PASSIVE VERSUS ACTIVE EXERCISE: AN EXAMINATION OF AFFECTIVE CHANGE

BY

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THESIS

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ABSTRACT

In the examination of affective responses to acute aerobic exercise, researchers have plodded over the appropriate control condition to use in comparison with aerobic exercise, as a true placebo has eluded the field. This has resulted in a variety of conditions constituting "control" in the literature (quiet rest, reading, sitting in a chair on a treadmill, stretching, etc.). One option that holds merit but has yet to be tested is that of passive exercise. As such the purpose of the present study was to examine the psychological and physiological effects of active versus passive exercise. A total of 17 (7 females) participated in both an Active exercise session (they pedaled a cycle ergometer) and a Passive exercise session (the ergometer pedals were moved by a motor while their feet were attached). Enjoyment, heart rate, and perception of exertion were higher in the Active session, but there were no differences in terms of other affective responses (e.g., energy, tension, calmness, state anxiety, valenced affect). The only affective variable that changed differently in the two conditions was Tiredness, which decreased following Active exercise but did not change following Passive exercise. The findings are discussed with respect to placebo and expectancy effects, with directions for future investigation in both able-bodied as well as spinal cord injured individuals.

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CHAPTER 1

INTRODUCTION

Importance of Exercise

Not only does frequent exercise have the ability to improve one's physical well-being, it has been shown to improve psychological well-being as well. The mind-body relationship is one that has been examined extensively in the past. In order to determine where passive exercise falls on the exercise spectrum, it is necessary to delineate the psychophysiological responses that result from passive and active exercise. If these two methods of exercise end up having more in common than previously thought, this would have important implications for kinesiologists studying the effects of exercise on mood, stress, and other psychophysiological changes within the body.

It is well known that physical activity and exercise reduces the risk of developing cardiovascular disease, Type 2 diabetes and metabolic syndrome, and some cancers, as well as increases in bone mineral density and muscle mass. Physical activity has also been associated with improvements in mental health (affect, emotions, mood, cognitive function) as well as improvements in one's ability to perform activities of daily living (ADLs), thus improving overall quality of life. If passive exercise elicits the same psychological effects as active exercise, in absence of physiological factors, this may provide an alternative for placebo control groups in exercise studies. Additionally, if no psychophysiological differences are found between passive and active exercise, this may provide an alternative method of exercise treatment to special populations such as those with spinal cord injury (SCI), the elderly, those with severe mental illness (e.g., depression, PTSD), or those who are morbidly obese or suffer from other comorbidities as a result of sedentary lifestyles.

In previous research, psychophysiologists have examined a broad array of effects that cardiovascular activity has on various psychological factors, including mood, affect, reaction time, stress levels, and memory recall. However, within the realm of exercise research specifically, few studies have considered using passive exercise as a placebo for an exercise condition. Instead, research has focused on active and passive recovery post-exercise or within rehabilitation therapy.

Currently, there is no known way to implement a true placebo for assigned exercise or physical activity. Researchers have utilized various manipulations as a placebo/control, including sitting on a chair placed on a treadmill, “light stretching”, or quiet rest (Bahrke & Morgan, 1978). However, even the brief amount of activity participants receive during very light activity manipulations (e.g., stretching) may be sufficient to elicit a psychological response for those particular participants (i.e., even minimal exercise could potentially elicit an affective response). Active exercise can be defined as exercise performed *with* volitional control. Conversely, passive exercise is defined as exercise performed *without* volitional control. It has been suggested that passive exercise can be done via functional neuromuscular stimulation [FNS; also referred to as facilitated electrical stimulated (FES) exercise], technician-assisted exercise, or through the use of specifically designed leg extension or leg-cycling apparatuses (Mahoney et al., 2005). FNS involves applying a low-level electrical current to the nerves that control muscles to stimulate movement. This method of passive exercise varies from technician-assisted passive movement in that an electrical impulse is passed through the muscle at amplitudes high enough to elicit a response, thus forcing the muscle to engage.

Given the general lack of information concerning the psychophysiological effects of passive vs active exercise, the present study aims to examine the following hypotheses:

1) Passive exercise will elicit similar psychological changes as active exercise.
2) Participants will exhibit more enjoyment for active exercise than passive.
3) Although similar in nature, Active exercise will have significantly stronger effects on affect compared to passive exercise.

CHAPTER 2

LITERATURE REVIEW

To date, there is a lack of information regarding whether or not passive exercise has the potential to be implemented as a true placebo. The only way to fully test the placebo effect of exercise is to sever the mind from the body. Determining the psychophysiological effects of passive exercise in spinal cord injured individuals would provide an understanding of the mind body connection. This would allow researchers to better equate affective changes associated with acute exercise to either a psychological expectancy or a psychophysiological change. In the latter, researchers would propose that an underlying physiological effect of exercise was influencing the mind in some way. Such knowledge would provide scientific evidence to support or refute currently proposed biological mechanisms of affective change (e.g., biochemical and physiological hypotheses) as reviewed by Mohammadi-nezhad (2011).

Examining the Placebo Effect

Various studies (e.g., Weiner & Weiner, 1996) examining the validity of placebos have shown that the placebo effect works even in the event that participants are aware they have received a placebo. Shapiro and Morris (1978) went as far as to claim that the "placebo effect is an important component and perhaps the entire basis for the existence, popularity, and effectiveness of numerous methods of psychotherapy" (p. 369). Initially viewed as an artifact to be controlled for, the placebo effect is now considered a powerful psychological mechanism in itself. That same effect has been speculated to occur regarding benefits of exercise. With the current study, we intend to examine the idea proposed by others (Anderson & Brice, 2011; Desharnais, Jobin, Côté, Lévesque, &

Godin, 1993; Otto et al., 2007; Plante, Lantis, & Giancarlo, 1998; Weiner & Weiner, 1996), namely that the individuals who perceive they have received psychological benefits from exercise have such perceptions strictly because they believe they should exhibit these assumed outcomes. However, this is due to previous knowledge (e.g., heard from others, read in popular literature), not necessarily because they are truly experiencing such feelings. As described by Weiner and Weiner (1996) "[t]he ceremony of taking a placebo, especially under conditions associated with a desire and expectation of relief, can initiate psychological and biophysical events of therapeutic significance" (p. 248). If the expectancy theory is controlled for properly, it would be possible to compare both the physiological and psychological effects of exercise of an experimental condition (active exercise) to a placebo condition (passive exercise) without the participants fully knowing what effects are being examined.

Moerman and Jonas (2002), in their article on deconstructing the placebo effect, openly state that one thing that is absolutely certain regarding placebos is that placebos do not cause placebo effects. Their understanding of placebos is that they are inert and do not cause anything (Moerman & Jonas, 2002); it is the reactions to placebos that cause an effect. Controlling for such expectancies in studies poses some difficulty. Moerman and Jonas (2002) identify a study where participants were asked to test two new drugs: a tranquilizer and a stimulant. Each participant was given either one or two, red or blue inert tablets and asked to identify which pills were the sedatives and which were the stimulants, as well as which dose (one pill, or two) had the greater effect (Moerman & Jonas, 2002). The participants' responses were similar in that they stated that the red pills were stimulants, the blue resulted in tranquilizing effects, and that two pills worked better than one (Moerman & Jonas, 2002). The effects of color and expectancy within the placebo effect have been replicated time and time again, with similar results.

A study conducted by Desharnais et al. (1993) set out to measure the influence of prompted expectations to psychological well-being (self-esteem) in two groups of 24 participants following a 10-week exercise training program. Each group of participants was assigned to identical training programs in terms of length (10-weeks), number of weekly sessions (3 per week), and length of each training session (90 minutes) (Desharnais et al., 1993). However, the only difference between the groups was that the experimental group was led to believe the training program was specifically designed to improve self-esteem, while the control group was not (Desharnais et al., 1993). Results of the study showed that both groups exhibited significant improvements in overall physical well-being, but only the group primed to believe they would experience improved self-esteem showed such improvements, which neared statistical significance (Desharnais et al., 1993).

In a later review of the research on the mechanisms and role of the placebo effect, Ernst (2007) discusses the difficulty in agreeing upon a specific definition of the terms 'placebo' and 'placebo effect' because there are so many definitions for the terms and that there is a myth that placebo effects are short in duration and that all placebos are equal in strength and work similarly for all ailments. Ernst (2007) suggests that patients with pain and depression seem to have a marked response to placebos.

According to Ernst (2007), ethical considerations for the use of placebos are highly debated in that they can lead to the withholding of effective treatment, yet at the same time, the use of placebos helps researchers interpret the results of studies.

Additionally, Ernst highlights that the lack of placebo control is itself unethical by definition (Ernst, 2007). Although passive exercise may not elicit the same level of physiological benefits as active exercise, the psychological benefits to exercise may be present following this mode of exercise.

Crum and Langer (2007) also tested the relationship between exercise and the placebo effect, The researchers attempted to determine whether the placebo effect could increase the perceived exercise levels of individuals engaging in occupational physical activity (Crum & Langer, 2007). Eighty-four hotel room attendants from seven different hotels participated in this study. Based on self-reported measures collected at the beginning of the study, room attendants met and exceeded the Surgeon General's recommendation of obtaining at least 30 minutes of physical activity per day during the course of an average workday (Crum & Langer, 2007). Each of the seven hotels and the room attendants that worked there were sorted into an informed condition or a control condition and neither group changed the amount of energy expended on the job. However, workers in the informed condition received information explaining that attending to rooms is "good exercise" (Crum & Langer, 2007, pg.167); workers in the control condition did not receive this information. After 4 weeks, Crum and Langer (2007) showed that although actual activity levels remained the same, attendants in the informed condition perceived they were engaging in higher levels of exercise compared to baseline. Additionally, room attendants experienced greater physiological benefits such as further reduced body mass index (BMI), body-fat percentage, waist-to-hip ratio, and blood pressure (Crum & Langer, 2007). Again, these results support the notion that the placebo effect can sway the benefits of exercise.

Expectancy

It is important to acknowledge the expectancy theory when studying the use of a placebo. The placebo effect is a great example of the expectancy theory in that if given a sham medication to help treat an ailment, some participants may experience relief from the sham (i.e., placebo) simply because they expect relief from the treatment. It is the belief of researchers that if expectancy theory is controlled for properly, it would be possible to compare both the physiological and psychological effects of exercise with an experimental condition (active exercise) to a placebo condition (passive exercise) without the participants fully knowing what effects are being examined. Placebo responses are enhanced through verbal instructions informing participants that the treatment they are about to receive is beneficial (Ernst, 2007). This can be seen in various studies such as workplace exercise studies (Crum & Langer, 2007; Stanforth et al., 2011) and medical procedures (e.g., sham acupuncture or drug treatment).

Since passive exercise has yet to be examined in this respect, a need for pilot study in able-bodied individuals is vital for the understanding of the mechanisms behind affective change via passive exercise, before examining the effects in individuals with spinal cord injuries. Since the publication by Desharnais et al. (1993), multiple studies have been conducted in an attempt to disentangle the placebo effect. Anderson and Brice (2011) examined memory bias and whether expectations of the benefits of exercise influenced perceived mood changes post-exercise. They informed participants (*N*=40) that they were studying the impact of various activities on mood. Participants were randomly split into a non-exercise group (*n*=20) who were asked to complete a word search activity, or an exercise group (*n*=20) who were required to jog lightly for 10 minutes. Prior to completing the assigned activities, participants were asked to complete the Incredibly Short POMS (ISP; Whelan, Epkins & Meyers, 1990) assessing their current mood. The ISP differs from the original Profile of Mood States (POMS) by shortening the measure from a 65-item questionnaire to a mere 6 items each measuring one of the subscales in the POMS (tension, depression, anger, fatigue, vigor, confusion). Immediately following the activities, participants completed two additional ISPs. The first, assessing their current mood, and a second asking them to recall their pre-activity mood. Results of the study demonstrated the beneficial effects of single, short bouts of exercise on mood, with significant mood improvements for the exercise group only. However, Anderson and Brice (2011) neglected to measure participants expectations or beliefs regarding the effects of exercise. Asking participants to recall their pre-activity mood is not the same as measuring expectations.

Anderson and Brice (2011) scrutinized the benefits of exercise being widely publicized within the media. It has been proposed that given that all participants within their study were regular exercisers, it is likely that individuals were aware of the potential beneficial effects of exercise prior to participation. “These expectations may have been crucial when, in retrospect, participants were asked to rate their pre-exercise mood state, leading them to overestimate/underestimate levels of negative/positive mood states to ensure the expected mood benefits occurred (Anderson & Brice, 2011 p. 81).” However, Anderson and Brice (2011) also state that a flaw within their methods arose, as they did not specifically measure participants’ beliefs of expectations regarding the effects of exercise and without further examination of preconceptions of the benefits of exercise, any conclusions drawn from this study were only speculative.

The primary goal of measuring the psychophysiological differences between active and passive exercise is to identify the active components of these differences as they relate to exercise, and then determining how and if these psychophysiological responses can be controlled for in an effort to use passive exercise as a placebo. The most widely accepted cognitively based explanation for the placebo effect is based on patients' expectations of therapeutic benefit (Desharnais et al., 1993). A placebo as defined by Shapiro and Shapiro is "any therapy or component of therapy that is deliberately used for its nonspecific, psychological, or psychophysiological effect, or that is used for its presumed specific effect but is without specific activity for the condition being treated." (1978, p.372). The placebo effect is defined as "a meaningful physiological or psychological response elicited after the use of inert or sham treatment response (Brooling, Pyne, Fallon & Fricker, 2008, p. 432)." These effects can be either positive (e.g., improved mood, improved speed, decreased pain) or negative (e.g., decreased mood, nausea).

Similarly, Desharnais et al. (1993) and Anderson and Brice (2011) express the belief that the increased publicity regarding the beneficial effects of exercise, especially aerobic activity, has encouraged more individuals to participate in exercise with the expectation of improvements in both physical and psychological well-being. Anderson and Brice (2011) also highlight that these expectations may influence pre and post-exercise changes for long term exercise programs as well as following a single bout of exercise (Anderson & Brice, 2011). However, as mentioned previously, these expectations can only be proposed at this time.

Active vs. Passive Exercise

Generally, individuals are more aware of the concept of active exercise rather than passive exercise. One of the first studies found (published in English) examining passive pedal motion with the legs was published by Dixon, Stewart, Mills, Varvis and Bates (1961). Since then, many studies have been conducted to examine and compare both the physiological similarities and differences between active and passive exercise in able-bodied (AB) individuals.

Benjamin and Peyser (1964) studied the physiological effects of active and passive exercise using two differing methods of cycling on able-bodied (AB) participants. During the first method, exercise was held at a constant rate, and in the second, experimenters attempted to match passive exercise oxygen consumption to that of active exercise. Participants in the second method were different than those who participated in the first method. Benjamin and Peyser (1964) modified a Monark bicycle so it could be used with pedal and handlebar movement for active exercise, or only pedal movement for passive exercise. For both passive and active series, participants "exercised" at a rate of 60rpm for 30 minutes. Metabolic demand, tympanic membrane temperature, five skin temperatures and heart rate data were collected (Benjamin & Peyser, 1964).

Results showed that passive exercise increased participant ventilation beyond their metabolic demand (Benjamin & Peyser, 1964). The authors considered the increased ventilation to be a reflex action initiated by stimulation of proprioceptors as a result of movement, displacement, or tension. Benjamin and Peyser also considered that local chemical changes occurring in active exercise may have increased the sensitivity of these receptors, thus producing an increased respiratory response.

This is similar to Dixon et al. (1961), who found that passive torso and arm movement increased ventilation in excess of participants' metabolic demands. However, leg movement alone did not produce this kind of hyperventilation (Dixon et al., 1961). That being said, hyperventilation cannot be stated to be a link with increased heat production. Although the increase in ventilation did show a corresponding increase in heart rate, passive exercise did not show an increase in heat production. These factors, also found by Benjamin and Peyser (1964), could support the concept of temperature being an important component in the hyperventilation occurring with exercise. However, a lack of electromyography (EMG) measurements within this study limit the interpretation of the results as there is no true way of determining if the passive exercise bouts were truly passive. Benjamin and Peyser (1964) cautioned the use of the term "passive" exercise as they expressed that passive exercise could never be purely passive as there is always some level of positive or negative active work involved in movement.

An example of such can be seen in a study by Bell, Ramsaroop, and Duffin (2003), in which participants took part in an experiment examining respiratory effects of passive exercise. During the experiment, participants either sat on the front seat of a tandem leg extension apparatus or a tandem bicycle, facing away from the experimenter who powered the apparatus. During each condition, leg muscle EMG was measured constantly via surface electrodes over the vastus lateralis of the left leg, using the patella as a ground site. Throughout the bicycle and leg extension conditions, a metronome was set so that limb movement would occur at 65 cycles$\cdot$min^{-1} so that one leg performed a downward cycle or a leg extension motion upward. In both conditions, participants were not told when passive exercise would begin or end.

Bell et al. (2003) also measured breathing techniques during passive limb movement to learn more about the absence of conscious drive to motor units, what they refer to as a "lack of central command," which may influence breathing (p. 544). While examining the average differences in the final breath of resting to the first breath of passive exercise (Fast Exercise Drive at Start), the final breath during passive exercise to the first breath of rest (Fast Exercise Drive at End), and the change from rest to steady-state exercise, the authors found no significant change from rest to steady-state exercise for the chair apparatus (Bell et al., 2003).

Following the conditions, participants reported that due to balance issues and having difficulty relaxing, the leg extension apparatus was found to be more comfortable than the upright bicycle (Bell et al., 2003). Synonymous with participant feedback, the EMG data collected showed that there was a significant active component in passive exercise using a tandem bicycle. This was not the case when exercises were performed using the chair apparatus. Additionally, Bell et al. (2003) noted a significant change of oxygen uptake (VO_2) and carbon dioxide production (VCO_2) from rest to steady-state exercise in the tandem bicycle protocol, but showed no such changed when using the chair apparatus. Bell et al. (2003) concluded that passive exercise on an upright bicycle required a significant amount of muscle activity that contributed to neural and metabolic influences toward the psychological adjustments observed. Use of a recumbent bicycle, as well as collecting EMG readings from abdominal, erector spinae, and gluteal muscles, may help answer any question regarding the degree of passivity. A comparison to an active group may have also been beneficial in comparing these passive exercises to active exercise.

In an attempt to identify the contributing mechanisms to the initial increase in HR response to exercise, Nóbrega and Araújo (1993) observed 29 participants while they performed two, 4 second bouts of active and passive exercise on a tandem bicycle where HR and muscular activation of the lower limb were measured via ECG and EMG tracings, respectively. While pedal rotations were similar during the 4-second bouts for active (7.4 ± 0.3 rpm) and passive (7.5 ± 0.2 rpm) exercise, there was a significant change in HR ($p < .001$) in both active and passive exercise (92 to 125 b·min^{-1}: 35.9% increase; 87 to 111 b·min^{-1}: 27.6% increase), which were not different from each other ($p = 0.185$; Nóbrega & Araújo, 1993). There was also no observable muscle activation via EMG in the passive condition compared to the active, suggesting that central command was absent (Nóbrega & Araújo, 1993).

Again, Nóbrega et al. (1994) tested 10 participants and evaluated them at rest and following 5 minutes of active and passive cycling (via tandem bicycle). HR, mean arterial pressure (MAP), cardiac output (CO), oxygen uptake (VO_2), RPE, and electrical activity of the lower limb via EMG were measured. Nóbrega et al. found that EMG, RPE, and VO_2 were significantly higher during active than passive exercise, as would be expected (Nóbrega et al., 1994). Additionally, CO increased during both passive and active cycling. However, during active cycling it rose as a result of increased HR (from 73±2 at rest to 82±2 b·min^{-1} at 60 rpm) with no change in SV, whereas SV increased (65±4 at rest to 71±3 ml at 60rpm; $p=0.003$) with no change in HR (Nóbrega et al, 1994). The authors state that these results support the concept that central command determines the HR response to exercise (Nóbrega et al., 1994).

Although there have been multiple studies comparing the physiological effects of passive and active exercise (Bell et al., 2003; Nóbrega & Araújo, 1993; Nóbrega et al., 1994), no studies have examined the psychological effects of passive exercise, specifically affective change.

In a small study conducted by Krzemiński, Kruk, Nazar, Ziemba, Cybulski, and Niewiadomski (2000), 8 male participants (age, 19.6 ± 3yrs; mass, 72.2 ± 3.2 kg; height, 177 ±6.3 cm) completed 3 trials of 2, 5-minute exercise tests consisting of passive cycling (electrically moved) at 50rpm, a 40-minute rest period, and a 5-minute bout of active cycling at 50rpm without any resistance. In both conditions, EMG was recorded at the rectus femoris, biceps femoris, tibialis anterior, and gastrocnemius, as well as other physiological measures including, but not limited to, heart rate (HR), oxygen uptake (VO_2), cardiac output (CO), rate of perceived exertion (RPE), and blood lactate (LA; Krzemiński et al., 2000).

Muscle activity (EMG) showed a slight, but insignificant increase from resting levels during the first and second passive trials (Krzemiński et al., 2000). During both active exercise trials, there was a significant difference between rest and exercise EMG activity at all four measurement sites from rest (Krzemiński et al., 2000). Unfortunately, there was no discussion of whether there was a significant difference found in EMG activity between passive and active trials, only rest.

CHAPTER 3

METHODOLOGY

Participants

Participants (*N*=17), both regular exercisers and non-exercisers, were recruited from the University of Illinois at Urbana-Champaign student population. Male (*n*=7) and female (*n*=10) college students comprised the sample for this study (*M* age=20.12 (1.83) years, *M* mass=66.92 (13.42) kg, *M* height=169.29 (19.94) cm). All participants were screened and only low-risk individuals were allowed to participate in the study. Health risk was determined by the completion of the Physical Activity and Health History Inventory and a Physical Activity Readiness Questionnaire (PAR-Q) (Thomas, Reading, & Shephard, 1992). All of the protocols used in the present study were approved by The University of Illinois at Urbana-Champaign Institutional Review Board (IRB). Participants were made aware of their right to remove themselves from the study at any time, for any reason, without fear of penalty of any kind.

Measures

Health risk and background information. The Physical Activity Readiness Questionnaire (PAR-Q; Thomas, Reading, & Shephard, 1992) was used to determine if it was physically safe for a participant to take part in this study, as it involved moderate aerobic exercise. The PAR-Q is made up of seven 'yes' or 'no' questions and was completed prior to any involvement in the study. If participant answered 'yes' to any of the seven questions they were considered to be ineligible, and were excluded from the study. The modified Health & PA History Form provided by the Department of

Kinesiology & Community Health, University of Illinois at Urbana-Champaign (2010) was used to assess participants' basic demographic and personal information (i.e., sex, age, year in school, height, body mass, and physical activity history).

Preference for and Tolerance of Exercise Intensity Questionnaire (PRETIE-Q). The PRETIE-Q is a 16-item Likert scale questionnaire that takes inventory of an individual's exercise habits by having them select whether they agree or disagree, on a continuum, with a statement about their exercise habits (Ekkekakis, Hall, & Petruzzello, 2005). Half of the questionnaires represent the idea of exercise preference, while the other half represents exercise tolerance.

Affect. The Feeling Scale (FS; Hardy & Rejeski, 1989), the Felt Arousal Scale (FAS; Svebak & Murgatroyd, 1985), and the Activation Deactivation Adjective Check List (AD ACL; Thayer, 1986) were used for assessment of affect. Taking a dimensional approach to assessing affect (Ekkekakis & Petruzzello, 2002), the FS was used to measure affective valence. The FS is an 11-point, single-item, bipolar measure of pleasure-displeasure, which is commonly used for the assessment of affective responses during exercise (Ekkekakis & Petruzzello, 1999). The scale ranges from +5 to -5, with anchors provided at zero (Neutral) and at all odd integers, ranging from 'Very Good' (+5) to 'Very Bad' (-5). The FAS was used to measure perceived activation during the exercise bouts. The FAS is a 6-point, single-item measure, ranging from 1 (Low Arousal) to 6 (High Arousal). The FAS is strongly correlated with valid single-item measures used to assess activation. The AD ACL is a 20-item measure, with five items comprising each of four subscales: Energy, Tiredness, Calmness, and Tension. Each item is rated on a 4-

point rating scale (definitely feel=4, feel slightly=3, cannot decide=2, definitely do not feel=1; Thayer, 1986).

Rating of Perceived Exertion (RPE) Scale. This scale ranges from 6 to 20, with 6 being low exertion, and 20 being exhaustion (Borg, 1998). Participants pointed to numbers on this continuum during the incremental exercise test and during both the passive and active conditions, in order to check their exertion levels in relation to heart rate measures.

Enjoyment. The Physical Activity Enjoyment Scale (PACES; Kendzierski & DiCarlo, 1991) was used in order to assess enjoyment following each condition. The PACES contains 18 bipolar statements that anchor the ends of a 7-point response scale where participants choose the number that most closely corresponds to the way they feel at the moment about the physical activity they have just finished doing [e.g., "*I enjoy it* (1)...*I hate it* (7)*"; "I dislike it* (1)*...I like it* (7)"]. Scores on the PACES range from 18 to 126. Kendzierski and DeCarlo (1991) demonstrated that the PACES was valid and had acceptable internal consistencies in two separate studies (Cronbach's alphas = 0.93 in both).

Procedures

Day One

All participants were initially screened over the phone using the PAR-Q (Thomas, Reading, & Shephard, 1992) and only those meeting the inclusion criteria (no more than one Yes response to any of the items) were allowed to participate in the study. Those meeting the inclusion criteria were scheduled for an initial visit to the Exercise Psychophysiology Laboratory (ExPPL).

On the first day of participation, upon arrival to the ExPPL, participants were asked to complete the Health and Physical Activity History Inventory to further establish safe participation in the study. Any Yes responses to items in the sections titled Cardiovascular Disease Symptoms, Recent Health Disturbances, or Family History were followed up with the potential participant to insure their participation would not put them at unnecessary risk. All study personnel were trained on what would constitute removal from the study (i.e., elevated risk), with final word in the cases of uncertainty being made by the Research Principle Investigator. After inclusion was established, participants completed a battery of questionnaires and were fitted with a Polar heart rate monitor (Polar Electro, Inc., Kempele, Finland). The testing procedure was explained and the participants were taken to a separate laboratory to complete the submaximal exercise protocol. This was used to determine an estimated level of aerobic fitness on a Monark 818E exercise bicycle. Participants were acquainted with the bicycle and the submaximal testing protocol (see next paragraph) was explained. Following bicycle fitting and answering any questions the participants had, the participants were fitted with headgear and mouthpiece with a one-way valve for collecting expired gas via an open-circuit spirometry metabolic cart (Parvomedics TrueOne 2400, Sandy, UT, USA).

Each participant performed a YMCA submaximal test protocol. The protocol consisted of three or four consecutive 3-minute workloads, lasting no more than 15-minutes. Participants were seated on the bicycle for 3 minutes so that resting metabolic gasses could be collected and analyzed to ensure proper functioning of the metabolic cart. Participants performed cycle ergometry at a pedal cadence of 50 rpm with an initial workload of 25 Watts (0.5Kp). Heart rate during the last 15-seconds was used to determine subsequent workloads (if HR <80 $b \cdot min^{-1}$: 125W; 80-90 $b \cdot min^{-1}$: 100W; 90-100 $b \cdot min^{-1}$: 75W; >100 $b \cdot min^{-1}$: 50W). Heart rate was measured with a Polar heart rate monitor. Expired air was collected and analyzed with open-circuit spirometry as mentioned above. To ensure that participants were not exercising to maximal exertion, the experimenters closely monitored the activity levels of each participant so they did not reach more than two (2) of any of the following maximal exercise criteria: (i) a rating of perceived exertion score (RPE) of ≥ 17 on the Borg scale (6-20 scale; Borg, 1998), (ii) a respiratory exchange ratio (RER) > 1.1, (iii) no change in HR with a change in workload (which would indicate maximal HR), (iv) a "plateau" (increase of no more than 150ml) in oxygen uptake with an increase in workload, or (v) volitional fatigue, defined as an inability to maintain a pedal rate ≥60 rpm. Participants then cooled down by pedaling for at least 2 minutes at a chosen pedal speed with the workload at 25W. During the exercise test, perceived exertion (RPE) and affect (FS) were assessed at each minute until completion of the test. Self-reported affect was obtained immediately prior to and following exercise testing.

Days Two and Three

Following completion of the Day 1 testing, participants were scheduled for 2 separate test sessions in the Exercise Psychophysiology Laboratory. In order to reduce the possible effect of bias, experimenters read a prewritten script to all participants. Participation in both the active and passive exercise session were randomly assigned and counterbalanced for each participant. Participants were asked to refrain from exercising and consuming caffeine 24 hours prior to, and eating 2 hours prior to testing. On each exercise day, immediately upon reporting to the laboratory, participants completed the

AD ACL, SAI, FS, and FAS. They were then instrumented (HR, EMG electrodes) and completed the AD ACL, SAI, FS, and FAS again immediately before the assigned condition for the day. Both sessions were identical in length of time cycled (25 min: 5 min warm-up, 15-min at assigned workload, 5-min cool-down), pedal cadence (50 rpm), and equipment used (Polar, Monark 818E cycle ergometer with foot straps). Every 5 min throughout the exercise sessions, participants were asked to rate their perceived exertion (RPE), affect (FS), and arousal (FAS). Immediately following the completion of the exercise session, the participants were again asked to complete the AD ACL, SAI, FS, and FAS, and Physical Activity Enjoyment Scale (PACES). At 10 minutes following the session they again completed the AD ACL, SAI, FS, and FAS for a final time.

On Active exercise days, participants manually pedaled the Monark 818E, with their feet strapped onto the pedals, at a rate of 50 rpm for 25 minutes according to the protocol listed above. On Passive exercise days, participants again had their feet strapped onto the bicycle pedals while an electric motor was used to turn the pedals of the bicycle at a rate of 50 rpm. Although the motor was turning the pedals during the Passive exercise condition, it was disengaged but turned on/running during the Active exercise condition so as to keep the noise stimulation constant between the trials. Participants were instructed to let the pedals turn from the power of the motor rather than through their own effort during the passive trials.

Data Analysis

Data analysis was conducted using SPSS 22.0.0.0 for Windows. Data were initially inspected for any unusual data points, with corrections made as needed. Analysis of differences in enjoyment between the two exercise conditions was done with a *t*-test.

All other analyses of pre- to post-exercise changes in affect and pre-, during, and post-exercise changes were conducted with repeated measures analyses of variance (RM-ANOVA), using the Huynh-Feldt epsilon correction to protect against violations of the sphericity assumption. Effect sizes were calculated as Cohen’s *d* (Cohen, 1988). All analyses were run with sex as a between subjects factor and none of the results were significant; as such, sex is not considered in subsequent analyses.

CHAPTER 4

RESULTS

All 17 participants completed both Passive and Active protocols on a modified Monark 818E stationary bicycle. Descriptive characteristics of the sample are presented in Table 1.

Table 1. Descriptive characteristics of the participants

Participant Characteristics	Male (*n*=10)		Female (*n*=7)		Total Sample (*N*=17)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age (years)	20.00	2.08	20.20	1.75	20.12	1.83
Height (cm)	175.62	12.47	162.56	10.62	169.29	12.32
Weight (kg)	74.58	14.85	61.55	9.77	66.92	13.42

Note: All participants who initially volunteered for the study completed all three sessions with a zero percent drop-out rate.

Enjoyment: Active vs Passive Exercise

Immediately following the completion of either the Active or Passive exercise condition, participants completed the PACES as a measure of the enjoyment they were experiencing as a result of the just completed exercise session. It was hypothesized that enjoyment would be greater immediately after the Active relative to the Passive condition. A one-tailed *t*-test was performed to test this hypothesis. Participants reported greater enjoyment ([*t*(16)= 1.871, *p*=.040) following Active versus Passive exercise (*M*=92.53 ± 14.13 versus *M*=84.24 ± 21.22, respectfully). Hedge's *g* (unbiased) as a measure of effect size resulted in a value of 0.449.

Affective Responses: Active vs Passive Exercise

It was hypothesized that there would be no difference in affect *following* the Active condition compared to the Passive condition, and no real difference in affect between exercise conditions from pre- to post-exercise.

Examination of the pre- to post-affective responses (Energy, Tiredness, Calmness, Tension) were initially done with a series of Exercise Condition (2: Active, Passive) x Time (4: pre-10, pre-0, post-0, post-10) repeated measures ANOVAs for each of the individual affective subscales of the AD ACL (i.e., Energy, Tiredness, Calmness, and Tension) as well as for State Anxiety.

Table 2. Scores for the AD ACL Tiredness and Tension subscales

	Time	**Active (*N=17*)**		**Passive (*N=17*)**	
		M	***SD***	***M***	***SD***
Tension	Pre-10	6.65	1.80	7.71	3.16
	Pre-0	7.18	2.30	7.29	2.59
	Post-0	6.65	1.69	6.24	1.72
	Post-10	7.18	1.32	6.06	1.71
Tiredness	Pre-10	11.12	3.89	9.94	3.61
	Pre-0	10.00	3.54	9.42	3.22
	Post-0	8.18	2.83	9.65	4.27
	Post-10	9.06	3.51	9.59	3.28

Table 3. Scores for the AD ACL Energy and Calmness subscales

	Time	**Active (*N=17*)**		**Passive (*N=17*)**	
		M	***SD***	***M***	***SD***
Energy	Pre-10	11.29	3.84	12.06	3.75
	Pre-0	11.06	3.19	12.06	3.80
	Post-0	13.12	2.89	12.41	3.78
	Post-10	11.41	3.74	11.76	3.77
Calmness	Pre-10	12.88	3.16	11.94	2.99
	Pre-0	12.59	2.67	12.59	3.43
	Post-0	11.53	2.45	11.88	2.60
	Post-10	12.82	2.04	13.35	2.69

For Energy, a significant Time main effect [$F(2.45, 39.16)=3.373$, $p= .036$, $\eta^2_{part} = .174$; H-F $\varepsilon=.816$] was seen, but the Condition ($p= .479$) and Condition x Time interaction ($p= .097$) were not significant. Energy was significantly increased from pre-10 exercise to immediately post-exercise (*M* difference= 1.09, $p= .051$, $d=0.342$), Energy immediately post-exercise (post-0) was significantly greater than pre-0 (*M* difference= 1.21, $p= .024$, $d= 0.387$), and Energy post-0 was significantly greater than Energy post-10 (*M* difference= 1.18, $p= .002$, $d=-0.377$).

Tension also displayed a significant Time main effect [$F(2.92, 46.75)=6.118$, $p= .001$, $\eta^2_{part} = .277$; H-F $\varepsilon=.974$], but the Condition ($p=.600$) and Condition x Time interaction ($p=.088$) were not significant. There was a significant decrease in Tension seen from pre-10 to post-10 (*M* difference= 1.09, $p= .002$, $d=-0.536$), from pre-0 to post-0 (*M* difference= .79, $p= .002$, $d=-0.337$), from pre-0 to post-10 (*M* difference= 1.15, $p= .008$, $d=-0.487$), and from pre-10 to post-0 (*M* difference= .74, $p= .054$, $d=-0.361$).

For Tiredness, neither the Time main effect ($p=.061$) nor the Condition main effect ($p=.940$) were significant. However, there was a significant Condition x Time interaction [$F(2.55, 40.77)=5.497$, $p= .004$, $\eta^2_{part} = .256$; H-F $\varepsilon=.849$]. As seen in Figure 1, there was a significant decrease in Tiredness across all time points (pre-10, pre-0, post-0) and a slight increase following exercise (post-10), but this was different depending on whether the exercise was Active or Passive. The Passive condition showed little change in Tiredness. The Active condition, on the other hand, resulted in a progressive decrease in Tiredness from Pre-10 to Post-0 (*M* difference= 2.94, $p= .002$, $d=0.891$) and post-10 (*M* difference= 2.06, $p= .023$, $d=0.574$ as well as from pre-0 to post-0 (*M* difference=

1.82, *p*= .010, *d*=0.584). There was no difference between pre-0 and post-10 (*p*= .203, *d*=0.275).

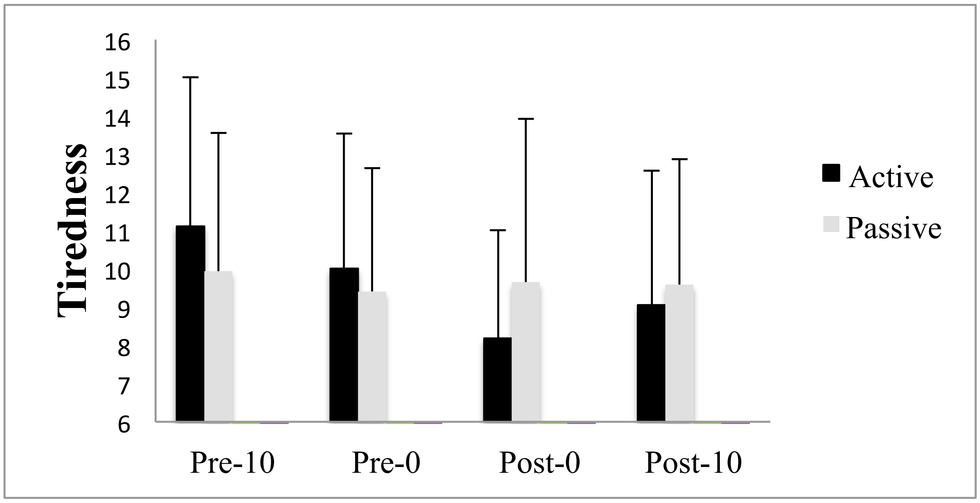

Figure 1. AD ACL scores for the Tiredness subscale pre- and post-exercise in the two exercise conditions.

For State Anxiety, a significant Time main effect [*F*(2.53, 40.44)=5.212, *p*= .006, η^2_{part} = .246; H-F ε=.842] was seen, but no Condition or Condition x Time interaction. SA was greater pre-10 relative to post-10 (*M* difference= 1.588, *p*= .008, *d*=-0.552), SA was greater pre-0 relative to post-10 (*M* difference= 1.618, *p*= .002, *d*=-0.522), and SA was greater post-0 relative to post-10 (*M* difference= 1.529, *p*= .002, *d*=-0.496). State anxiety did not change significantly from pre-0 to post-0.

Table 4. Scores for the State Anxiety before and following the exercise conditions

	Time	Active (*N=17*)		Passive (*N=17*)	
		M	**SD**	**M**	**SD**
SAI	Pre-10	15.58	3.38	16.53	4.17
	Pre-0	16.12	3.66	16.29	4.24
	Post-0	16.12	3.37	16.12	3.95
	Post-10	14.59	3.02	14.59	3.36

Finally, for Calmness, the Time main effect (*p*=.092), Condition main effect (*p*=.977), and Condition x Time interaction (*p*=.344) were not significant.

FS, FAS: Active vs Passive

To examine the affective responses to the different exercise conditions, Feeling Scale (FS) and Felt Arousal Scale (FAS) scores were subjected to the Condition (2: Active, Passive) x Time (9: pre-10, pre-0, warm-up, 5-, 10-, and 15-min during exercise, cool-down, post-0, and post-10) RM ANOVA. The analysis revealed no significant effects for Condition (*p*=.853), Time (*p*=.067), nor the Condition x Time interaction (*p*=.815). As seen in Figure 2, there was a general trend toward increasing FS scores (indicating greater pleasantness) over the course of the exercise bout from pre-exercise to recovery, but no significant changes.

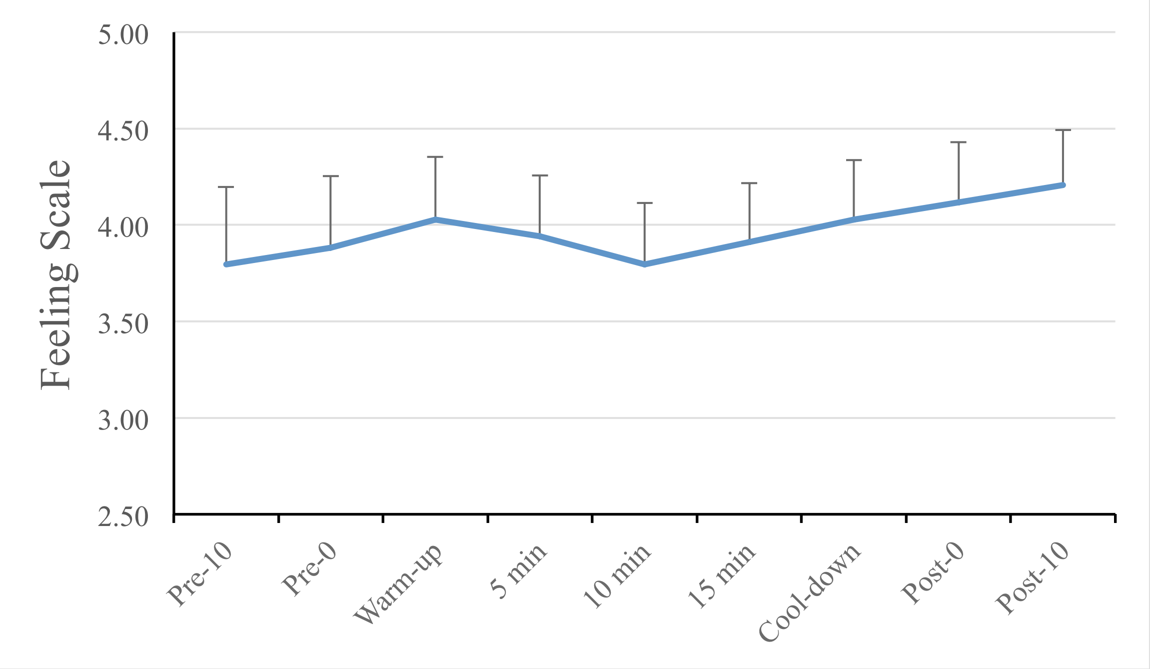

Figure 2. Feeling Scale before, during, and following the two exercise conditions

Table 5. Scores for the Feeling Scale and Felt Arousal Scale before, during and following the exercise conditions

	Time	**Active (*N=17*)**		**Passive (*N=17*)**	
		M	***SD***	***M***	***SD***
Feeling Scale	Pre-10	3.88	1.93	3.88	1.72
	Pre-0	3.88	1.93	4.00	1.36
	Warm-up	4.06	1.64	3.88	1.17
	5 mins	4.00	1.66	3.76	1.17
	10 mins	3.82	1.63	3.88	1.20
	15 mins	3.94	1.56	3.76	1.17
	Cool down	4.00	1.50	3.88	1.14
	Post-0	4.06	1.48	3.76	1.24
	Post-10	4.24	1.35	3.88	1.13
Felt Arousal Scale	Pre-10	1.94	1.48	2.06	1.56
	Pre-0	2.06	1.56	2.00	1.46
	Warm-up	2.29	1.76	2.12	1.50
	5 mins	2.59	1.66	2.18	1.38
	10 mins	2.65	1.62	2.29	1.40
	15 mins	2.76	1.64	2.41	1.37
	Cool down	2.53	1.74	2.24	1.44
	Post-0	2.12	1.80	2.06	1.48
	Post-10	2.12	1.83	2.12	1.54

For FAS, there was a significant Time main effect [$F(3.49, 55.78)=8.500$, $p<.001$, $\eta^2_{part} = .347$; H-F $\varepsilon=.436$], , but no Condition ($p=.188$) or Condition x Time interaction ($p=.251$). Figure 3 reveals the increasing scores on FAS from pre-exercise until the end of the exercise itself, with a decrease occurring during cool-down and continuing into the post-exercise recovery period.

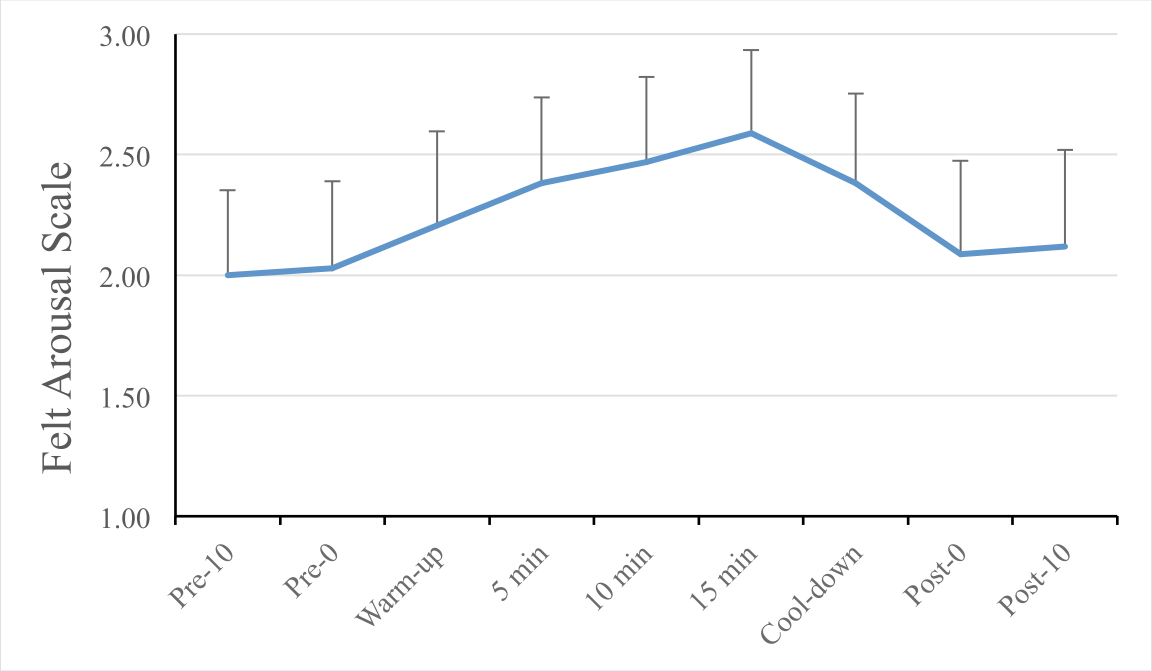

Figure 3. Felt Arousal Scale before, during, and following the two exercise conditions

HR, RPE: Active vs Passive

For HR, the Condition effect [$F(1.0, 16.0)=21.33$, $p< .001$, $\eta^2_{part} = .571$; H-F $\varepsilon=1.0$] was significant, the Time main effect was marginally significant [$F(2.90, 46.37)=2.72$, $p= .057$, $\eta^2_{part} = .145$; H-F $\varepsilon=0.725$], and the Condition x Time interaction was significant [$F(2.71, 43.28)=3.61$, $p= .024$, $\eta^2_{part} = .184$; H-F $\varepsilon=0.676$]. Overall, participants had greater HR in the Active condition ($M=93.95\pm11.54$) relative to the Passive condition ($M=82.33\pm14.10$) (M difference= 10.78, $p= .002$, $d=0.804$). Within the Active condition, HR increased significantly from the Warm-up to 5-min (M difference= 6.06 b·min^{-1}, $p= .023$, $d=0.437$) and 10-min (M difference= 8.29 b·min^{-1}, $p= .024$, $d=0.638$) into the exercise bout and then decreased from 10-min into exercise to the warm-down (M difference= -7.53 b·min^{-1}, $p= .010$, $d= -0.594$), whereas in the Passive condition HR did not change over the course of the bout.

For RPE, the Condition main effect [*F*(1.0, 16.0)=7.538, *p*=.014, η^2_{part} = .320; H-F ε=1.0] and Time main effect [*F*(3.021, 48.329)=7.055, *p*<.001, η^2_{part} = .306; H-F ε=.755] were significant. However, the Condition x Time interaction was not statistically significant (*p*=.397). Similar to HR, participants responded with larger RPE scores in the Active (M=7.49±1.03) relative to the Passive condition (M=6.83±0.89) (*M* difference= 0.66, *p*= .014, *d*=0.707).

Table 6. Heart Rate (HR) and Rating of Perceived Exertion (RPE) values during the exercise conditions

	Time	**Active (*N=17*)**		**Passive (*N=17*)**	
		M	**SD**	**M**	**SD**
HR	Warm-up	89.53	14.75	83.88	15.33
	5 mins	95.59	13.81	82.18	14.71
	10 mins	97.82	11.88	82.88	15.14
	15 mins	92.29	25.37	81.88	14.24
	Cool down	90.29	14.16	80.82	13.32
RPE	Warm-up	6.91	0.80	6.44	0.56
	5 mins	7.65	1.32	6.68	0.73
	10 mins	7.71	1.16	6.91	0.80
	15 mins	7.82	1.29	7.21	1.34
	Cool down	7.35	1.17	6.91	1.70

Figures 4 & 5 show representative heart rate (HR) and rate of perceived exertion (RPE) measurements for all participants for both Passive and Active exercise protocols. HR for Active and Passive exercise were as predicted in that HR rose throughout the Active condition (89 to 98 $b \cdot min^{-1}$) and declined during the cool down period (back to around 90 $b \cdot min^{-1}$) while in the Passive condition, HR remained somewhat steady throughout the entire condition at around 82 b·min^{-1}. Rate of perceived exertion (RPE) also increased throughout the exercise conditions, beginning at 6.7±0.56 during the warm-up phase and increasing to 7.5±1.04 at minute 15 of the bout, then decreasing to 7.1±1.18 during the cool-down. The lack of a significant interaction was due to the fact that, while lower, RPE also increased during the Passive condition. The magnitude of RPE change in the Active condition was 0.91 while for the Passive condition it was 0.77 RPE units (see Figure 5).

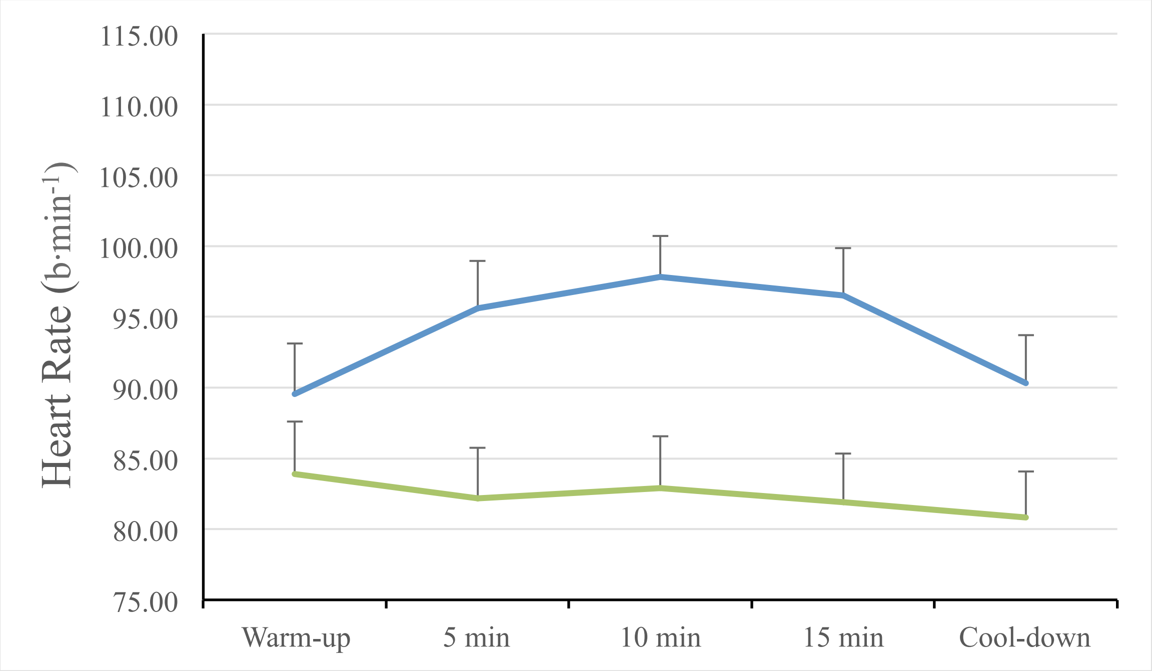

Figure 4. Heart rate responses during exercise in the two intensity conditions

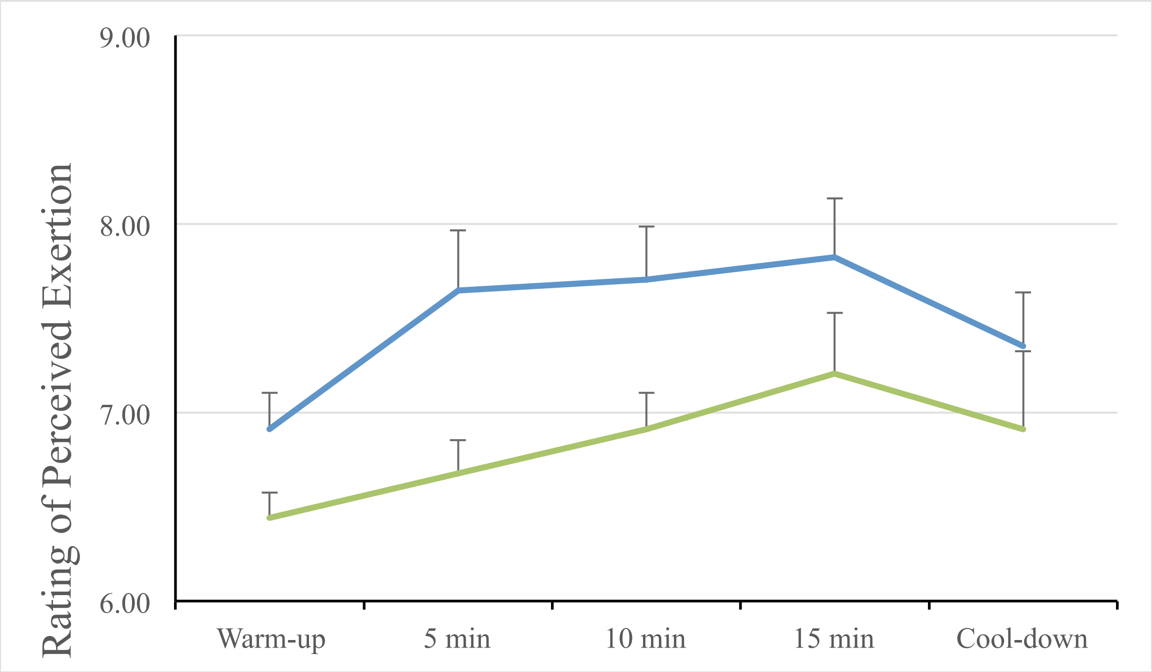

Figure 5. Rating of Perceived Exertion during the two exercise conditions

CHAPTER 5

DISCUSSION

This present study was conducted to determine the extent to which active and passive lower limb exercise (i.e., cycling) had an influence on affective and physiological responses during and following acute exercise. The participants were either asked to pedal at a constant rate of 50rpm for 25-minutes (Active exercise) or to refrain from pedaling while an exterior motor rotated the pedals for them for an identical duration and pace (Passive exercise).

One of the main outcomes of the study was that enjoyment was greater following Active cycling compared to Passive cycling. It is important to recognize that the participants did not find Passive exercise unpleasant (mean PACES score = 84.24 out of a possible score of 126), but merely less enjoyable than Active exercise. This greater level of enjoyment following Active exercise relative to Passive exercise may suggest that the active component of exercise is of value when seeking increased enjoyment or that it may have implications for mechanisms underlying the determination of enjoyment from exercise.

For Energy, defined as an activated, pleasant affective state, there was no difference between conditions, but there were significant changes over time. Numerous studies examining the effects of exercise on perceptions of Energy often show that participants express greater feelings of energy immediately following physical activity. This was seen in the current study, albeit not significantly, as Energy increased slightly more than 2 units from immediately pre to immediately post-exercise in the Active condition whereas it only increased about 0.35 units in the Passive condition. Perhaps a greater, longer energetic effect could be seen if the intensity of the cycling was increased. Although this was not specifically measured within the current study, the expectancy theory could be another reason for the increase in energy seen expressed by participants. Expecting to have increased energy following physical activity may have contributed to the changes in energy seen across both conditions.

Since Energy increased following the exercise conditions, we would expect Tiredness to decrease as they are often inverse states of one another (i.e., increases in energy are often accompanied by decreases in tiredness). While Tiredness decreased over time throughout the Active condition, there was little change in Tiredness in the Passive condition. This could suggest that the Passive condition was indeed passive enough that little effort was exerted throughout the condition. This would offer support for either the expectancy theory, or the use of passive exercise as a placebo (Lindheimer, O'Connor & Dishman, 2015).

The decrease in Tension seen across each time point could also have been due in part from the expectancy theory, the time-out hypothesis, or placebo effect. It is important to note that the pre-exercise levels of Tension were not very high, with the highest score at any time point being approximately 7.7 on a scale ranging from 5 to 20. Again, pre-exercise expectancy was not examined because we did not want to elicit any ideas of expectancy prior to, or throughout, the study. Additionally, pre-exercise Tension could have been elevated prior to the start of the study as a result of participation in an experimental study. Further investigation into participant beliefs and understanding of exercise may be beneficial in answering these questions at a later time.

As with Tension, there was no difference seen between conditions for State Anxiety, but there was a decrease in State Anxiety over time for both conditions. This supports the idea of similar beneficial effects for Passive exercise as seen with Active exercise in reducing State Anxiety. This effect could be due in part again from the expectancy theory and/or the placebo effect. We cannot determine what expectations participants had at the onset of the study, but we can agree that a decrease in State Anxiety is a beneficial in mental well-being, regardless of the reasoning behind such decreases.

There was a trend toward increased FS scores regardless of condition, but the change was not significant. The lack of significance, but trend toward increasing FS scores, could be a dose response issue in that the Active condition was not vigorous enough to elicit a significant response over time.

Again, there was no interaction between the conditions over time, but there was a significant change in felt arousal scores over time across both conditions. This demonstrates that there was an arousing effect on participants throughout the exercise conditions as a result of physical activity. This implies that both Active and Passive exercise elicited similar arousal responses, regardless of whether the participant actively pedaled or whether they allowed their legs to be moved passively. Whether this was the result of a placebo response to exercise or that there was an active component being elicited throughout each condition needs to be more carefully explored.

While there was a significant difference in heart rate (HR) between conditions and across time, this increase in HR seen in the Active condition can be interpreted as a normal physiological response to physical activity. The steady HR during the passive condition can be attributed to a lower intensity activity, which failed to elicit a HR response throughout the passive condition. Interestingly, ratings of perceived exertion (RPE) changed similarly throughout each condition, increasing from baseline to 15 minutes, and decreasing at the completion of the exercise condition. While there was minimal affective change across conditions, RPE during Passive cycling seemed to mimic the trend of Active cycling, but at a lower rate. When comparing this to HR measures of both conditions, one would not expect to see an increase in RPE without an increase in HR over time. With a lack of increasing HR and a lack of significant difference in RPE (due to an increase in RPE during the passive condition), it could be inferred that there is some sort of placebo response occurring during the passive cycling condition, something we could not confirm until we noticed these results in feedback.

Reflecting on the hypotheses set for this study, we find that: 1) Passive exercise elicits psychological changes that are similar to active exercise with respect to perceptions of energy, tension, calmness, state anxiety, and valenced (i.e., positive, negative) affect; 2) participants reported more enjoyment following Active than Passive exercise; and 3) Active exercise has significantly stronger effects on Tiredness compared to Passive exercise. The truth is that regardless of the reasoning behind the changes in affect, the changes still occur, and these changes are generally good (with negative changes typically being seen at much higher intensities than those used in the present study). The questions that have yet to be answered are exactly why these changes occur and how the benefits to individuals can be maximized. To reiterate Ernst's (2007) thoughts on the ethical considerations for the use of placebos, with exercise being treated as medicine, there is little issue with the withholding of effective treatment by prescribing exercise as a placebo. If passive exercise can be used as a true placebo in exercise studies, the data collected and interpreted has the potential to be more accurate than that of past studies using quiet rest or wait-list controls. Although passive exercise may not elicit the same level of physiological benefits as active exercise, the psychological benefits to exercise seem to be present following this mode of exercise.

Limitations

Krzemiński et al. (2000) said it best by stating that it is “difficult, if not impossible, to design the experiment in which only one of the neural mechanisms involved in cardiovascular adjustment to exercise is active (pg. 274).” Without EMG data comparisons, it is difficult to determine if the affective change seen in passive exercise is in fact due to a placebo like response, or other hypothesized theories linking affective change and exercise. During passive exercise on an upright bicycle, it is impossible to completely avoid the muscle recruitment and activation which may be responsible for eliciting some sort of physiological response. This activation may come in the form of muscle recruitment necessary to maintain balance on the bicycle, or from the inability to shut off the natural reflex to pedal.

There are currently no studies which have examined the use of passive exercise without some sort of human interaction (e.g., tandem cycling where another individual pedals while the participant sits and lets their legs be moved passively) as a placebo for volitional physical exercise in order to elicit and examine acute psychological changes. Perhaps the biggest limitation to this study is the inability (impossibility?) to separate the mind from the body in order to perform truly passive exercise. In order to truly test the min-body connection, one would need to sever the mind from the body in some way.

The recruitment of individuals with spinal cord injuries would allow for the continuation of this study.

Future Studies

Spinal Cord Injury (SCI)

Researchers have begun to examine differences between active and passive muscle stimulation and exercise in individuals with SCI in an attempt to identify physiological changes in this population compared to able-bodied individuals. The distinction between complete and incomplete SCI is defined by whether or not an individual has control of his or her bowl and bladder. With an increased understanding of the spinal cord, injury level/location, and severity of the injury, new understandings of SCI are becoming more prevalent and more complex. The American Spinal Injury Association (ASIA) created the Standard Classification for Spinal Cord Injury to establish uniform standards and ensure consistent and accurate classifications for individuals with SCI (ASIA, 2014). However, for the purpose of this review, classification will be simplified to include completeness and lesion level.

Incomplete SCIs are characterized as having sensation and/or voluntary movement below the injury site, whereas complete SCI leaves the individual with no sensation and/or voluntary movement below the injury site (ASIA, 2014; Jacobs & Nash, 2004). Complete paraplegia results in the permanent loss of movement and sensation at the T1 level or below. At T1, the individual has normal hand function and as the injury site moves further down the spinal column, improved abdominal control, respiratory function, and balance may occur (ASIA, 2014; brainandspinalcord.org). Quadriplegia, or disability to all four limbs, can also be classified as complete or incomplete as a result from injuries to levels C1-C7 and the degree of function is a direct result of where the injury to the spine occurred (ASIA 2014). While these classifications are established, it is important to understand that they are merely a guideline for diagnosis and not every SCI is identical at every level. Many factors such as immediate and long-term medical treatment post-injury, as well as individual differences account for variability in every SCI. It is highly unlikely that two individuals with identical lesion levels and completeness will exhibit the same biomechanical and physiological characteristics as one another.

A fairly recent study involving passive leg movement compared the impact of SCI on vascular function and changes in peripheral vascular function below lesion levels to that of able-bodied (AB) age-matched controls. Venturelli et al. (2014) assessed the change in leg blood flow (BF) compared to thigh muscle volume in SCI and AB participants following 2 minutes of passive (technician-assisted) leg extension. Participants (*N*=16; 8 AB control, 8 SCI) were non-smokers and physically active in endurance type exercise of 7.0±3.5 and 5.5±2.5 hours per week in SCI and AB, respectively. Spinal cord injured participants were classified as T6-T12 complete (ASIA-A) averaging 9±3 yrs post-injury and none of the SCI subjects exhibited muscle spasticity/tone at the time of the study (Venturelli et al., 2014). Due to the nature and duration of SCI, as expected, severe lower limb muscle atrophy was present in each participant by the time of the study as well.

Baseline participant characteristics indicated that higher triglyceride levels were observed in SCI (96±15) compared to AB controls (78±19). Although Venturelli et al. (2014) noted that there were no significant differences in height and body mass of each group, percent body fat was not discussed and it should be noted that increased triglyceride levels are associated with increased adipose tissue, as triglycerides are stored in fat cells for the body to use as energy. Higher triglyceride levels would be expected in individuals higher percent body fat.

For cholesterol, HDL in SCI (43±5) was significantly lower compared to AB controls (65±2), and this too is to be expected as increased HDL is associated with cardiovascular fitness. What is interesting regarding the blood work collected by Venturelli et al. (2014) is that total cholesterol was said to be significantly higher in AB controls than that of SCI, 184±6 and 160±8, respectively. With lower HDL, generally lower physical activity in SCI individuals compared to AB controls, and increased body fat percentage associated with SCI, one would expect to see total cholesterol reversed. Although not significantly different, individuals with SCI also had lower LDL than AB controls, and both groups exhibited ideal or near ideal cholesterol levels according to the standards set by the American Heart Association (2014).

A lack of detailed participant characteristics leaves unanswered questions regarding fitness level (VO_2), detailed body composition (lean vs. fat mass), individual lesion levels and how these factors can influence individual data and response to exercise. This information would be especially helpful following study of the effects of participation in a long term FNS exercise program rather than an acute exercise study.

Hemodynamic variables

Following technician assisted passive exercise, there was no significant difference between SCI and AB controls in cardiac output (CO), heart rate (HR), stroke volume (SV), or mean arterial pressure (MAP) during rest (Venturelli et al., 2014). However, AB controls also exhibited higher leg blood flow (BF) in the passive leg compared to SCI, 195±32 and 145±28 respectively (Venturelli et al., 2014). During passive exercise, however, AB controls did exhibit significant differences in MAP, HR and CO compared to their baseline measurements (Venturelli et al., 2014).

Within SCI individuals, there was a significant correlation between change in leg BF and thigh muscle volume (r=0.95, p> .01) (Venturelli et al., 2014). This relationship was not true for the AB control group. Additionally, there was a significant correlation between change in leg BF and time post SCI (r=0.84, p> .01) (Venturelli et al., 2014). When expressed per unit of thigh muscle volume, change in leg BF was not significant between the two groups. However, when muscle volume was taken into account, leg BF levels demonstrated evidence of preserved vascular function within SCI, despite the absence of HR and CO responses following acute passive exercise. Venturelli et al. (2014) highlight that peripheral vascular dysfunction does not necessarily accompany SCI and that the data actually suggests that there is an increase in vascular sensitivity. This increase in leg BF may be a result of compensating for any cardiorespiratory changes in the SCI population, suggesting that vascular sensitivity may be a referred response to passive leg movement.

Functional Neuromuscular Stimulation (FNS)

As of 1990, Hooker et al. (1990) found that there were no published reports on continuous, prolonged (>20 minutes) FNS leg-cycling in persons with SCI. In an attempt to determine the hemodynamic and metabolic responses to prolonged FNS leg-cycle exercise in individuals with SCI, Hooker et al. (1990) examined the effects of long duration (30 minute) FNS leg-cycling on paraplegic and quadriplegic participants at a pedal rate of 50rpm, following 5 minutes of passive (technician-assisted) cycling and 1 minute of FNS cycling at 0W. Participants with incomplete SCI were instructed not to provide any voluntary muscle contractions during the FNS cycle session. During the final 5 minutes of rest and throughout the 30 minutes of FNS leg-cycling, measurements of oxygen uptake (VO_2), carbon dioxide production (VCO_2), minute ventilation (V_E), and respiratory exchange ratio (RER) were measured.

Hooker et al. (1990) expressed concern that organ system adjustments, which normally accompany voluntary exercise, may not occur to the same degree with FNS exercise in persons with SCI due impaired sympathetic nervous system function and the bypassing of the CNS. In able-bodied individuals, a functional sympathetic nervous system maintains optimal control of hemodynamic and metabolic systems during exercise (Hooker et al, 2003). Individuals with SCI have difficulty controlling these physiologic responses due to poor CNS function and, thus, may be unable to safely and effectively perform prolonged FNS leg-cycle exercises. Although there was a trend for paraplegic subjects to have higher stroke volume (p= .07) and QT (p= .11) at baseline compared to quadriplegics, there were no significant differences for heart rate, stroke volume, QT, VO_2, and V_E responses to have higher stroke volume (Hooker et al., 1990).

Almost 20 years following Hooker et al. (1990), Fornusek and Davis (2008) compared the physiologic effects of prolonged FNS-evoked cycling at various cadences (15, 30, and 50 RPM) for 35 minutes in SCI participants. Each participant (N=9) exercised 2-3 times per week for 6 weeks. During the first 10 minutes of the study, participants completed 10 minutes of passive cycling immediately before their FNS session to test pedal cadence. The researchers chose to use bilateral stimulation of the quadriceps, hamstrings, and gluteal muscles to facilitate leg-cycling, as FNS of these muscles have been shown to demonstrate the highest metabolic and cardiorespiratory responses (Fornusek & Davis, 2008).

FNS cycling elicited significant cardiorespiratory, hemodynamic, and muscle oxygenation responses above passive and resting values (Fornusek & Davis, 2008). Additionally, FNS cycling showed significant increases in HR (40%), VO_2 (180%), and CO (52%) over the duration of the 6 week FNS trial (Fornusek & Davis, 2008). Fornusek and Davis (2008) note that there was an accelerated fatigue rate in high cadence FNS compared to low cadence exercise that has not yet been explored. They suggested that the accelerated fatigue during high cadence FNS in SCI could be due in part to impaired blood flow, decreased muscle oxidative capacity, and/or poor circulation which may affect oxygen and substrate delivery or the clearance of metabolic byproducts (Fornusek & Davis, 2008). However, as Venturelli et al. (2014) noted, when muscle volume was taken into account, results demonstrated evidence of preserved vascular function within SCI, despite the absence of HR and CO responses. Venturelli et al. (2014) highlight that peripheral vascular dysfunction does not necessarily accompany SCI and that the data actually suggests that there is an increase in vascular sensitivity, possibly due to unaccustomed limb movement which may be a result of compensating for any cardio respiratory changes in the SCI population.

Autonomic Dysreflexia

As shown in a few examples within this review, functional neuromuscular stimulation offers some physiological benefits for those with SCI. However, FNS also has the potential to trigger dangerous symptoms of autonomic dysreflexia (AD) that have been used as performance enhancers (Webborn, 1999). AD is a phenomenon unique to persons with SCI and is characterized by autonomic nervous system overstimulation and/or parasympathetic dysfunction that results in significant increases in blood pressure, noradrenaline levels (7.1 and 2.35 $nmol \cdot l^{-1}$ in boosted and unboosted states, respectively) and sweating (Karlsson, 1999; Webborn, 1999). AD is most common in those with SCI lesion levels at or above T6 (Karlsson, 1999; Webborn, 1999); however, it is not uncommon in lower level SCIs. Aside from being an extremely dangerous reaction to hyperreflexia (over active reflexes), undetected urinary tract infection (UTI), or other painful stimuli, AD has been shown to be a successful doping method in disability sport known as "boosting". Boosting is the intentional induction of AD to enhance performance and has been banned by the International Paralympic Committee (IPC) since 1994 (Webborn, 1999). It was found that AD could be intentionally induced through practices such as clamping of the urinary catheter to produce bladder discomfort, over tightening of leg straps, or other methods such as induced pain (e.g., inserting thumb tack into paralyzed limbs, or purposefully twisting the scrotum) to produce referred pain and an increased pain response (Webborn, 1999).

Another study of 8 athletes using the boosting technique during maximal treadmill tests found a 9.7% enhancement in performance time as a result of lower heart rate, thus allowing athletes to perform at above normal levels (Burnham et al., 1994). Webborn (1999) equated the enhancement in performance time equal to that of reducing an able-bodied marathon time by 12 minutes. When AD occurs in individuals with SCI, the response to stimuli occurs without direct neural connection through the spinal cord due to lesion damage. However, the central nervous system still receives signals through referred pain signals. This referred pain is the body's way of signaling that something is wrong in the area of the body that is unable to communicate with the brain. It is hypothesized that some sort of AD related signal occurs within the body as a result of the electrical stimulus used in FNS, thus triggering a physiologic response that technician-assisted or machine-assisted passive exercise may not.

Conclusion

Using a relatively low intensity exercise stimulus, the present study demonstrated similar affective responses during and following both active cycling and passive cycling. This presents numerous opportunities for future study. It would be worthwhile to replicate the work reported here at increasingly higher intensities (for the active manipulation) to determine whether the psychological changes seen in the current study would be replicated at these higher intensities. It would also be worthwhile to continue to tease apart the magnitude of affective change that is due to a placebo response or some type of expectancy effect. Finally, it would be worthwhile to begin examining some of these same affective responses in spinal cord injured individuals to determine whether similar affective change can be elicited via passive exercise in those who may not be able to engage in active exercise.

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