCO_2), pulmonary ventilation (VE), the respiratory exchange ratio (RER), heart rate (HR), subjective ratings of perceived exertion (RPE) and time to exhaustion (TTE) at 80% peak power. The independent variables were the condition in which the tests took place, a control condition and a music condition. HR was collected using a wireless heart rate monitor at the end of every minute interval and until the tests were completed. The respiratory data (VO_2, VCO_2, RER and VE) was found using an Oxycon gas analysis system. Borg's scale (Borg, 1982) was used to determine the RPE at 1-min intervals for the first 5-mins of the test. Finally, the time to failure at 80% peak power was measured on the timer that ran on the screen of the Oxycon system.

3.7 - Data Collection

Data collection began as soon as the test protocol started. The Oxycon system started recording all the respiratory data from the beginning of the test and stopped recording data as soon as the participant had reached exhaustion and stopped. Crank rate was recorded every 15-s and HR every minute. The RPE was collected at the end of every minute for the first 5-mins. All the data, except the respiratory values, was collected on a data sheet. The respiratory values were collected from a 30-s screen report produced by the Oxycon system. All the data was then collated in tables in Microsoft Excel (2010) in preparation for the statistical analysis.

3.8 - Statistical Analyses

Analyses were performed using the Statistical Package for Social Sciences (SPSS, version 20; Chicago, II, USA) to allow significant differences in the raw data to be identified. A paired t-test was used to analyse time to exhaustion in both test conditions. The values for 1-min, 2-min and the peak value were analysed using a 2-way (time x test) repeated-measures Analysis of Variance (ANOVA) test. Initially, the data was tested for sphericity using Mauchly's test. If sphericity was not assumed, the figure for Huynh-Feldt correction was used. However, this was not necessary as sphericity was assumed for all tests. A significant difference was assumed if the P value was less than 0.05 ($P < 0.05$).

CHAPTER FOUR

RESULTS

4.1 - Peak Power

The data displayed in Table 1 was collected during the VO_{2peak} protocol. This data was used to make comparisons between peak values achieved in the peak power protocol and peak values in the control or music condition. No significant differences ($P > 0.05$) were found between the VO_{2peak}, control and music condition in peak VO_2 and HR values, suggesting that participants were working to their maximum in all three tests.

Table 1. Average (±SD) values collected during the peak power protocol

Test Time (s)	Absolute Power (W)	VO_{2peak} ($ml \cdot min^{-1}$)	VCO_{2peak} ($ml \cdot min^{-1}$)	VE_{peak} ($l \cdot min^{-1}$)	RER_{peak}	HR_{peak} ($b \cdot min^{-1}$)	RPE_{peak}
586.16 (141.7)	130 (18)	2568.66 (447.92)	3049.33 (363.09)	114.66 (22.44)	1.22 (0.08)	187 (6)	14. (1)

Table 2. Peak values (±SD) for VO_2 and HR in the VO_{2peak}, control and music conditions

	VO_{2peak} Protocol	**Control Condition**	**Music Condition**
$VO_{2\ peak}$($ml \cdot min^{-1}$)	2568.67 (447.93)	2393.5 (226.3)	2235 (384.61)
HR_{peak} ($b \cdot min^{-1}$)	191 (6)	184 (8)	190 (11)

4.2 - Control and Music Condition

All the data collected during the two sub maximal tests to exhaustion are presented in Table 3. No significant differences ($P > 0.05$) were observed in any of the physiological parameters or crank rate between either test conditions. However, significant differences ($P < 0.05$) were experienced in all the physiological parameters between 1-min, 2-min and the peak value, except HR, suggesting a progressive increase in physiological responses throughout the duration of exercise. In regards to HR, there was no significant difference ($P <$ 0.05) between 1-min and 2-min, however, a significant difference ($P < 0.05$) was evident between 2-min and the peak value. No significant difference (P < 0.05) was found in mean crank rate between 1-min and 2-min, suggesting that the crank rate was kept constant for this period of time. Similarly, there were no significant differences to report for the test and time interaction. Figure 1 illustrates the time to exhaustion between test conditions, where no significant difference ($P < 0.05$) was observed.

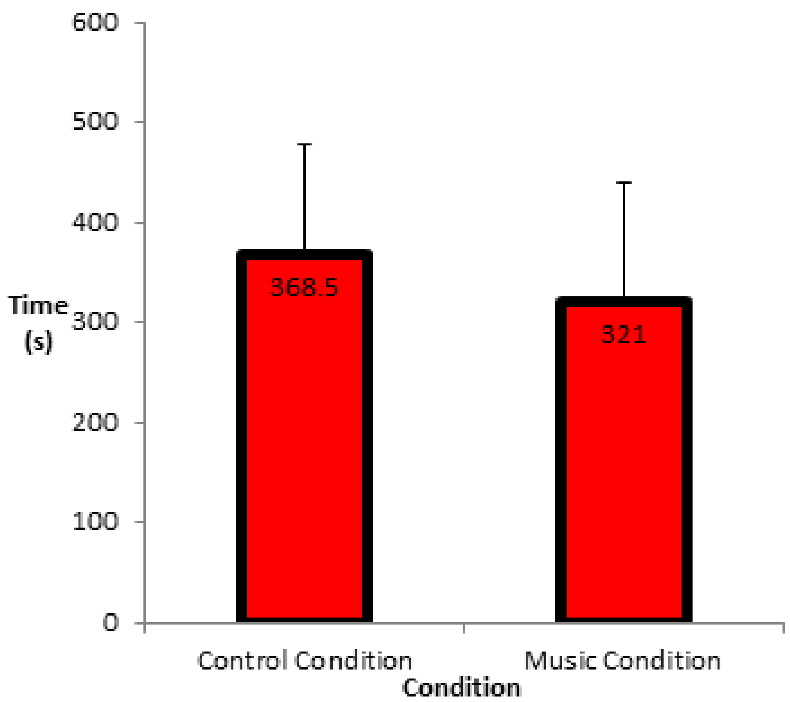

Figure 1. Illustration of the time to exhaustion in both conditions.

Table 3. Average (±SD) values for all measured parameters during the control and music condition

	Control Condition			Music Condition		
	1-min	2-min	Peak	1-min	2-min	Peak
Mean Crank Rate (revs·min^{-1})	77 (14)	77 (17)	86 (12)*	69 (17)	70 (16)	77 (21)*
HR (beats·min^{-1})	143 (21)	159 (17)*	183 (8)	142 (13)	160 (11)*	184 (11)
RPE	11 (2)	14 (1)*	1 (1)*	10 (1)	13 (0)*	17 (2)*
VO_2 (ml·min^{-1})	1449 (142.63)	1817.66 (311.02)*	2393.5 (226.30)*	1240.33 (300.41)	1761.5 (339.2)*	2235.83 (384.60)*
VCO_2 (ml·min^{-1})	1252.16 (229.3)	2084.33 (351.09)*	2774.16 (302.49)*	1029.66 (243.99)	1961 (331.18)*	2535 (524.29)*
RER #	0.86 (0.11)	1.15 (0.12)*	1.25 (0.11)*	0.84 (0.16)	1.13 (0.17)*	1.24 (0.19)*
VE (l·min^{-1})	37.33 (6.12)	63.5 (12.62)*	103.5 (13.72)*	33.66 (10.30)	61 (13.53)*	99.83 (33.2)*

Note: * denotes a significant difference from the previous time point

CHAPTER FIVE

DISSCUSSION

5.1 - Interpretation of Findings

Within the test, responses gradually evolved throughout the duration of the constant load tests, and there were no significant differences in peak responses. The results of this research fall in line with the minority of research that has suggested that a music intervention does not bring about any increase in an athletic performance, nor heightened physiological responses. Supporting this research, Pujol and Langenfeld (1999) also found that in a similar study design there was no significant ($P > 0.05$) difference in time to exhaustion in a control or music test condition. Similarly, Yamamoto et al*.* (2003) concluded that a music intervention before exercise did not improve performance. Both studies, albeit focused on lower body exercise, provide some evidence to support the findings of this study. Therefore, the original null hypothesis that stated the music intervention would have no effect on performance or related physiological responses, in comparison to the control condition, can be accepted. However, due to the limited research into music and the impact it has upon upper body exercise, the findings of this preliminary study should not be discarded. Goosey-Tolfrey et al. (2011) reported contradictory research findings in which they suggested a slow music tempo had more of an impact upon wheelchair mechanical efficiency than a control condition or a fast music tempo. Conversely, this study observed the music intervention during exercise as opposed to the previously mentioned study where music was listened to during a three week training period, thus suggesting a slower music intervention during training may prove more beneficial. However, there is a limited amount of research to support this. Unlike some research (Rendi et al. 2008; Adnan et al. 2009) that tested different tempos of music on performance, this study attempted to follow current recommendations made in recent research (Karageorghis et al. 2011) and assess the impact of one tempo of music on performance. Once more, due to the limited research on the subject area, this may have been less constructive in trying to identify overall whether there is an appropriate musical intervention for upper body exercise that can act as an ergogenic aid.

5.2 - Physiological Parameters

During both constant load exercise tests, there were gradual increases in all the measured physiological responses linked to the delay in evolution of HR, RER, VO_2 and other related respiratory responses. Of these responses, crank rate, RPE, VO_2, VCO_2, RER and VE were lower during 1-min and 2-mins in the music condition than the control condition, suggesting that overall, the same amount of work can be completed but with initial lower physiological responses during the first 2-mins of exercise. The lower physiological responses within the music condition add further support to the theory proposed by Yamashita et al. (2006) that suggested music reduced the perceived exertion of the work. Similarly, all the peak values except HR were lower in the music condition than the control condition, adding further evidence. The peak values for the sub maximal protocol under both conditions were lower than the peak values achieved in the peak power protocol, yet statistical analysis revealed no significant differences in peak HR and VO_2 between the peak power, control and music conditions. This could suggest that the participants were working near to or at their maximum ability for the tests. These results provided contrasting evidence to those of Birnbaum et al. (2009) who found increased responses in the cardiovascular system during exercise to fast tempo music. A number of studies did not identify the peak responses of physiological parameters within their research. However, for the studies that did monitor peak responses in HR (Atan, 2013; Eliakim et al., 2007; Jarraya et al., 2012) and RPE (Eliakim et al., 2007; Jarraya et al., 2012) there appeared to be no major differences in peak values. Nonetheless, conclusions cannot be drawn between the peak values across studies as a statistical analysis would need to be undertaken.

5.3 - Addressing Previous Reasons for Performance Increases

A number of previous studies identified potential reasons for increases in performance linked with music interventions. Originally, Copeland & Franks (1991) suggested a performance increase occurred due to increased relaxation. If the participant was relaxed, HR may have appeared lower in the music condition, but the fact that there was no significant difference between HR suggested that this mechanism did not occur. Subsequently, Karageorghis & Terry (1997) suggested that performance improved due to increased levels of arousal. However, there was no evidence of increased arousal during this study, as there was no significant difference in HR between test conditions. Increased HR is a response normally triggered by the release of adrenaline in the sympathetic nervous system stimulated by arousal. The aforementioned reasons for performance increase did not occur during this study and could be the reason that there were no increases in performance. However, the theory proposed by Simpson & Karageorghis (2006) suggested music encouraged synchronisation of movement patterns in time with the tempo of the music. This study provided some evidence supporting this theory although there was no increase in performance. The mean, self-selected crank rate during the music condition at 1-min was 69 s = 17 rev·min^{-1} and at 2-min was 70 s = 16 b·min^{-1}. This equated to approximately half of the 140 b·min^{-1} of the music intervention and suggested a ratio of roughly 2 b·min^{-1} per 1 rev·min^{-1} on the arm ergometer. This may prove more beneficial for longer, aerobic exercise than anaerobic exercise as anaerobic exercise requires a short maximal effort whereas an aerobic exercise adopts a pacing strategy and lasts longer, in which synchronisation may improve performance. This information regarding synchronisation may also be useful for both coaches and athletes as it could allow the tempo of a piece of music to be manipulated to influence performance during training or competition. In a practical context, using the ratio identified in this study, a wheelchair athlete could theoretically listen to a music track of 200 b·min^{-1} during training and maintain a 100 rev·min^{-1} crank rate. This may lead to potential chronic physiological adaptations thus causing an increase in performance.

Some research suggested that music can act as a physiological ergogenic aid as it bought about responses in physiological measures such as HR (Copeland and Franks, 1991; Atkinson, Wilson and Eubank, 2004) and oxygen consumption (Birnbaum et al., 2009). Likewise, some research suggested that music could act as a psychological ergogenic aid, as these studies have reported, regardless of improvements in physiological measures, differences in the subjective measure of RPE, between music conditions and control conditions (Copeland and Franks, 1991; Mohammadzadeh et al., 2008; Goosey-Tolfrey et al., 2011). The current study provided no evidence of music acting as a physiological ergogenic aid as there were no significant differences in the physiological parameters. In contrast, the peak RPE value in the music condition was lower than the control condition (17 s = 2 and 18 s = 1 respectively) which suggested that music may provide psychological responses which reduce the perception of fatigue (Yamashita et al., 2006).

5.4 - Strengths and Limitations

Strengths of this study were that it allowed a fast tempo music intervention to be rejected as an ergogenic aid, unless it is the personal preference of the participant. This was supported in the research by Adnan et al. (2009), although it did not involve an upper body exercise protocol. This research was also able to add some depth to the limited, currently available research and could act as a guide for future research to examine other potential musical interventions. The design of this study added to the strength of this research. The design meant there would be no external influence on the test protocol and the subsequent results collected as it allowed the full effectiveness of the intervention to be measured and accurate conclusions to be drawn. Throughout testing, the same protocol was followed rigorously using the same equipment without the aid of any additional researchers. This meant that there was reliability and consistency in data collection throughout the test protocols and the subsequent data collected.

As with all research, this study contained a number of limitations. Firstly, the sample size was originally designed to involve at least 12 participants. However, issues arose in regards to being able to recruit sufficient number due to a lack of interest and a preconceived idea that people already have in relation to music aiding performance, despite not understanding the available yet contrasting literature. If a greater sample size could have been recruited, this would have added greater strength to the statistical analyses. Secondly, it was worth noting that after a test session using the music intervention, the participant commented on the music selection and how it was not necessarily to their preferred choice. The participants' results for this test were also notably lower than the control condition. As previously mentioned, this narrowed the potential of the research to provide evidence of an effective music intervention. Furthermore, within the sample, there was a gender bias as all the recruited participants were males. Future research may benefit from including females into the sample; this would not only allow the resulting conclusions to be applied to a wider population but also allow comparisons to be made between genders. Additionally, participants were not familiarised with either test protocol. This may have caused an initial shock to the participants and impacted upon their performance within the test protocols. Future research may wish to integrate a familiarisation session within the design of the study to counteract the potential decreases in performance from being unfamiliar with the intensities of the test protocols. Following on, despite some data (HR and respiratory data) being collected prior to exercise, it did not form part of the analyses and therefore was not used for the current study as attention was focused on the effects of the music intervention upon the constant load protocol. This could have been useful to analyse whether any benefits would have occurred if listening to music prior to sub maximal upper body exercise. This also provides a future direction for research as there is only a small body of literature currently available that has studied the impact of a music intervention prior to sub maximal exercise. Finally, the lack of research into the impact of music on upper body exercise can make supporting conclusions in this research challenging. Without scientific support, conclusions drawn upon could be deemed weak and therefore have little standing within a scientific setting.

CHAPTER SIX

CONCLUSION

The null hypothesis stated at the end of the literature review can be accepted because no significant differences ($P > 0.05$) were observed between the control and music condition in time to exhaustion or crank rate. Physiological responses during both constant load tests were statistically similar ($P > 0.05$) suggesting that during anaerobic upper body exercise, music cannot enhance physiological responses. Interestingly, peak responses in VO_2 and HR_{max} were statistically similar ($P > 0.05$) in both constant load tests and the peak test suggesting that music is not needed in order for an individual to reach their peak performance during anaerobic upper body exercise. However, the use of music may provide psychological benefits that reduce the perception of fatigue or encourage synchronisation of movement patterns with the tempo of the music, thus making the work completed easier.

Therefore, conclusions can be drawn that a fast tempo music intervention did not enhance performance or physiological responses during sub maximal arm crank ergometry that contained a major component of anaerobic work. . However, this study provided some evidence towards synchronisation between music tempo and the frequency of the movement patterns. This information can be useful for coaches and athletes as the tempo of a piece of music can be manipulated to encourage a higher work rate during training or competition, leading to potential chronic physiological adaptions such as an increased VO_{2peak}. It could be beneficial for future research to emulate this study. Based upon anecdotal reports from the participants in this study it is highly recommended that future research allows individuals the freedom of choice to select their own music. As a result of this, it is more likely that the genre and tempo of music will be more appropriately suited to the participants' individual preference, therefore optimising the likelihood of eliciting potential changes in physiological responses and subsequent performance capacity.

REFERENCES

Atan, T. (2013). Effect of music on anaerobic exercise performance. *Biology of Sport,* **30**(1), p35-39.

Atkinson, G., Wilson, D. & Eubank, M. (2004). Effects of music on work-rate distribution during a cycling time trial*. International Journal of Sports Medicine*, **25**(8), p611-615.

Barney, D., Gust, A. & Liquori, G. (2012). College Students' Usage of Personal Music Players (PMP) during exercise. *International Council for Health, Physical Education, Recreation, Sport, and Dance Journal of Research,* **7**(1), p23-26.

Bernatsky, G., Bernatsky, P., Hesse, H., Staffen, W. & Ladurner, G. (2004). Stimulating music increases motor coordination in patients afflicted with Morbus Parkinson. *Neurosci Lett*, **361**, p4-8.

Birnbaum, L., Boone, T. & Huschle, B. (2009). Cardiovascular responses to music tempo during steady-state exercise. *Journal of Exercise Physiology*, **12**(1), p50-57.

Borg, G. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise*, 14(5), p377-381.

Brooks, K. & Brooks, K. (2010). Difference in Wingate power output in response to music as motivation*. Journal of Exercise Physiology online*. **13**(6).

Copeland, B. & Franks, B. (1991). Effects of types of intensities of background music on treadmill endurance. *Journal of Sports, Medicine, and Physical Fitness*, **31**(1), p100-103. cited in, Goosey-Tolfrey, V., West, M., Lenton, J. & Tolfrey, K. (2011). Influence of varied tempo music on wheelchair mechanical efficiency following 3-week practice. *International Journal of Sports Medicine*, **32**(2), p126-131.

Eliakim, M., Meckel, Y., Nemet, D., & Eliakim, A., (2007). The effect of music during warm-up on consecutive anaerobic performance in elite adolescent volleyball players. *International Journal of Sports Medicine*, **28**(4), p321-325.

Eliakim, E., Meckel, Y., Gotlieb, R., Nemet, D. & Eliakim, A. (2012). Motivational music and repeated sprint ability in junior basketball players. *Acta Kinesiologiae Universitatis Tartuensis.* **18**, p29-38.

Elliott, D., Carr, S. & Orme, D. (2005). The effect of motivational music on sub-maximal exercise. *European Journal of Sport Science*,**5**(2), p97-106.

Glaser, R., Sawka, M., Brune, M. & Wilde, S. (1980). Physiological responses to maximal effort wheelchair and arm crank ergometry. *Journal of Applied Physiology*, **48**(6), p1060-1064. cited in, Martel, G., Noreau, L., Jobin, J., (1991). Physiological Responses to Maximal Exercise on Arm Cranking and Wheelchair Ergometer with Paraplegics. *Paraplegia*, **29**(7), p447-456.

Goosey-Tolfrey, V., West, M., Lenton, J. & Tolfrey, K. (2011). Influence of varied tempo music on wheelchair mechanical efficiency following 3-week practice. *International Journal of Sports Medicine*, **32**(2), p126-131.

Hagan, J., Foster, C., Rodriguez-Marroyo, J., Koning, J., Mikat, R., Hendrix, C. & Porcari, J. (2013). The Effect of Music on 10-km Cycle Time-Trial Performance. International Journal of Sports Physiology and Performance, **8**, p104-106.

Haluk, K., Turchian, C., & Adnan, C., (2009). Influence of music on Wingate anaerobic test performance. *Science, Movement and Health*, **9**(2), p134-138.

Jarraya, M., Chtourou, H., Aloui, A., Hammonda, O.,Chamari, K., Chaouachi, A. & Souissi, N. (2012). The Effects of Music on High-intensity Short-term Exercise in Well Trainined Athletes. *Asian Journal of Sports Medicine,* **3**(4), p233-238.

Karageorghis, C. & Terry, P. (1997). The psychophysical effects of music in sport and exercise: A review. *Journal of Sport Behaviour*, **20**, p54-68.

Karageorghis, C., Terry, P. & Lane, A. (1999). Development and initial validation of an instrument to assess the motivational qualities of music in exercise and sport: the Brunel Music Rating Inventory. *Journal of Sports Sciences*, **17**(9), p713-724.

Karageorghis, C., Jones, L., Priest, D., Akers, R., Clarke, A. & Perry, J. (2011). Revising the exercise heart rate-music preference relationship. *Research Quarterly for Exercise and Sport*, **82**, p274-284.

Mohammadzadeh, H., Tartibiyan, B. & Ahmadi, A. (2008). The effects of music on the perceived exertion rate and performance of trained and untrained individuals during progressive exercise. *Physical Education and Sport*, **6**(1), p67-74.

Pujol, T. & Langenfeld, M. (1999). Influence of music on Wingate Anaerobic test performance. *Perceptual and Motor Skills*, **88(1)**, p292-296.

Rendi, M., Szabo, A. & Szabo, T. (2008). Performance enhancement with music in rowing sprint. *The Sports Psychologist*, **22**, p175-182.

Simpson, S. & Karageorghis, C. (2006). The effects of synchronous music on 400m sprint performance. *Journal of Sports Sciences*, **24**, p1095-1102.

Yamamoto, T., Ohkuwa, T., Itoh, H.,Kitoh, M., Terasawa, J., Tsuda, T., Kitagawa, S. & Sato, Y. (2003). Effects of pre-exercise listening to slow and fast rhythm music on supra-maximal cycle performance and selective metabolic variables. *Archives of Physiology and Biochemistry*, **111**(3), p211-214. cited in, Karageorghis, C., & Preist, D. (2012). Music in the exercise domain: a review and synthesis (Part 1). *International Review of Sport and Exercise Psychology,* **5**(1), p44-66.

Yamashita, S., Iwai, K., Akimoto, R., Sugawara, J. & Kono, I. (2006). Effects of music during exercise on RPE, heart rate and the autonomous nervous system. *Journal of Sports Medicine and Physical Fitness*, **46**(3), p425-430. cited in, Karageorghis, C., & Preist, D. (2012). Music in the exercise domain: a review and synthesis (Part 1). *International Review of Sport and Exercise Psychology,* **5**(1), p44-66.