AN EXAMINATION OF AFFECTIVE CHANGE IN THE ABSENCE OF PHYSICAL SENSATION

BY

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DISSERTATION

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ABSTRACT

In the examination of affective responses to acute aerobic exercise, researchers have struggled to find an appropriate control condition to use in comparison with aerobic exercise, as a true placebo has evaded 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 cycling in spinal cord injured individuals. As such the purpose of the present study was to examine the psychological and physiological effects of Passive versus Placebo cycling. A total of 21 (10 females) participated in a Rest session, Passive cycling session (the ergometer pedals were moved by a motor while their feet were attached), and Placebo cycling session (the motor was on, running, but disengaged while their feet were attached). Passive cycling elicited psychological changes that varied significantly with respect to perceptions of Energy and Calmness, but not valenced (i.e., positive, negative) affect. The Passive condition had no significant effects on physiological factors such as HR or Temperature Participants reported more enjoyment following the Passive condition compared to Rest and Placebo conditions. Rating of Perceived Exertion was significantly higher during the Passive condition compared to both Rest and Placebo. There may be some merit in future research studying affective responses throughout and following exercise in individuals with disabilities.

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CHAPTER 1

INTRODUCTION

Examining the Placebo Problem in Exercise Studies

The primary goal of measuring differences in psychophysiological responses between active and passive exercise is to identify the active contributors to the pre-to-post-exercise psychological changes. This will allow researchers to determine if and how these psychophysiological responses can be controlled, in an effort to find the active ingredients in psychological changes and an appropriate "true placebo control" for active exercise participation. The most widely accepted, cognitively-based explanation for the placebo effect is based on a patient's expectation of therapeutic benefit (Desharnais, Jobin, Coté, Lévesque & Godin, 1993). A placebo, as defined by Shapiro and Shapiro (as cited in Desharnais et al, 1993, p.372), 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." The placebo effect can be 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). The implementation of a placebo control is considered a gold standard in scientific (human and animal) research.

Currently, there is no known way to implement a placebo for assigned exercise or physical activity. Researchers have employed various manipulations as a way to attempt to implement a placebo, including: sitting on a chair placed on a treadmill, light stretching, relaxation exercises, or quiet rest (e.g., Bahrke & Morgan, 1978; Ojanen, 1994). However, even the brief amount of activity participants receive during very light activity manipulations (e.g., stretching) may be sufficient enough 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, such as technician assisted, or motor assisted, which will be discussed later.

Desharnais et al. (1993) and Anderson and Brice (2011) expressed the similar belief that the increased publicity regarding the beneficial effects of aerobic exercise, may have encouraged more individuals to participate in exercise with the expectation of improvements in both physical and psychological well-being. Additionally, there may be some selection bias that skew results of exercise studies such that those who enjoy exercising, tend to participate in exercise studies more often. Conversely, those individuals who have a negative association with exercise may be less likely to volunteer for physical activity studies (Salmon, 2000). Anderson and Brice (2011) also highlight that these expectations and benefits may influence pre and post-exercise changes for long-term exercise programs as well as following acute bouts of exercise. However, as mentioned previously, these expectations are only speculative at this time.

Another gold standard of scientific research is the ability to blind participants (single blinding) and researchers (double blinding) from knowing what assigned intervention that they are taking part in so as to not influence the results based on that knowledge (Schulz & Grimes, 2002). In medication-based studies it is possible to blind the participant, and even double-blind experimenters. While double blinding (blinding both the participant and researcher) in many scientific trials is ideal, Ojanen (1994) suggested that controlling for expectations is limited to the impossibility of blinding participants during exercise studies. Additionally, it was suggested that it is also impossible to distinguish between the actual effects of exercise from those effects associated with the placebo effect (Ojanen, 1994).

While Ojanen suggests the impossible, this statement may only hold true for able-bodied (neurologically complete) individuals who have full bodily control and sensation. Theoretically, researchers may be able to blind participants with a complete spinal cord injury (SCI) as to whether or not they are passively moved, or exposed to passive motor-driven cycling. If one were to blind SCI individuals from observing their lower extremities, and passively performed movement (exercise), researchers may be able to ascertain the true psychophysiological effect of exercise on the human body. By introducing a population to exercise that has limited expectations of an effect, and limited cardiovascular response, researchers may have the opportunity to delve deeper into the psychophysiological response to said exercise without bias and with some potential blinding.

Rougeau (2015) conducted a study 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 an acute bout. College-aged participants [$N = 17$, age = 20.12 ± 1.83 yrs) years], both regular exercisers and non-exercisers, volunteered for the study. In order to reduce the possible effect of bias, experimenters read a prewritten script to all participants explaining the exercise they were about to participate in. Participation in both the active and passive exercise session were randomly assigned and counterbalanced for each participant. 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 $r \cdot min^{-1}$), and equipment used (Polar, Monark 818E cycle ergometer with foot straps; Rougeau, 2015). Results of the study demonstrated passive exercise elicited psychological changes that were similar to active exercise with respect to perceptions of

Energy, Tension, Calmness, State Anxiety, and valenced (i.e., positive, negative) affect. Additionally, Rougeau stated that participants reported greater enjoyment following active relative to passive exercise ($M_{diff} \pm$ SE = 8.29 ± 4.43; d = 0.47), and active exercise resulted in significantly greater Tiredness compared to passive exercise. Specifically, Tiredness following the Active condition was significantly lower than 10 min before the condition [Post-0 M_{diff} = 2.94, d = 0.89; Post-10 M_{diff} = 2.06, d=0.57]. Additionally, following the Active condition, Tiredness was significantly lower than immediately before the condition (M_{diff} = 1.82, d=0.58; Rougeau, 2015).

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). 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 placebo in exercise studies, the data collected and interpreted has the potential to be more informative than 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.

Evidence to support the use of passive exercise as a placebo control is lacking at this time. 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 $d \cdot week^{-1}$), and length of each training session (90 minutes). 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. 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 (although this only approached statistical significance; Desharnais et al., 1993).

The psychophysiological response to passive exercise clearly involves complex mechanisms, such as proprioceptive responses and changes that occur via blood flow within the body that, to this point, have been understudied in relation to psychological outcomes. With a lack of evidence to support the notion that passive exercise may elicit some psychological effects, there is an additional gap in the literature on the perception of exercise on the psychophysiological responses in the spinal cord injured (SCI) population. This review will introduce spinal cord injuries and quality of life measures (including positive and negative affect), as well as ways in which these items are measured within the population. Finally, a study to determine the effects of passive, motor-driven cycling on various psychological outcomes (e.g., affect, perceptions of exertion) in individuals with SCIs will be presented.

Affective Response to Exercise

Williams, Dunsinger, Ciccolo, Lewis, Albrecht and Marcus (2008) suggested that studies in which affective response is measured prior to and following exercise bouts actually measure how one feels with the completion of the exercise, not necessarily affective response to the exercise itself. Additionally, Ekkekakis and Petruzzello (1999) critiqued that many studies pose the assumption that too little exercise is unlikely to have a significant impact on affect.

Conversely, they suggest that too much exercise could have adverse effects on affect. As described by Ekkekakis and Petruzzello (1999), low intensity exercises (30-40% VO_{2max}) have been shown to effectively reduce state anxiety and improve mood. This is contradictory to the 70% VO_{2max} or HR_{max} over a 20-minute duration proposed by Dishman (1995).

In an effort to measure the immediate affective response to increased levels of exercise intensity Hall, Ekkekakis, and Petruzzello (2002) measured affective response during acute bouts of exercise [i.e., treadmill graded exercise testing (GXT)] in 30 young, healthy adults volunteers (13 women, 17 men; 23.9 ± 3.6 yrs). Affective responses were measured every minute during the GXT, and immediately, 10 minutes, and 20 minutes post-GXT. As was seen in Ekkekakis and Petruzzello (1999), results demonstrated a "pronounced and instantaneous rebound from affective negativity" immediately post-exercise (Hall et al., 2002, p. 60). Hall et al. found that that vigorous exercise produced negative, albeit transient, during exercise affective responses, but resulted in positive affective change post-exercise. The practical implication for these findings fails to support the concept that any positive affective change post-exercise outweighs any negative during-exercise affect according to Hall et al.

Ekkekakis, Hall & Petruzzello (2004) expanded on the previous study (Group A) by adding an additional group of similar participants (Group B, $N = 30$) for a longer GXT as compared to the 2002 study. The intended purpose was to compare the heart rate (HR), perceived exertion (RPE), perceived activation (FAS), and affective (FS) responses across the GXTs in relation to ventilatory threshold (VT). The only difference between groups, noted by Ekkekakis et al., was affective improvement from the warm-up. While stated to be non-significant, Group B had a longer (5-min) warm-up compared with Group A (2-min) which led to an increase in and higher average affective valence prior to the onset of the GXT (Ekkekakis et al., 2004). This adds support to the notion that low-intensity physical activity, or passive exercise, may have an impact on affective change. Aside from improvements in the physiological effects of exercising at or just below VT, Ekkekakis et al. found that exercise that exceeds the lactate or ventilatory threshold has negative effects on affective response and have suggested that this negative association may lead individuals to avoid regular exercise participation. Conversely, activity that produces positive affective responses may encourage future exercise participation.

In their 2008 study, Williams et al. expanded on the possibility suggested by Ekkekakis, Hall and Petruzzello (2005) that affective response during exercise may help predict future PA participation. Williams et al. (2008) examined affective response to a moderate-intensity sub-maximal GXT to determine if responses could predict exercise participation at 6 and 12-months post-test. Healthy, sedentary adults (*N* = 31, age = 43.92 ± 8.63 yrs) completed a sub-max treadmill GXT (Balke) while responding to the Feeling Scale (FS; Hardy & Rejeski, 1989) and Borg's RPE scale (Borg, 1998) every 2-minutes throughout the test. Following the treadmill test (baseline) day, participants received motivational PA materials, via print or email, encouraging them to exercise 30-minues per day most days of the week. The Physical Activity Recall Assessment (PAR) was completed at baseline, 6 months, and 12 months post-baseline. Results showed that FS responses during moderate-intensity exercise predicted PAR-minutes both 6 and 12 months post-test: those participants who reported more positive affective responses to moderate-PA reported more minutes of PA 6 and 12 months later.

Spinal Cord Injury (SCI)

Researchers have begun to explore differences between muscle stimulation (active and electrically stimulated) and exercise in individuals with spinal cord injuries (SCI) in an attempt to identify physiological responses to exercise in this population compared to able-bodied (AB) individuals. With 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 International Standards for Neurological Classification for Spinal Cord Injury (Appendix A; Figure A.1) to establish uniform standards and ensure consistent and accurate classifications for individuals with SCI (ASIA, 2015). However, for the purpose of this review, classification will be simplified to include motor completeness and lesion level.

Incomplete SCIs are characterized by presence of 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, 2015; Jacobs & Nash, 2004). Complete paraplegia results in the permanent loss of movement and sensation at the first thoracic (T1) level or below (ASIA; brainandspinalcord.org). 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; brainandspinalcord.org). Tetraplegia (preferred to "quadriplegia"), or disability to all four limbs, can also be classified as complete or incomplete as a result of injuries to any of the cervical spine (levels C1-C7). The degree of function is a direct result of where the injury to the spine occurred (ASIA; brainandspinalcord.org). 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 numerous individual differences, can account for variability in every SCI (ASIA; brainandspinalcord.org). It is highly unlikely that two individuals with identical lesion levels and completeness will exhibit identical biomechanical and physiological characteristics as one another.

Clinical Implications. It is well known and accepted that exercise has a positive impact on psychological well-being (PWB; e.g., Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991; Hall, Ekkekakis & Petruzzello, 2002) and overall physical health (e.g., Forman-Hoffman et al., 2015; Myers, Lee, & Kiratli, 2007). If passive exercise can elicit psychological outcomes similar to active exercise and functional electrical stimulated (FES) exercise, this may provide an avenue for individuals with SCI to partake in exercise regimens and reap the benefits. It may also provide an alternative method for getting sedentary adults to adopt an exercise program. For instance, if a sedentary individual with severe depression or anxiety is able to tolerate passive cycling and finds that such activity relieves their symptoms, perhaps it would motivate future exercise participation

Martin Ginis, Jetha, Mack and Hetz (2010) conducted a meta-analysis of 21 studies which examined the effects of PA (exercise and sport) on subjective well-being (SWB) in individuals with SCI. While not limited to positive and negative affect, SWB measures included affect (e.g., stress, anger), mental health (e.g., depression) and overall quality of life (QOL). Martin Ginis et al. found a significant positive relationship between PA and SWB ($r_{obs} = 0.25$; 95% CI 0.19-0.31) as well as significant relationship for reductions in depression ($r_{obs} = 0.22$; 95% CI 0.16-0.28) and an association with greater life satisfaction ($r_{obs} = 0.23$; 95% CI 0.16-0.30). These results help support the continued understanding that sport and PA have a positive impact on one's psychological health and subjective well-being.

Myers, Lee, and Kiratli, (2007) point out that respiratory and renal conditions are the most prevalent in SCI populations. However, the authors point out that a *major* concern to the increased risk of cardiovascular disease (CVD) in SCIs is due to the increased prevalence of other risk factors such as hyperlipidemia, obesity, and diabetes. The primary concern should be that of inactivity, which contributes to the loss of physical function and disrupts the autonomic nervous system (Myers et al., 2007). However, the authors list this as a secondary concern. Without PA, the risk of hyperlipidemia, obesity, and diabetes rise drastically. This is true of both the AB and disability populations.

Cardiovascular disease, although not as popularized as some cancers, is currently the leading cause of mortality in the US overall (CDC, 2016). When Forman-Hoffman et al. (2015) examined the effects of functional disability on all-cause mortality cause-specific deaths in US adults, they found that heart disease and cancers (malignant neoplasms) where the leading cause of death for individuals with and without disabilities, respectively. It was also found that adults with any disability were more likely to die than those without a disability (19.92% vs. 10.94%; hazard ratio = 1.51, 95% CI, 1.45–1.57). Compared to those without a disability, those with a disability at baseline were more likely to die of heart disease (5.93% vs. 3.14%; hazard ratio = 1.55; 95% CI, 1.44-1.68; Forman-Hoffman et al., 2015). One thing that researchers (CDC, 2016; Forman-Hoffman et al., 2015; Myers et al., 2007) do agree on is the understanding that PA is an important moderator for comorbidities associated with sedentary behavior of individuals, including those with SCIs. Passive, motor-driven, cycling may be a favorable place to start, as a way to encourage PA in those individuals who lack the motivation or the means for participation in active exercise.

Barriers (and Facilitators?) for PA in SCI. Dishman (1994) attempted to explain reluctance to exercise in AB individuals through psychological deficits such as self-motivation, self-efficacy, inappropriate health benefits, or lack of internal locus of control. Dishman emphasized that behavior change is dependent upon an individual's readiness to change and their outcome-expectancy. While this is an active readiness, one may be able to assist individuals through stages by suggesting passive cycling as an avenue for behavior change without a great deal of effort on the part of the participant, and the potential to achieve similar psychological benefits as active cycling

Scelza, Kalpakjian, Zemper, and Tate (2005) surveyed individuals with SCI (*N* = 72) to describe barriers to exercise. While they indicated that predominant barriers may change based on the location and socioeconomic differences between the SCI samples studied, there was no distinctly prominent factor at the time of the study. Scelza et al. highlight a damaging interpretation of lack of information from doctors to patients with SCI in that if doctors don't mention PA, then it may not benefit them as a whole. The most frequently stated concerns as barriers to PA were those relating to lack of motivation, energy, and interest in PA. This is not unlike AB individuals. Additionally, according to the Scelza et al., less than half (47.2%) of the survey participants reported that their physicians had recommended exercise to them. This may also hinder mental health and emotional well-being according to Putnam, Geenen, Powers, Saxton, Finney, and Dautel (2003).

Similar to Scelza et al. (2005), Vissers, van de Berg-Emons, Sluis, Bergen, Stam and Bussmann (2008) focused their survey on barriers to, and facilitators of, daily PA following discharge from medical rehabilitation programs. Individuals (*N*=32) with SCI felt the largest perceived barriers to PA were self-care in nature (prevalence 94%; e.g., lack of adaptations to the home, dependent on others for self-care assistance), followed by physical and emotional distress (prevalence 81% for both), with feelings of sadness being mentioned most frequently (Vissers et al., 2008). Vissers and colleagues admittedly limited the study to manual wheelchair users; omitting those SCIs who were ambulatory or used power-assist wheelchairs. However, they did not believe this had an impact on the representativeness of the study.

Martin Ginis, Jörgensen, and Stapleton (2012) conducted a review on exercise and sport for individuals with SCI. Physical health barriers for exercise and sport were autonomic dysreflexia (AD; to be discussed later), thermal and circulatory dysregulation, musculoskeletal injury and risk of recurring infections (Martin Ginis et al., 2012). Physiological barriers listed in the review included depression, lack of motivation, energy and time, lack of skill, lack of interest, lack of self-confidence, fear of pain and injury, and fear of failure and/or embarrassment, to name a few. Participants in surveys such as these gave similar feedback as their AB counterparts in terms of lack of time, energy and motivation. However, individuals with SCI have expressed concern for their physical and mental health that extend beyond their AB peers.

Improving psychological well-being. Literature (e.g., Gauvin, Rejeski, & Norris, 1996) suggests that the psychological effects of exercise are clearer when mood is poor prior to exercise, as it would be beneficial for researchers to recruit participants with poor PWB and no clear expectations of exercise. While Salmon (2000) suggests using sedentary samples due to their positive response to mild to moderate exercise, this may only combat the ceiling effect for those who already have a positive feeling toward exercise and mood prior to participation. Additionally, it was proposed that the psychological benefits of physical activity have been somewhat neglected because the research focus has been placed on more formal exercise programs (Salmon, 2000). The use of truly passive exercise has yet to be studied in terms of a psychophysiological response, specifically affective responses pre, during, and post-exercise. By concentrating research on participants with complete SCI, there is room for determining the true mind-body connection in exercise, and explore the expectancy effect and priming of participants.

Passive Exercise

Generally, individuals are more aware of the concept of active (with volitional control) exercise than passive (without volitional control) exercise. To expand on this, there are additional types of assisted movement: (a) technician-assisted, in which a participant limb movement is facilitated by another individual; (b) mechanically-assisted, where a machine is responsible for the movement of limbs; and (c) autonomous movement, where an individual physically picks up the paralyzed limb and moves it themselves.

One of the oldest studies to examine passive pedal motion with the legs was published in 1961 by Dixon, Stewart, Mills, Varvis, and Bates. They found 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.). Thus, hyperventilation cannot be stated to be a link between increased heat production and passive exercise. Although the increase in ventilation did show a corresponding increase in heart rate, passive exercise did not show an increase in heat production. Since then, various studies have been conducted to examine 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 with AB individuals. During the active condition, exercise was held at a constant rate (60 $r \cdot min^{-1}$ for 30 minutes); in the passive condition, experimenters attempted to match exercise oxygen consumption to that obtained during active exercise. Using a between-subjects design, the participants in the passive condition were not the same individuals who participated in the active condition. 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 the passive and active series, participants "exercised" at a rate of 60 $r \cdot min^{-1}$ for 30 minutes while tympanic membrane temperature, five skin temperatures, and heart rate were all measred (Benjamin & Peyser, 1964). Results indicated that passive exercise increased participant ventilation beyond resting metabolic demand (Benjamin & Peyser, 1964). The increased ventilation was thought to be a reflex action initiated by stimulation of proprioceptors as a result of movement, displacement, or tension. They also considered that local chemical changes occurring during exercise may have increased the sensitivity of these receptors, thus producing an increased respiratory response (Benjamin & Peyser, 1964). These factors could support the notion of temperature being an important element in the hyperventilation of exercise. However, a lack of electromyography (EMG) measurements within this study limit the interpretation of the results as there is no way of determining if the passive exercise bouts were truly passive.

Benjamin and Peyser (1964) cautioned against 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. Examples of such can be seen in a study by Bell, Ramsaroop, and Duffin (2003), who studied the respiratory effects of passive exercise. During the study, participants sat on either the front seat of a tandem leg extension apparatus or a tandem bicycle, facing away from an experimenter, who powered the apparatus. During each condition, leg muscle EMG was measured over the vastus lateralis constantly via surface electrodes. Throughout the bicycle and leg extension conditions, a metronome was set so limb movement would occur at 65 $r \cdot min^{-1}$ and in both conditions, participants were not told when passive exercise would begin or end. Additionally, Bell et al. (2003) 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," that may influence breathing (p. 544). There was no significant change from rest to steady-state exercise for the bicycle or tandem leg extension (Bell et al., 2003; see their Figure 5, p. 549).

Following the conditions, participants reported the leg extension apparatus was more comfortable than the upright bicycle, due to balance issues and having difficulty relaxing on the tandem bicycle (Bell et al., 2003). Synonymous with participant feedback, the EMG data 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, there was 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 no such change occurred when using the leg extension apparatus (Bell et al.). Bell et al. concluded that passive exercise on an upright bicycle required a significant amount of muscle activity that contributed to neural and metabolic influences toward the physiological changes observed. The use of a recumbent bicycle as well as collecting EMG readings from areas such as, the abdominal, erector spinae, and gluteal muscles may help answer any question regarding the degree of passivity. Additionally, the use of an active group may have also been beneficial in comparing these passive exercises to active exercise.

Over a decade later, Peterman, Wright, Melanson, Kram and Byrnes (2016) conducted a study comparing three conditions: sitting, passive (motor-driven) cycling (80 $r \cdot min^{-1}$), and moderate-intensity cycling (64-76% of participant maximum heart rate) as determined by treadmill GXT. Inactive males (*N*=24) participated in this counterbalanced study where energy expenditure (EE) and cognition were measured via respiratory gas exchange and computerized testing, respectively (Peterman et al., 2016). Compared to sitting (1.25 ± 0.17 $kcal \cdot min^{-1}$), Peterman et al. found EE to be significantly higher during both passive cycling (2.61 ± 0.65 $kcal \cdot min^{-1}$) and moderate-intensity cycling (7.75 ± 1.78 $kcal \cdot min^{-1}$).

While Rougeau (2015) found that HR did not increase with passive cycling, some studies have demonstrated that HR does increase with passive cycling (Peterman, Kram & Byrnes, 2012; Peterman et al., 2016). However, others (Bell et al., 2003) suggest that HR is not the physiological change to be observed during passive cycling. Instead, VO_2 and VCO_2 have been shown to increase during passive cycling as mentioned previously (Benjamin & Peyser, 1964; Bell et al., 2003). With these physiological changes, Peterman suggests that there may be some implications for passive cycling to be used as a way to help reduce cardiometabolic risk factors such as increased HDL, triglyceride and lipoprotein lipase levels compared to other sitting interventions for AB individuals (e.g., standing, sitting on an exercise ball; Peterman et al., 2016). Further, passive exercise may have the potential to reduce metabolic risk factors in disabled persons (e.g., wheelchair users; McKinley, Jackson, Cardenas & DeVivi, 1999; Myers et al., 2007) as well as those exposed to prolonged sitting (Hu et al., 2001; Hu et al., 2003). There is evidence that risks associated with decreased physical activity and increased sedentary behavior have surpassed pulmonary risk factors (e.g., DVT, pulmonary embolism; Forman-Hoffman et al., 2015).

It is known that passive exercise has many physiological benefits for able-bodied and/or those individuals who are sedentary in nature, but not those who lack complete use of the lower extremities. Inconsistencies in this type of study include the inability to prescribe truly passive exercise to a treatment group. As mentioned in Peterman et al. (2012), a previous study by De Meersman, Zion, Weir, Lieberman, and Downey (1998) found no increase in muscle activity during passive cycling through the use of EMG. However, two other studies found significant increases in EMG data with passive exercise (Bell et al. 2003; Reger, Peterman, Kram & Byrnes, 2009). Additionally, while asking participants to remain relaxed enough during cognitive tasks is challenging at best. While completing cognitive tasks (Peterman et al., 2016), participants may have been distracted and forgot not to pedal, as remaining relaxed on the motorized cycle is quite difficult according to the participants from the Rougeau study. This potential could perhaps be seen in Peterman et al. (2016) as it was suggested by the authors that EE and HR were significantly higher than sitting. Recruiting participants without volitional control (e.g., those with a SCI) could have the potential to alleviate these shortcomings.

Functional Electrical Stimulation (FES)

The changes seen in psychological and subjective well-being (PWB and SWB, respectively) through functional electrical stimulation (FES) leg-cycling are quite inconsistent at this time. Given that FES is primarily used to increase range of motion and decrease muscle atrophy, few studies have examined the psychological aspects associated with FES leg-cycling. Increases in depression could have been due in part to unrealistic expectations (Alexander & Sipski, 1990; Bradley, 1994) that FES would facilitate some functional gain (i.e., walking) by misinterpreting the term "functional;" FES does not lead to functional or voluntary action. While Alexander and Sipski took their study one step further, finding therapeutic effects of FES leg cycling, there is still a lack of evidence supporting the psychological outcomes from FES leg cycling.

It has been suggested that passive exercise can be done via FES exercise, technician-assisted exercise, or through the use of a specifically designed leg extension or leg-cycling apparatus (Dixon et al., 1961; Mahoney et al., 2005). FES 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, or action potential, is passed directly through the muscle body at an amplitude high enough to elicit a contraction response at the target muscle, thus forcing the muscle to engage. The differences between active exercise, FES, and passive exercise are being examined because FES is considered a passive form of exercise. However, it is hypothesized that there is still an active muscular component in FES with the use of electrical stimulation of the muscle, unlike truly passive exercise. The most common forms of FES leg exercises are static contractions, knee extension, and tandem cycling (Mahoney et al., 2005). Through the understanding of the human body and what is known about the psychophysiological response to active exercise, it is expected that FES will elicit responses similar to that of active exercise (i.e. increased heart rate, mean arterial pressure, cardiac output, positive affect), and thus, should not be considered a form of passive exercise. While there are similarities in the physiological changes seen from FES and active exercise, it has also been shown that similar psychological benefits from active exercise are seen with FES.

Non-significant psychological findings. Following a 12-week, 3-5 $d \cdot wk^{-1}$ FES leg-cycling protocol, Bradley (1994) failed to find significant changes in positive affect using the Multiple Affect Adjective Check List-Revised (MAACL-R). However, there was a significant increase in negative affect following the FES protocol, which will be discussed below. Additionally, Dolbow, Gorgey, Ketchum and Gater (2013) recruited 11 male veterans to participate in an 8-week FES leg-cycling intervention where the objective was to reach a goal of between 40 and 60 min of active cycling. Cycling duration was initially based on the participant's ability to perform the cycling activity. Participants were asked to cycle 3 $d \cdot wk^{-1}$ with at least one rest day between active days. While there was no significant change in psychological or social quality of life (QOL), there were nominal increases in both. Again, this could have been due to the small sample size. Although there was no significant improvement in psychological or social QOL, Dolbow et al. (2013) did find a significant improvement in physical and environmental QOL from pre- to post-exercise testing.

Significant psychological findings. With the new advent of FES leg-cycling, Sipski, Delisa and Schweer (1989) found a significant increase in self-image for participants who completed a FES leg-cycling program over the course of about 2 years. Due to the infancy of FES ergometry programs at the time, the authors created their own questionnaire asking participants to describe the effects of the training. These items were based on endurance, self-image, spasticity, breathing, and skin integrity, to name a few (Sipski, et al., 1989). Of the participants (N=47) who responded to their post-training questionnaire, 56-62% reported improvements in self-image while 54-77% reported improvements in appearance (Sipski et al., 1989). Contrary to other studies around the same time, Twist et al. (1992) found support for the notion that FES leg-cycling did indeed show significant decreases in depression using the Beck Depression Inventory (BDI) and the Hamilton Rating Scale for Depression (HRSD) following a regimented 30-week study. Twist et al. (1992) noted that although only 5 of the 9 participants in the study could be classified as clinically depressed according to pre-test BDI scores, 8 of the 9 recorded significant decreases in depression at week 30 (M= 6.63±6.09) compared to baseline (M= 12.67±8.49). HRSD showed findings similar to BDI scores from baseline to week 30.

As referred to previously, Bradley (1994) used the Multiple Affect Adjective Check List-Revised (MAACL-R) to assess depression, anxiety, hostility, positive affect, and sensation seeking following a 12-week, 3-5 $d \cdot wk^{-1}$ FES leg-cycling intervention. Interestingly, there was a significant increase in depression and hostility following the protocol for those individuals (N=

5) who had “unrealistic expectations” regarding the functional outcome of the study (Bradley, 1994, p. 677). Unrealistic expectations were defined as the desire to walk without assistance and/or the use of assistive devices, and were considered to be unattainable (Bradley, 1994). The author noted that due to the final, small sample size (*N*= 37; 22 treatment group, 15 control) and high attrition rate of 38% (23 participants failed to complete post-testing) this conclusions were only speculative (Bradley, 1994).

Dolbow, Gorgey, Moore, and Gater (2012b) proposed that FES could be an alternative to traditional exercise, by removing some of the limitations and external barriers to PA, for individuals with SCI. In order to test this hypothesis, the authors conducted a case study of a 53-year old male, 33 years post-injury, completing a FES home leg-cycling protocol 3 $d \cdot wk^{-1}$ for 24-weeks. Both physical (comfort or pain level, energy level, and restfulness) and psychological (positive feelings, self-esteem, body-image and appearance, and concentration) measures were collected via the World Health Organization Quality of Life (WHO-QOL) Brief Questionnaire, a validated measure of QOL following SCI. Results showed an increase in both physical (25%) and psychological (4.5%) QOL scores following the intervention, with an exercise adherence rate of 82% (Dolbow et al., 2012b). While the authors highlight the importance of removing perceived barriers to exercise as being a key factor in improved physical and mental health, it was interesting to the authors that the participant found himself reporting lower scores about personal relationships and social support (a reduction of 12.5%; Dolbow et al., 2012b). These results in the social domain are particularly thought-provoking due in part because of the association that personal and social relationships have on PWB.

In a second single-subject case study, Dolbow, Gorgey. Cifu, Moore, and Gater (2012a) set out to determine the feasibility of a 9-week, home-based FES intervention. The participant, a male (age= 64 yrs; 18-mos post injury) with C5 motor complete SCI, completed 25 or the 27 exercise sessions over the 9-week intervention period for a 93% compliance rate. Again, QOL was measured via the World Health Organization Quality of Life (WHO-QOL) Brief Questionnaire and DEXA scanning was used to measure body composition and bone mineral density (BMD). Over the 9 weeks, the QOL questionnaire data improved from 12.67 to 14, an improvement reflective of improved perception of body image, appearance and self-esteem (Dolbow et al., 2012a). Body composition also improved over the course of 9-weeks. While total body weight, fat mass, and BMD remained unchanged, total lean body mass increased 8.3% and body fat percentage decreased 1.2% (Dolbow et al., 2012a). While the results of the previous studies (Dolbow et al., 2012a, Dolbow et al., 2012b) are promising, they are only suggestive at this time being that they were individual case studies. However, if they were more generalizable, this would support the idea that passive exercise may be a feasible home-based exercise regimen that may decrease perceived or actual barriers to PA as a way to improve QOL.

Following their case studies, Dolbow, Gorgey, Ketchum, and Gater (2013) examined the use of an 8-week, home-based, FES-LEC program on the QOL (physical, psychological, social, and environmental health) of 11 (non-ambulatory, 2 motor complete) individuals with SCI. All participants were initially trained a medical center on how to use the Internet monitored, FES-LC apparatus before being cleared for in-home use for the duration of the study. Following the FES protocol set by Petrofsky, Stacy and Laymon (2000), all participants were asked to cycle 3 $d \cdot wk^{-1}$ with at least 1 rest day between sessions.

The speed of the FES-LEC was set between 30 and 50 $r \cdot min^{-1}$ as tolerated by each participant, with a baseline resistance of 0.5 Nm. Participant comfort, preference, and safety were taken into account by maintaining the speed of the ergometer between 30-50 $r \cdot min^{-1}$

(Dolbow et al., 2013). Dolbow and colleagues stated that a maximal speed of 50 $r \cdot min^{-1}$ was selected because they wanted to avoid unnecessary stress to the hip and knee joints, which may have been related to excessive trunk movement associated with increased pedal speed. While there was an increase in all four QOL domains, only the physical and environmental domains changed significantly (Dolbow et al., 2013). There were also non-significant increases in both psychological (increased by 1.02 units) and social (increased by 1.27 units) QOL scores. Although these increases occurred, Dolbow et al., suggested that the nominal gain seen in the psychological domain was due in part to perceptions of increased physical health being linked to positive feelings like self-esteem. However, the results of the study supported the results seen in the case studies mentioned previously (Dolbow et al., 2012a; Dolbow et al., 2012b).

Some studies have shown potential physiological benefits of FES interventions, such as increased muscle mass and cross-sectional area (more so in resistance training than in aerobic training), improved blood flow and oxygen delivery to exercising muscle (Hooker et al., 1990), and the potential for prolonged FES leg cycling to produce a load in cardiac volume that is appropriate for cardiac training in persons with SCI (Hooker et al., 1990; Scremin et al., 1999). Other studies have failed to examine any psychological benefits of chronic FES exercise (Clark et al., 2007; Hooker et al., 1990; Scremin et al., 1999). Noticeable improvements have also been shown in levels of depression, self-image, and appearance, as well as physical and environmental QOL (e.g., Dolbow et al., 2012; Dolbow et al., 2013; Sipski et al., 1989; Twist et al., 1992). These findings could be more clearly determined, and perhaps generalizable, by increasing the number or participants included in the studies. This is strategically difficult at times because individuals with spinal cord injuries may be difficult to recruit outside of a medical/rehabilitation setting.

A major limitation in the currently available literature is that there are so few studies which have either measured or reported psychological outcomes or affective change. Many studies that have focused on FES and SCI were done with interest in physiological and overall QOL outcomes from FES cycling. It is evident that there is a need for measured psychological outcomes to be assessed following acute bouts of passive exercise, with an understanding that these measurements may inform how exercise studies are conducted in the future. While studies such as these are limited, both short and long-term interventions will be explored.

Autonomic Dysreflexia

As shown in a few examples within this review, functional electrical stimulation (FES) offers some physiological benefits for those with SCI. However, FES also has the potential to trigger dangerous symptoms of autonomic dysreflexia (AD, hyperreflexia, or hyper-reflexia) that have been used as performance enhancers (Webborn, 1999). Autonomic dysreflexia 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/l in boosted and unboosted states, respectively) and sweating (Karlsson, 1999; Webborn, 1999). Autonomic dysreflexia is most common in those with SCI lesion levels at or above T6 (Karlsson, 1999; Webborn, 1999), although it is not uncommon in lower level SCIs. Aside from being an extremely dangerous reaction to hyperreflexia (overactive reflexes) that can occur at any time, for a number of reasons, such as an undetected/untreated urinary tract infection (UTI), or other painful stimuli, AD has been shown to be a successful doping method, known as “boosting,” in disability sport. Boosting is the intentional induction of AD to enhance performance and was banned by the International Paralympic Committee (IPC) in 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 inducing pain (i.e., inserting thumb tack into paralyzed limbs, or purposefully twisting the scrotum) to produce referred pain and an increased pain response (Webborn, 1999).

Burnham et al. (1994) examined the potential effects of boosting during a study of eight athletes using the technique during graded exercise treadmill tests (GXT) and found a 9.7% increase in performance time as a result of lower heart rate, thus allowing athletes to perform at above normal levels. Webborn (1999) equated the enhancement in performance time 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 FES, thus triggering a physiologic response that technician-assisted or machine-assisted passive exercise may not. Functional electrically stimulated cycling may have the potential to trigger AD-like signals within the body. It is for these reasons that motor-assisted cycling may be the best avenue to perform passive exercise research in SCI individuals. By doing so, researchers may better be able to understand the true mechanisms of change rather than those potentially induced by an AD response as a result of FES.

Conclusion

Since individuals with physical disabilities (e.g., spinal cord injuries) are often unable to participate in conventional exercise programs, previous research has examined passive exercise as a possible alternative to gaining physiological benefits. The main objective of the present review was to ascertain the differences in physiological responses elicited by FES along with active and passive exercise. In order to determine if passive exercise can elicit similar effects to active exercise, comparison of: sham passive exercise (motor running but disengaged, legs not moving), passive exercise (motor running, engaged, & legs moving), and the universally accepted gold standard, true control, (i.e., quiet seated rest on an exercise apparatus) must be explored. Tympanic temperature, psychological perceptions [feelings, affect, arousal, rating of perceived exertion (RPE), post-exercise enjoyment], and perceived energy levels post-exercise need to be measured because they can help reveal the active ingredient(s) in exercise for provoking psychological improvements. They could also potentially reveal a dose-response effect of these differing levels of physical movement. Additionally, there seems to be a gap in the literature comparing motor complete SCI participants to those who are incomplete, or have sensation below their injury level. As can be inferred through the above examples, there is little convincing to be done in regards to determining if FES and passive exercise have an effect on the psychological well-being of motor incomplete persons. Due to the fact that there are still neurological connections in incomplete SCIs, there is still the question as to the impact of the mind-body connection in exercise.

CHAPTER 2

RESEARCH DESIGN & METHODS

Participants

Following approval by the University of Illinois at Urbana-Champaign Institutional Review Board, participants were recruited from the University of Illinois at Urbana-Champaign through the Division of Disability Resources and Educational Services (DRES) and the University community. Both male and female sedentary, recreationally active, and elite athletes who were full-time wheelchair users were included. Participants were screened and only non-risk individuals were allowed to participate in the study. Health risk was determined by the ACSM's guidelines for persons with disabilities as well as guidelines for exercise testing and prescription (Durstine, Moore, Painter & Roberts, 2008; Thompson, Gordon & Pescatello, 2010).

Exclusion criteria included uncontrolled autonomic dysreflexia, uncontrolled pain, uncontrolled spasticity or spasms, fragility bone fracture, pressure sores/ulcers within the past 3 months, deep venous thrombosis within the past 3 months, pregnancy, or any physical limitation that would preclude the ability to perform physical activity.

Motorized Cycle System/Ergometer

A custom-designed, stationary cycle ergometer was used for pedaling (see Figures 1 & 2). A padded table and foam wedge were used to protect skin integrity of the participants (reducing the risk of pressure sores/ulcers), support the participants' hips, and absorb some of the vibration effects of the motor. Additionally, a pillow was offered to support the participant's head during pedaling. A digital goniometer was used to determine the angular position of the participant's knee joint while pedaling to ensure each participant was matched as close as possible to the range of motion of pedaling.

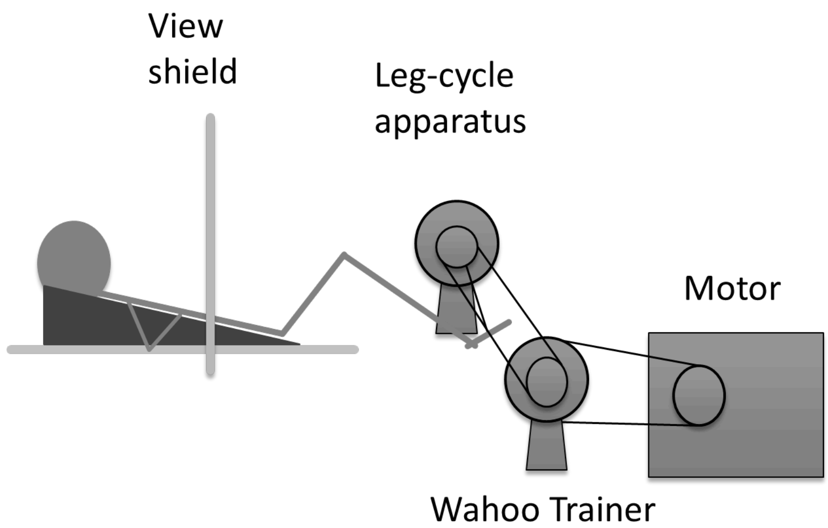


Figure 1. Design mock up for the custom-designed, stationary cycle ergometer.

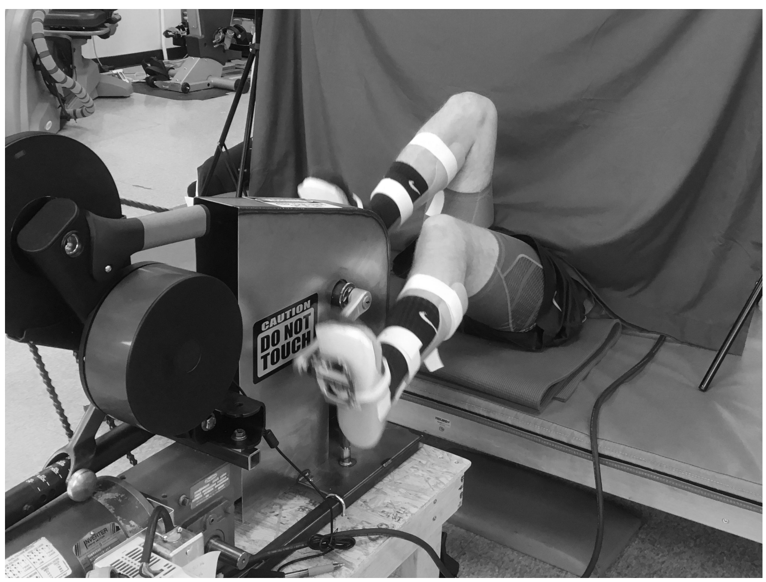


Figure 2. Actual image of custom-designed stationary cycle ergometer.

Measures

Health risk and background information were collected via the Physical Activity Readiness Questionnaire (PAR-Q; Thomas, Reading, & Shephard, 1992) and used to determine if it was physically safe for a participant to take part in this study. A modified Health & PA

History Form was used to assess basic demographic and personal information (i.e., sex, age, year in school, height, body mass, and physical activity history).

PASID. The Physical Activity Scale for Persons with Physical Disabilities is a 13-item, 4-point (e.g., Never, Seldom, Sometimes, Often) questionnaire specifically designed to measure the physical activity of individuals with physical disabilities (Washburn, Zhu, McAuley, Frogley, & Figoni, 2002). The scale measures current levels of physical activity and exercise in the domains of: leisure time activity, household activity, and work-related activity. While the PASID does not evaluate athletic/elite level individual training, questions were added to address time spent in sport/training related activities so as to not underestimate the PA levels of wheel-chair athletes.

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 (e.g., -5 = very bad, 0 = neutral, +5 = very good), bipolar measure of pleasure-displeasure, which is commonly used for the assessment of affective responses during exercise (Ekkekakis & Petruzzello, 1999; Hardy & Rejeski, 1989). The FAS is a 6-point (1 = low to 6 = high), single item, unipolar measure of arousal, which is commonly used for the assessment of how “worked up” an individual is during exercise (Svebak & Murgatroyd, 1985). The AD ACL is a multidimensional test of various temporary arousal states. The AD ACL is comprised of 20-items, which form with the subscales of Energy, Tiredness, Tension, and Calmness. Scoring is based on a 4-point Likert scale for each item (definitely feel, feel slightly, cannot decide, or definitely do not feel). Finally, participants completed the 10-item short form of the Spielberger State Anxiety Inventory (SAI; Spielberger, 1983). This measure of state anxiety is well-suited for studies where repeated assessments need to be made relatively quickly (Spielberger et al., 1983). It has been shown to be a valid and reliable measure of anxiety. As with the AD ACL, each item is rated on a 4-point rating scale (definitely feel=4, feel slightly=3, cannot decide=2, definitely do not feel=1) with the instructions to base the response on how "you feel right now".

Rating of Perceived Exertion (RPE) Scale. Borg's RPE scale is a self-report measure for the assessment of how hard an individual perceives a particular workload. This scale ranges from 6 to 20, with 6 being low exertion, and 20 being maximal exertion (Borg, 1998). Participants will point to numbers on this continuum during the conditions, in order to check their perceived exertion levels in relation to heart rate measures.

Enjoyment. The Physical Activity Enjoyment Scale (PACES; Kendzierski & DeCarlo, 1991) will be used in order to assess enjoyment following each condition. Participants respond to 18-items on a 7-point bipolar rating scale regarding the activity they just completed. 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).

Temperature. Forehead skin temperature will be measured throughout the experimental days to determine if there is any change in temperature within each experimental protocol that may influence affective change.

Experimental Protocol

All participants were initially screened over the phone using the PAR-Q (Thomas et al., 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 research laboratory. Due to the relatively exploratory nature of the study, an intended sample of at least 12 individuals was the minimum sample size (Julious, 2005).

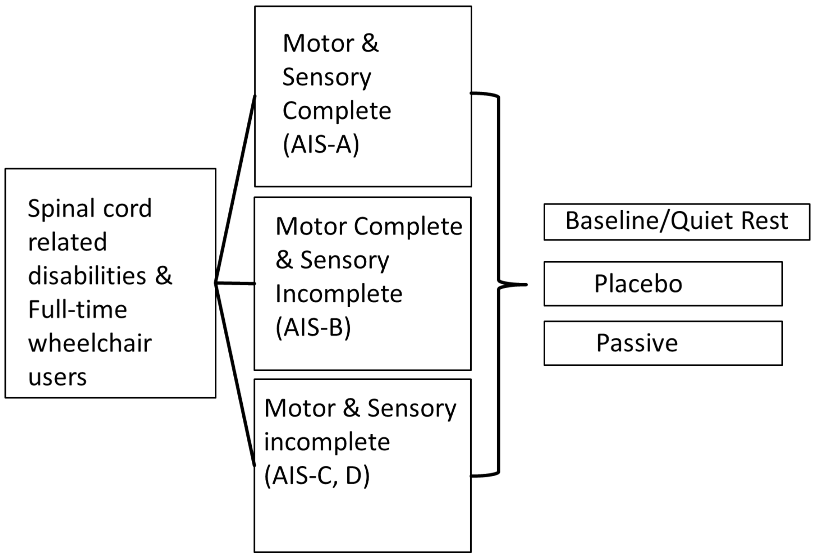


Figure 3. Research design.

Day 1 Baseline. Upon arrival at the laboratory, testing procedures and study protocol were explained to the participants. Informed consent was explained and any questions regarding the study were answered prior to signing the informed consent. After inclusion was established and verified in person by trained research staff and supervisors, participants completed a battery of questionnaires (AD ACL/SAI, FS, FAS) and were fit with a Polar heart rate monitor (Polar Electro, Inc., Kempele, Finland). Participants were acquainted with the cycle ergometer and the exercise protocol was explained. As this was a novel activity, to better familiarize participants to the protocol, they had the opportunity to observe/be shown a video clip demonstrating what to expect during the exercise session.

Each participant was fit with a HR monitor and engaged in a quiet rest/baseline test. Participants lay recumbent on a pressure absorbing mattress, and angled wedge, with their feet attached to the cycle ergometer pedals (see Figure 2). The participant's lower limbs were shielded from view with a curtain and the head was placed on a bead-filled pillow for stabilization and comfort. Participants laid quietly for baseline collection for 30 minutes. Every 5 min throughout the baseline session, participants were asked to rate their perceived exertion (RPE), affective valence (FS), and arousal (FAS). Immediately following the completion of the 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 completed the AD ACL/SAI, FS, and FAS for a final time.

Days 2 & 3 (randomized & counter balanced). Immediately upon arrival to the lab, participants completed the AD ACL, SAI, FS, and FAS. They were then instrumented with a HR monitor and completed the AD ACL, SAI, FS, and FAS again immediately prior to the assigned condition for the day. Participants lay on a mattress with their feet strapped into the pedal system, while their lower limbs were shielded from view and their head was placed on a bead-filled pillow for stabilization. Each participant performed sham/placebo and passive pedaling on separate, non-consecutive experimental days.

(i) Passive pedaling. For the passive trials, the participants were equipped with a Polar heart rate monitor (Polar Electro, Inc., Kempele, Finland). They lay on the mattress and their feet remained strapped to the pedals of the custom-designed stationary cycle ergometer, shielded from view, while the crank was rotated via electrical motor. The speed of passive pedaling was set at a warm-up and cool down cadence of 35 $r \cdot min^{-1}$, and a steady cadence of 50 $r \cdot min^{-1}$ for each participant (Dolbow et al., 2013; Rougeau, 2015). The resistance to pedaling was kept at minimum for all trials and participants. The participants were asked to completely relax, but remain awake. A single trial of 30-minutes was recorded (5-minute warm-up, 20-minute exercise session, 5-minute cool down). Every 5-minutes throughout the session, participants were asked to rate their perceived exertion (RPE), affect (FS), and arousal (FAS). Immediately following the completion of the passive 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 completed the AD ACL, SAI, FS, and FAS for a final time.

(ii) Sham/placebo pedaling. For the sham/placebo trial, the participants were equipped with a Polar heart rate monitor (Polar Electro, Inc., Kempele, Finland). They lay on the mattress and their feet were strapped to the pedals of the custom-designed stationary cycle ergometer, shielded from view. While the motor was still turned on and running during this time, it was disengaged from the pedal system. The speed of motor system was set at a warm-up and cool down cadence of 35 $r \cdot min^{-1}$, and a steady cadence of 50 $r \cdot min^{-1}$ for each participant. The participants were asked to completely relax, but remain awake. A single trial of 30-minutes was recorded. Every 5-minutes throughout the session, participants were asked to rate their perceived exertion (RPE), affect (FS), and arousal (FAS). Immediately following the completion of the session, the participants were asked to complete the AD ACL, SAI, FS, and FAS, and Physical Activity Enjoyment Scale (PACES). At 10-minutes following the session they were asked to complete the AD ACL, SAI, FS, and FAS for a final time.

Data Analysis

Data analysis was conducted using SPSS 24.0.0.0 for Windows. Data was initially inspected for any unusual data points, with corrections made as needed. Analysis of differences in enjoyment between the three exercise conditions was done with a oneway repeated measures analyses of variance (RM-ANOVA). All other analyses of pre- to post-exercise changes in affect and pre-, during, and post-exercise changes were conducted with RM-ANOVA, using the Huynh-Feldt epsilon correction to protect against violations of the sphericity assumption. Effect sizes were calculated as partial eta^2 (η^2_{part}) and as Cohen's *d* (Cohen, 1988). All analyses were run with ASIA classification (A, B, CD) as a between subjects factor.

Hypotheses

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

1) Passive exercise would elicit similar psychological changes as the placebo condition, but would be significantly different from baseline.
2) Participants would exhibit similar enjoyment for passive and placebo conditions, but both would be significantly more enjoyable compared to baseline.
3) Passive exercise and placebo would have significantly stronger effects on affect compared to baseline.
4) There would be no change in HR or RPE across conditions or participant groups.
5) Forehead skin membrane temperature would increase significantly during the passive condition, but not during baseline or placebo conditions.

CHAPTER 3

RESULTS

All 21 participants completed both Passive and Placebo protocols on a manufactured stationary motorized pedal system. Descriptive characteristics of the overall sample are presented in Table 1. There were three other participants who could not complete the study for safety concerns: one participant had too much spasticity and two others had insufficient range of motion in their hips or knees, which prevented completion of the cycle revolutions. These three individuals were not different in any other significant respect from the rest of the sample. Individual characteristics for each participant are presented in Table 2 (see Tables A1 & A2 in Appendix for characteristics separated by traumatic vs. non-traumatic SCI).

Table 1

Descriptive Characteristics of All Participants

Participant Characteristics	Male (n = 11)		Female (n = 10)		Total Sample (N = 21)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age (years)	29	7.74	26	4.74	27	6.52
Height (cm)	173.87	12.13	158.77	13.99	169.38	14.88
Weight (kg)	65.29	14.76	57.68	15.30	66.67	73.76

Table 2

Physical Characteristics of All Participants

Participant	Age (yrs)	Weight (kg)	Height (cm)	LOI	ASIA[a]	TSI (yrs)	Sex
1	27	37.27	134.62	T4	C	27	F
2	19	45.45	157.48	T10-11	A	14	M
3	19	50.00	165.10	T10	C	7	F
4	22	74.09	172.72	L2-3	B	16	F
5	22	54.55	152.40	T12-L1/2	B	22	M
6	39	72.73	185.42	T5-6	A	13	M
7	41	70.45	180.34	T9	A	22	M
8	26	90.91	176.64	T6-9	A	15	F
9	23	60.91	165.10	T11	B	14	F
10	32	94.55	180.34	L3-5	B	23	M
11	36	79.55	193.04	T12	A	14	M
12	20	54.55	172.72	T8-9	A	9	M
13	24	56.82	142.24	T11-12	B	24	F
15	25	59.09	180.34	T8-9	A	7	F
16	23	51.36	162.56	L1-3	A	17	F
17	30	41.82	149.86	T9-L2	A	26	F
18	23	68.18	167.64	T6-10	C	9	M
20	27	48.64	162.56	T10	B	27	M
21	31	72.73	185.52	T11	B	18	M
23	24	56.82	175.26	T9	B	24	M
24	36	54.55	157.48	T10	B	30	F

Note: ASIA = American Spinal Injury Association Impairment Scale; LOI = level of injury; M = male; TSI = time since injury. [a]ASIA-A = no motor or sensation below injury; ASIA-B = no motor but some sensation below the level of injury; ASIA-CD = some motor and some sensation below the level of injury.

Heart Rate (HR) and Rating of Perceived Exertion (RPE)

HR response over time in each of the three conditions is depicted in Table 3 and Figure 4. A Condition (3) x Time (11) RM ANOVA revealed a significant Time main effect ($p < .001$) which was superseded by a significant Condition x Time interaction [$F(13.32, 226.50) = 1.87$, $p = .034$, $\eta^2_{part} = .10$]. To decompose the interaction, separate Condition (2) x Time (11) RM ANOVAs were run comparing pairs of the three conditions (e.g., Rest vs. Passive, Rest vs. Placebo, etc.). There were Time main effects for both Rest and Passive conditions compared to the Placebo condition, ($p_s < .001$). Additionally, there was a Time main effect ($p < .001$) and Condition x Time interaction between the Rest and Passive conditions [$F(7.45, 134.18) = 3.51$, $p = .001$, $\eta^2_{part} = .16$]. There were some slight deviations over time across the three conditions. There was very little change in HR during the Placebo condition, but more significant changes during the Rest and Passive conditions, particularly from Pre10 to Warm-up and again from Cool-down to Post0. Notably, HR decreased in all three conditions and then increased during the post-condition time period. There were no main effects or interactions found for ASIA classification.

Table 3

Heart Rate (HR) and Rating of Perceived Exertion (RPE) Values during Each Condition

	Time	Rest (*N* = 19)		Passive (*N* = 19)		Placebo (*N* = *19*)	
		M	***SD***	***M***	***SD***	***M***	***SD***
Heart Rate	Pre-10	79.05	14.05	83.20	15.16	80.30	14.62
	Pre-0	68.11	13.76	73.20	12.68	74.85	15.31
	Warm-up	70.53	10.44	68.70	12.01	69.60	12.43
	8 mins	67.26	9.77	68.80	13.10	68.95	12.76
	11 mins	69.26	9.10	68.30	12.04	68.25	13.50
	14 mins	67.79	10.57	67.85	11.18	68.55	12.75
	17 mins	67.63	9.38	67.10	13.15	67.85	12.94
	20 mins	66.42	8.95	66.90	12.41	66.80	12.35
	Cool-down	68.26	10.26	63.80	10.74	68.15	15.49
	Post-0	75.37	11.77	71.75	13.43	76.85	15.67
	Post-10	70.47	11.91	67.85	13.39	72.95	15.63
Rate of Perceived Exertion	Pre-10	6.26	0.93	6.32	1.16	6.32	1.16
	Pre-0	6.11	0.46	6.16	0.38	6.32	1.16
	Warm-up	6.05	0.23	7.37	1.71	6.37	1.38
	8 mins	6.00	0.00	7.47	1.90	6.37	1.38
	11 mins	6.05	0.23	7.63	1.95	6.32	1.16
	14 mins	6.05	0.23	7.68	2.08	6.32	1.16
	17 mins	6.16	0.50	7.74	2.05	6.26	0.93
	20 mins	6.05	0.23	7.84	2.27	6.37	1.38
	Cool-down	6.16	0.69	6.95	1.68	6.21	0.71
	Post-0	6.16	0.69	6.16	0.50	6.26	0.93
	Post-10	6.16	0.69	6.21	0.92	6.37	1.38

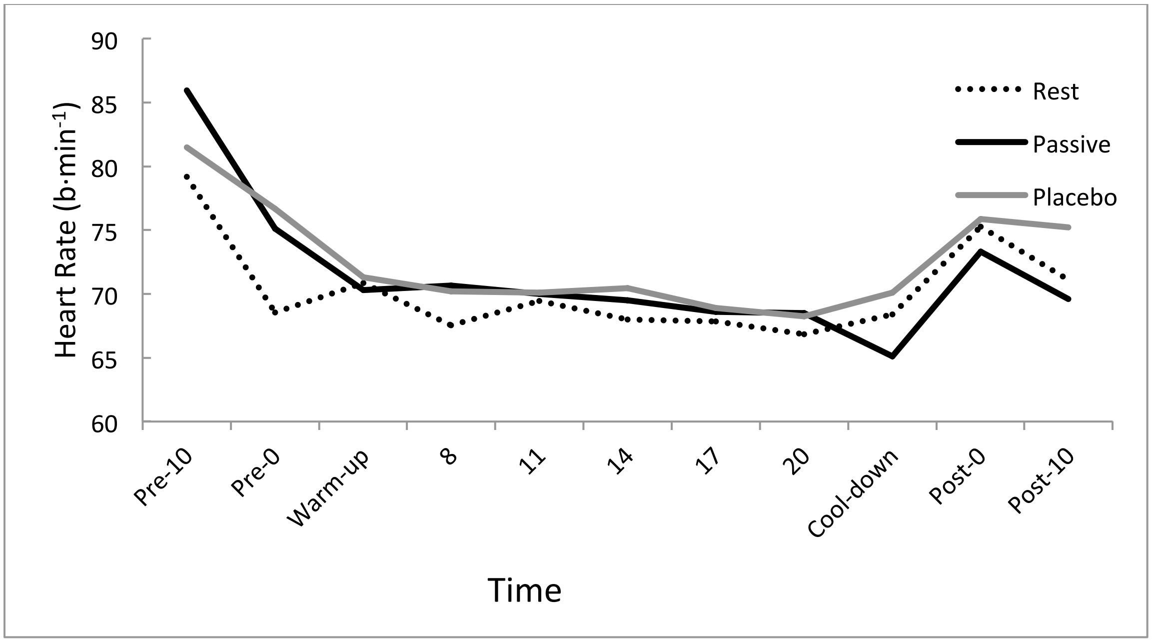


Figure 4. Heart Rate responses over time during the Rest, Passive and Placebo conditions.

RPE responses over time in each of the three conditions are depicted in Table 3 and Figure 5. For RPE, there were significant Time (p= .008) and Condition main effects (p= .016), which were superseded by a Condition x Time interaction [F(2.72, 48.98)= 7.01, p= .001, η^2_{part}= .28]. Decomposing the interaction with separate Condition (2) x Time (11) RM ANOVAs (e.g., Rest vs. Passive, Rest vs. Placebo, etc.) revealed that the Passive condition was the cause of significant Condition x Time interactions when compared to both the Rest [F(2.51, 47.68)= 9.38, p< .001, η^2_{part}= .33] and Placebo [F(2.15, 40.77)= 8.25, p= .001, η^2_{part}= .30] conditions. There were no statistically significant differences between Rest and Placebo conditions (p= .44), nor were there any interactions with ASIA classifications. As seen in Figure 5, participants responded with larger RPE scores in the Passive condition (M= 7.05±0.70) relative to the Rest (M= 6.11±0.08) and Placebo (M= 6.32±0.05) conditions.

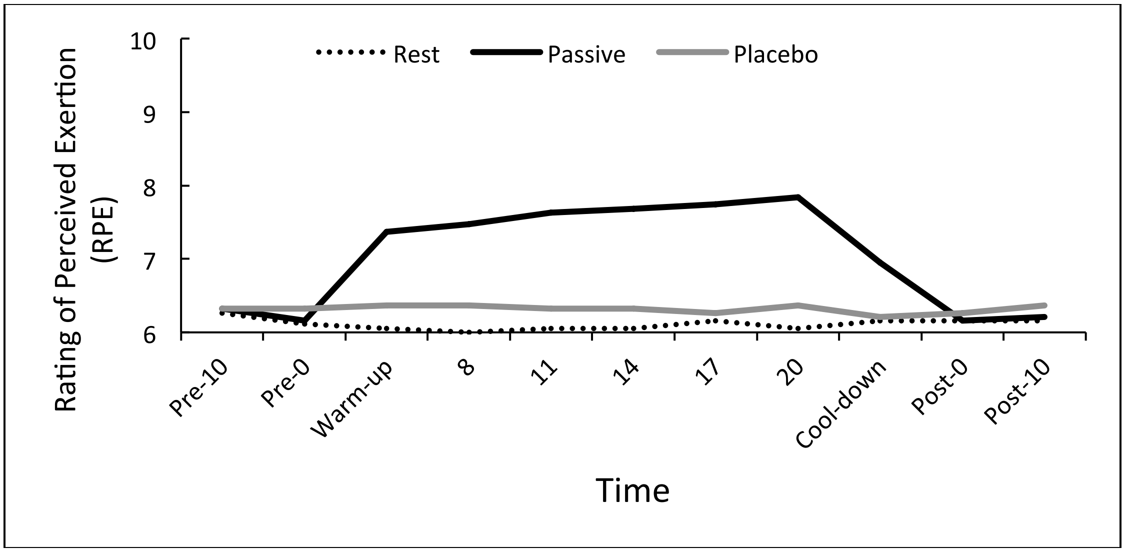


Figure 5. Rating of Perceived Exertion during Rest, Passive and Placebo conditions.

Temperature

For Temperature, which can be seen in Table 4, there were no significant effects.

Table 4

Temperature Responses During Each Condition

		Rest		Passive		Placebo	
	Time	***M***	***SD***	***M***	***SD***	***M***	***SD***
Temperature (°F)	Pre-10	96.47	2.77	97.05	0.93	97.15	0.77
	Pre-0	97.47	0.63	97.45	0.76	97.31	0.58
	Warm-up	97.45	0.63	97.22	0.43	97.31	0.59
	8 mins	97.27	0.71	97.14	0.48	97.21	0.69
	11 mins	97.35	0.53	97.22	0.53	97.37	0.58
	14 mins	97.20	0.71	97.05	0.47	97.15	0.56
	17 mins	97.44	0.65	97.04	0.55	97.02	0.70
	20 mins	97.39	0.54	96.87	0.55	97.18	0.67
	Cool-down	97.22	0.74	96.84	0.45	97.03	0.63
	Post-0	97.31	0.69	96.95	0.50	96.93	0.65
	Post-10	97.00	0.66	96.84	0.35	97.07	0.64

Note. Due to technical issues, temperature was only obtained from 17 participants.

Affective Responses

Energy. Energy responses over time in each of the three conditions are depicted in Table 5 and Figure 6. For Energy, there was a significant Condition x Time interaction with ASIA classification [$F(11.9, 101.2) = 2.39$, $p = .009$. $\eta^2_{part} = .22$]. Overall, there was a difference in the change of Energy from Rest versus Passive [$F(6, 54) = 4.31$, $p = .001$. $\eta^2_{part} = .32$] and Passive versus Placebo [$F(4.9, 41.3) = 2.46$, $p = .050$. $\eta^2_{part} = .23$]. Decomposing this interaction by examining Condition (2) x Time (4) RM ANOVAs within each ASIA category revealed that for ASIA-As only (n=9; depicted in Table 6 and Figure 8), there were only significant Time main effects within each condition [$F(2.6, 20.5) = 6.43$, $p = .004$, $\eta^2_{part} = .45$]. For the Rest condition, there were significant changes in Energy from Pre-10 to Post-0 ([9.44-7.78]= 1.67; $p = .042$) and Pre-10 to Post-10 ([9.44-7.67]= 1.78; $p = .039$). For the Passive condition, there was a significant change in Energy from Pre-10 to Post-10 ([10.00-7.57]= 2.44 $p = .019$]). Finally, in the Placebo condition, there were significant changes seen from Pre-10 to Post-0 ([9.56-7.78]= 2.22 $p = .013$]).

For ASIA-Bs only (n=9; see Figure 9), there was a significant Condition x Time interaction [$F(5.1, 36.0) = 5.95$, $p < .001$, $\eta^2_{part} = .46$]. Only within the Rest condition were significant changes seen over time, with Pre-10 being greater than Post-0 ([10.78-7.33]= 3.44 $p = .003$]) and Post-10 ([10.78-7.78]= 3.0 $p = .002$]), and Pre-0 being greater than Post-0 ([9.44-7.33] = 2.11 $p = .039$]) and Post-10 ([9.44-7.78]= 1.67 p= .051]), which only approached significance. There were no significant effects for ASIA-CD (see Figure 10).

Calmness. Calmness responses over time in each of the three conditions are depicted in Table 5. For Calmness, the Condition x Time interaction with ASIA classification approached significance [$F(12, 102) = 1.86$, $p = .053$. $\eta^2_{part} = .18$]. Decomposing this interaction by examining

Condition x Time within each ASIA category (see Table 7) revealed that for ASIA-As only (*n*=9), there was a significant interaction and a significant Time main effect (Figure 11). Examining change over time within each Condition revealed that Calmness increased from Pre-10 (11.33) to every other time point, but only in the Placebo condition (Pre-10-Pre-0 [11.33-12.89]= -1.56, p= .038; Pre-10-Post-0 [11.33-13.78]= -2.44, p= .019; Pre-10-Post-10 [11.33-13.11]= -1.78, p= .056). For ASIA-Bs only (*n*=9; Figure 12), there were significant Condition [$F(2, 13.9)$= 10.88, p= .001, η^2_{part}= .61] and Time [$F(3, 21)$= 5.36, p= .007, η^2_{part}= .43] main effects, but post hoc follow-ups revealed only that Calmness was higher in the Rest condition relative to the other two conditions. There was a significant Condition x Time interaction from Rest to Passive [$F(6, 12)$= 4.03, p= .019. η^2_{part}= .67] within ASIA-CDs (Figure 13).

Table 5

Scores for the AD ACL Energy and Calmness Subscales

	Time	Rest (*N* = 19)		Passive (*N* = 19)		Placebo (*N* = *19*)	
		M	***SD***	***M***	***SD***	***M***	***SD***
Energy	Pre-10	10.11	3.07	9.53	2.99	9.79	2.53
	Pre-0	8.89	2.64	8.79	2.49	8.84	2.93
	Post-0	7.74	2.79	9.74	2.47	7.63	2.39
	Post-10	7.84	2.97	8.53	2.65	7.79	2.78
Calmness	Pre-10	14.58	2.39	11.89	2.58	12.16	2.41
	Pre-0	13.84	2.59	12.74	2.58	12.84	2.79
	Post-0	14.47	2.70	11.47	3.44	13.26	2.96
	Post-10	14.11	2.60	11.84	2.99	12.79	2.15

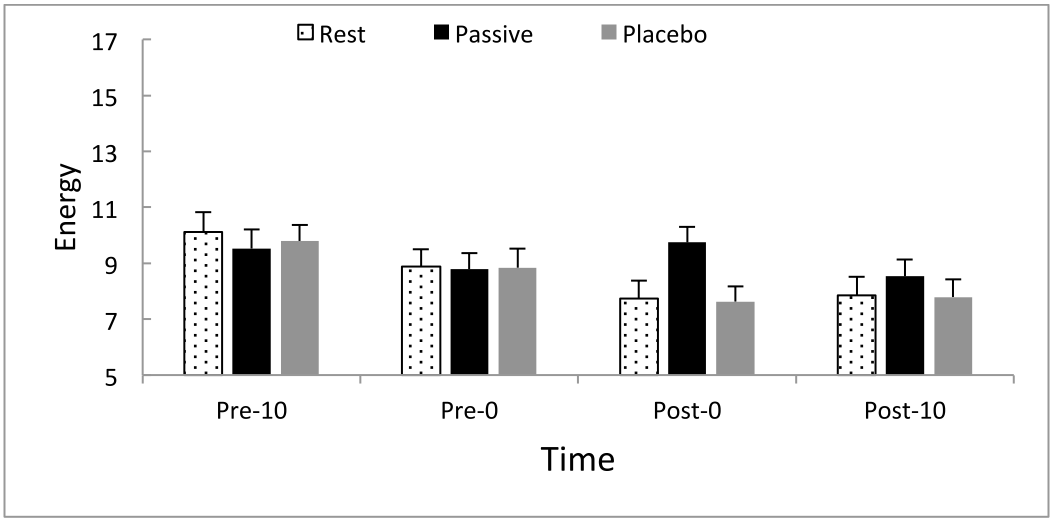


Figure 6. Total AD ACL scores for the Energy subscale pre- and post-exercise in the three conditions.

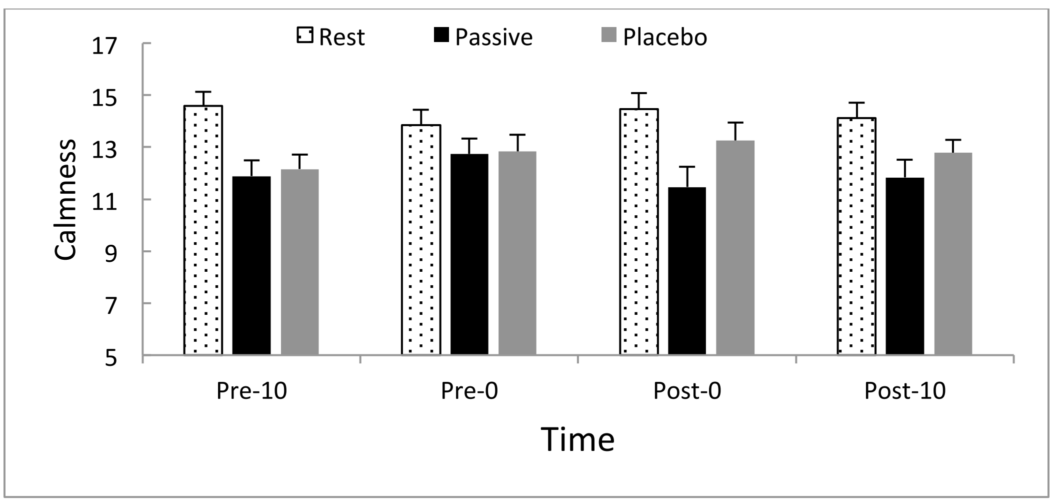


Figure 7. Total AD ACL scores for the Calmness subscale pre- and post-exercise in the three conditions.

Table 6

Scores for the AD ACL Energy Subscale by ASIA Classification

	Time	Rest (*n* = 9)		Passive (*n* = 9)		Placebo (*n* = 9)	
		M	***SD***	***M***	***SD***	***M***	***SD***
Energy ASIA-A only	Pre-10	9.44	2.46	10.00	2.35	9.56	2.70
	Pre-0	7.89	2.37	8.89	2.47	8.33	2.78
	Post-0	7.78	2.11	8.56	2.70	7.33	2.40
	Post-10	7.67	2.50	7.56	1.88	7.44	2.74
	Time	**Rest (*n* = 8)**		**Passive (*n* = 8)**		**Placebo (*n* = 8)**	
		M	***SD***	***M***	***SD***	***M***	***SD***
Energy ASIA-B only	Pre-10	10.78	3.98	9.78	3.99	9.88	3.09
	Pre-0	9.44	2.98	8.44	3.20	9.75	3.28
	Post-0	7.33	3.82	10.67	2.71	8.13	2.75
	Post-10	7.78	3.91	9.56	3.38	8.50	3.16
	Time	**Rest (*n* = 3)**		**Passive (*n* = 3)**		**Placebo (*n* = 3)**	
		M	***SD***	***M***	***SD***	***M***	***SD***
Energy ASIA-CD only	Pre-10	9.00	2.00	7.67	1.53	8.67	2.08
	Pre-0	7.67	2.31	8.33	1.16	6.67	2.08
	Post-0	7.00	2.00	9.00	0.00	6.33	1.16
	Post-10	6.67	1.53	7.33	2.08	6.00	1.00

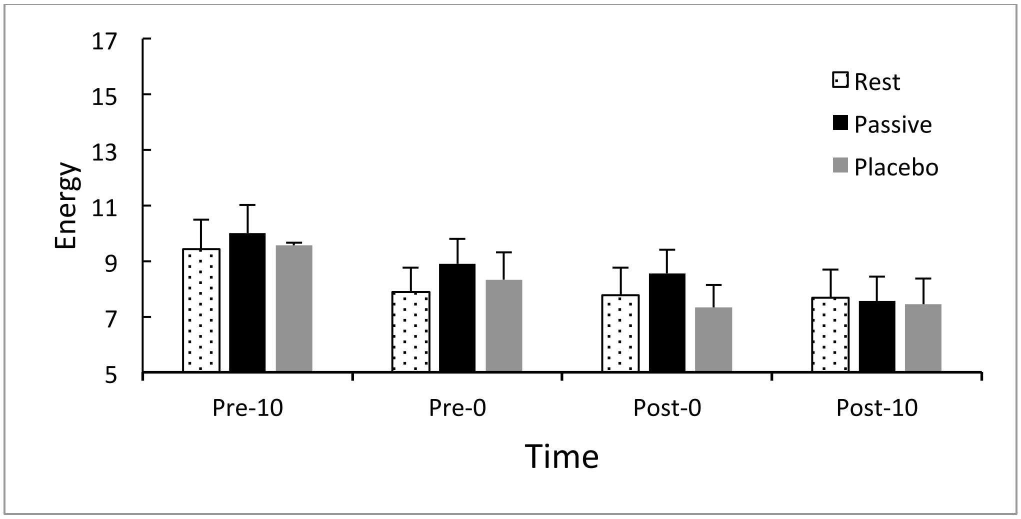


Figure 8. AD ACL Energy subscale scores for ASIA-As only (*n*=9).

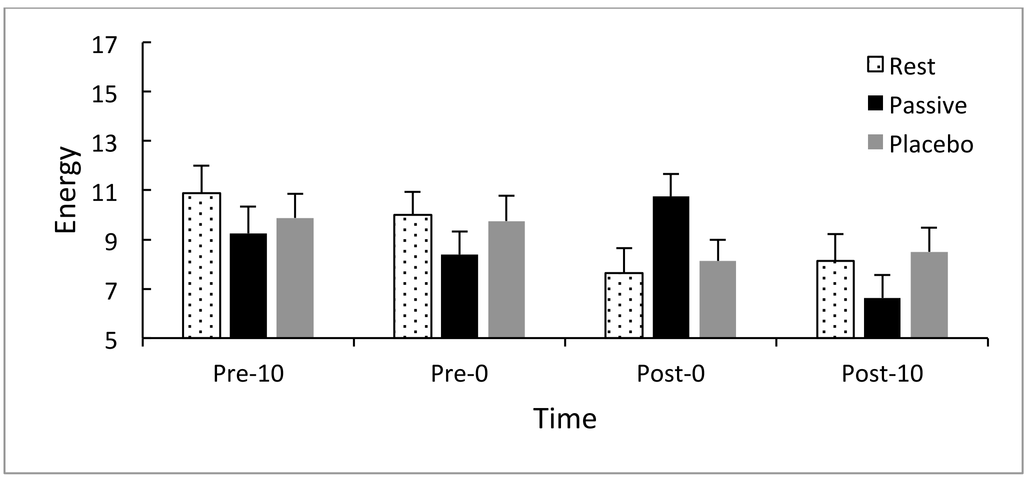


Figure 9. AD ACL Energy subscale scores for ASIA-Bs only (*n*=9).

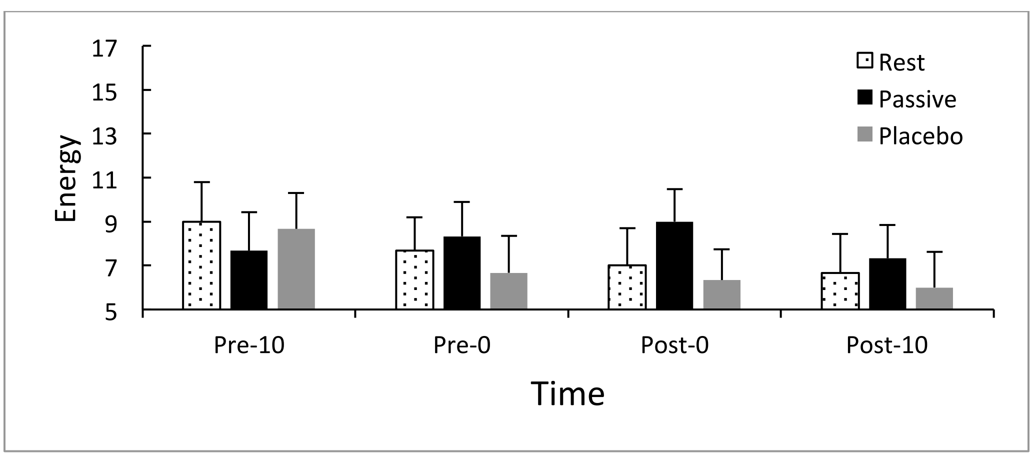


Figure 10. AD ACL Energy subscale scores for ASIA-CDs only (*n*=3).

Table 7

Scores for the AD ACL Calmness Subscale by ASIA Classification

	Time	Rest (n = 9)		Passive (n = 9)		Placebo (n = 9)	
		M	*SD*	*M*	*SD*	*M*	*SD*
Calmness ASIA-A only	Pre-10	13.78	1.20	14.33	2.24	11.33	1.50
	Pre-0	13.44	1.59	12.78	2.39	12.89	2.89
	Post-0	15.33	2.06	11.33	3.46	13.78	2.86
	Post-10	12.11	2.32	12.22	2.59	13.11	2.57
	Time	**Rest (n = 8)**		**Passive (n = 8)**		**Placebo (n = 8)**	
		M	*SD*	*M*	*SD*	*M*	*SD*
Calmness ASIA-B only	Pre-10	15.25	2.82	12.38	2.83	12.88	3.14
	Pre-0	15.00	2.83	13.00	2.93	12.63	3.02
	Post-0	13.88	2.53	12.00	3.42	12.25	3.24
	Post-10	14.13	2.75	11.25	3.20	12.25	2.12
	Time	**Rest (n = 3)**		**Passive (n = 3)**		**Placebo (n = 3)**	
		M	*SD*	*M*	*SD*	*M*	*SD*
Calmness ASIA-CD only	Pre-10	14.33	4.04	9.67	1.53	12.33	2.08
	Pre-0	11.67	3.06	11.67	2.31	12.67	2.52
	Post-0	13.00	4.36	10.33	3.79	13.33	3.06
	Post-10	13.00	3.61	11.67	4.16	12.00	2.00

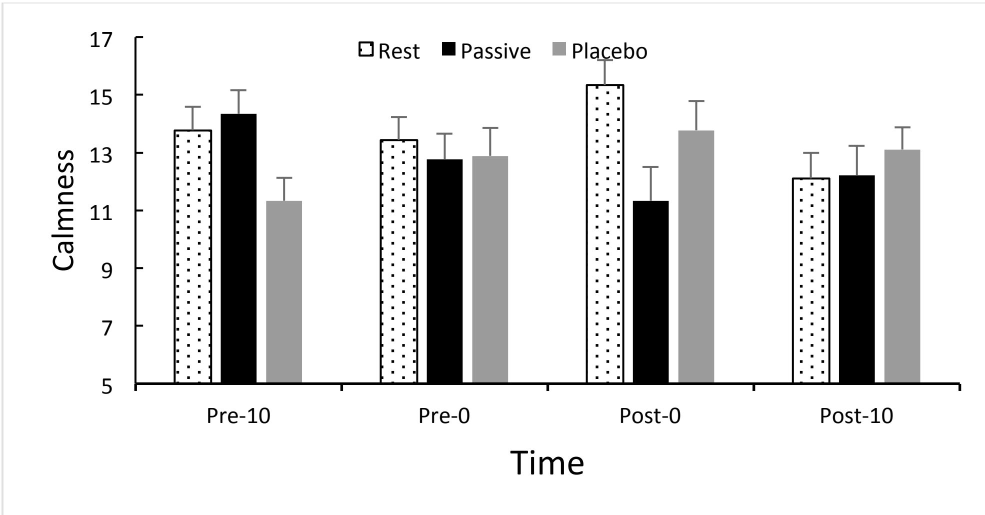


Figure 11. AD ACL Calmness subscale scores for ASIA-As only (*n*=9).

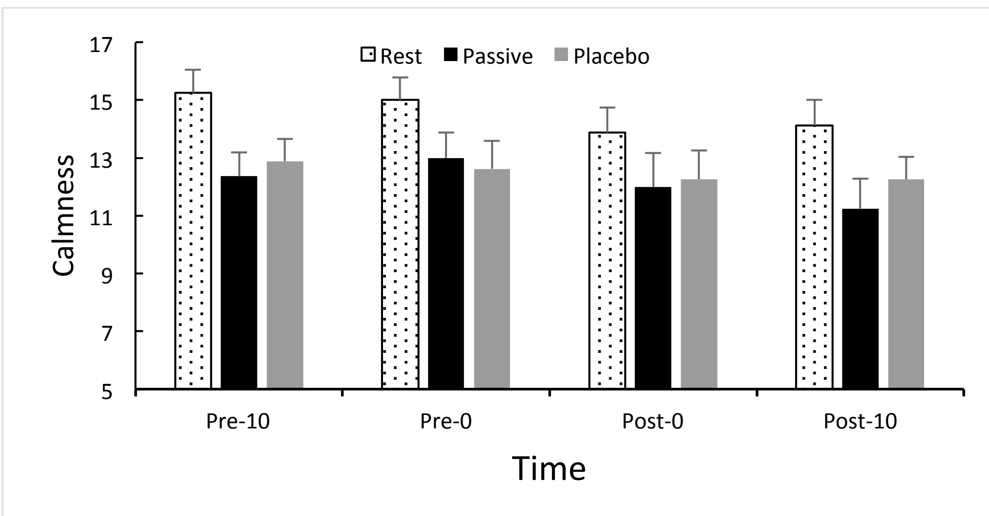


Figure 12. AD ACL Calmness subscale scores for ASIA-Bs only (*n*=9).

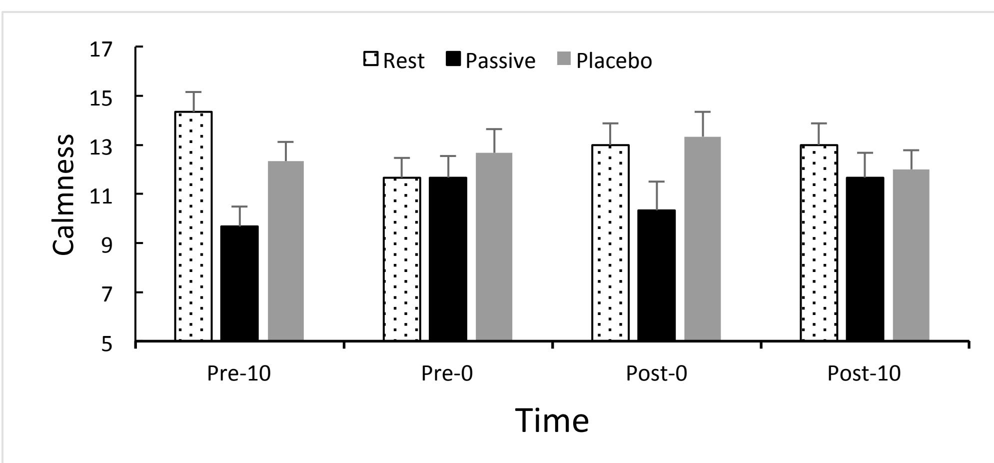


Figure 13. AD ACL Calmness subscale scores for ASIA-CDs only (*n*=3).

Tension. For Tension, there was a marginal Time main effect (p=.063), while the Condition main effect (p=.411), and Condition x Time interaction (p=.539) were not significant (see Table 8 and Figure 14). Additionally, there was no interaction with ASIA classification.

Tiredness. Finally for Tiredness, there was no significant effect of Time (p=.475), or Condition (p=.875). However, there was a significant Condition x Time interaction [F(3.85, 69.9)= 3.15, p= .02. η^2_{part}= .149]. There was no interaction with ASIA classification. The interaction was driven exclusively by a change over time in the Placebo condition (see Table 8 and Figure 15), with a significant increase in Tiredness from Pre10 to Post0 (M_{diff}= 1.70, p= 0.15). There were no significant changes in either the Rest or Passive conditions.

Table 8

Scores for the AD ACL Tiredness and Tension Subscales

	Time	**Rest (*N* = 19)**		**Passive (*N = 19*)**		**Placebo (*N = 19*)**	
		M	***SD***	***M***	***SD***	***M***	***SD***
Tension	Pre-10	5.79	0.90	5.58	0.90	5.68	1.11
	Pre-0	5.84	0.78	5.47	0.84	5.32	0.75
	Post-0	5.37	0.90	5.47	1.02	5.26	0.65
	Post-10	5.42	0.84	5.16	0.50	5.32	0.67
Tiredness	Pre-10	10.05	2.16	11.05	3.84	9.74	3.45
	Pre-0	10.05	3.21	11.00	3.89	10.58	3.30
	Post-0	10.84	4.17	10.05	3.17	11.53	4.06
	Post-10	10.68	3.71	11.53	3.32	11.00	3.50

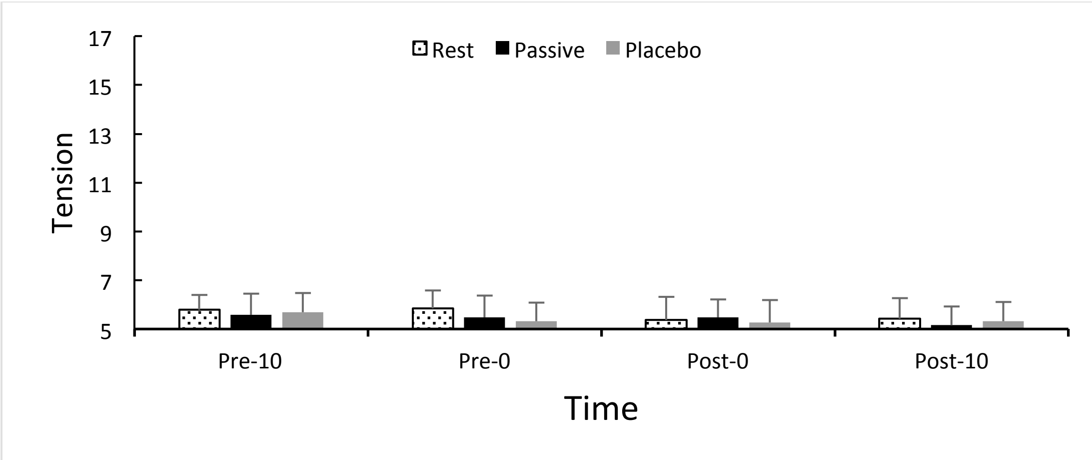


Figure 14. Tension during Rest, Passive and Placebo conditions.

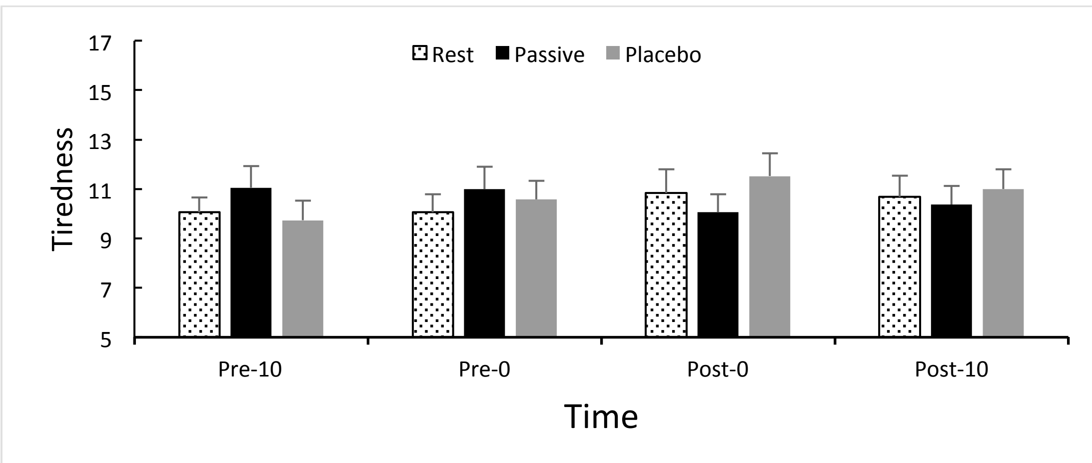


Figure 15. Tiredness during Rest, Passive and Placebo conditions.

State Anxiety

For State Anxiety (see Table 9, Figure 16), a significant Condition main effect [F(1.95, 35.01)= 15.72, p< .001, η^2_{part} = .47] was seen, but no Time or Condition x Time interaction. State anxiety was significantly lower during the Rest condition (M= 13.55, p< .001) compared to the Passive (M= 15.26) and Placebo (M= 15.15) conditions, which were not significantly different from each other (p= .668; see Table 10 and Figure 17).

Table 9

Scores for State Anxiety Before and Following the Conditions

	Time	Rest (*N= 19)*		Passive (*N= 19*)		Placebo (*N= 19*)	
		M	***SD***	***M***	***SD***	***M***	***SD***
SAI	Pre-10	13.74	2.60	15.32	3.06	15.47	2.53
	Pre-0	14.00	2.75	15.21	2.84	15.53	2.04
	Post-0	13.05	2.12	15.42	3.36	14.74	2.64
	Post-10	13.42	2.32	15.11	2.45	14.84	2.22

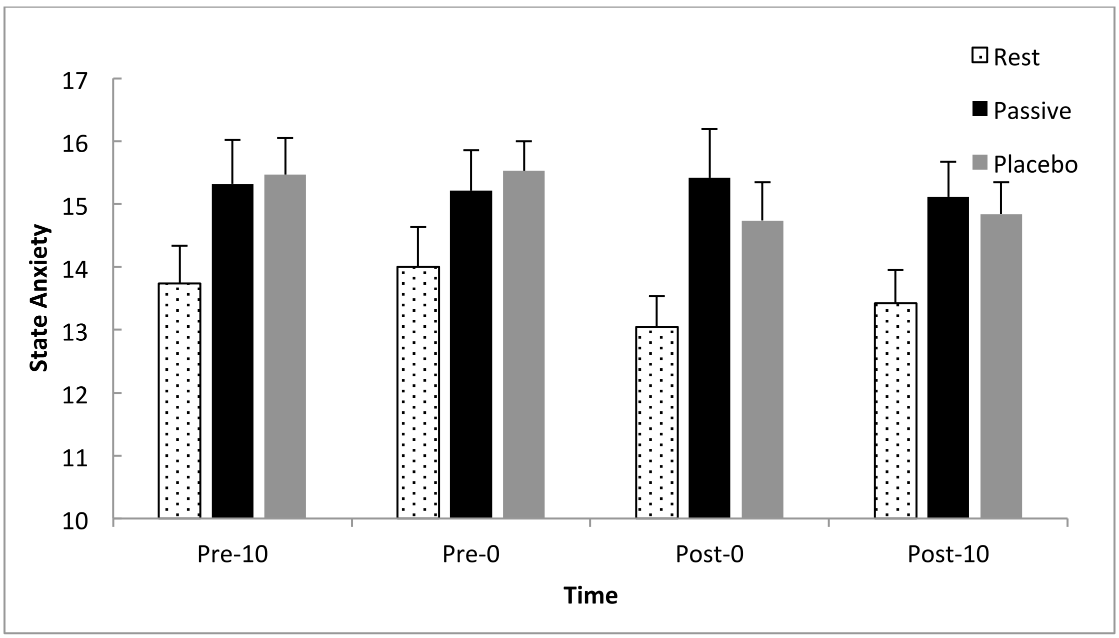


Figure 16. State Anxiety over time during Rest, Passive and Placebo conditions.

Table 10

Scores for State Anxiety During Each Condition

	Condition	M	SD
SAI	Rest	13.55	2.06
	Passive	15.26	2.57
	Placebo	15.15	2.04

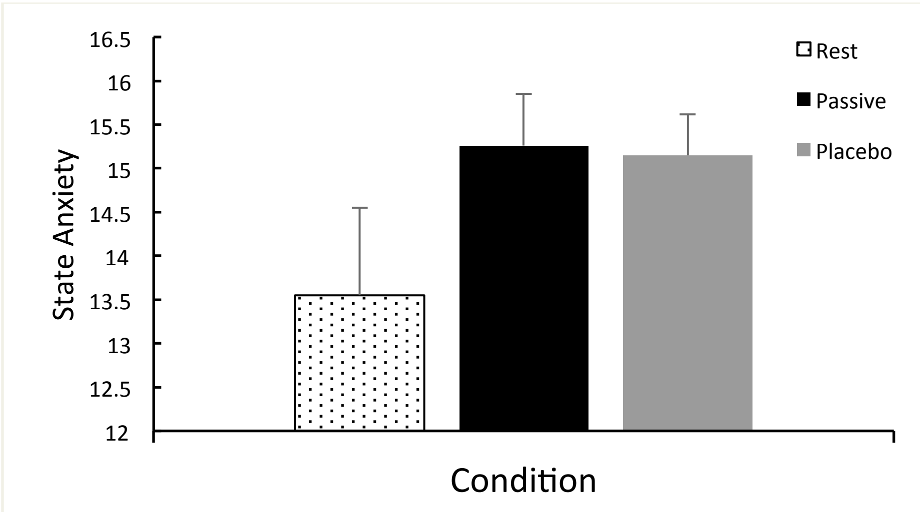


Figure 17. State Anxiety during Rest, Passive and Placebo conditions.

Feeling Scale (FS) and Felt Arousal Scale (FAS)

FS responses over time in each of the three conditions are depicted in Table 11 and Figure 18. For the Feeling Scale, neither the Condition (p= .39), Time (p= .06), nor Condition x Time interaction (p= .091) were significant. There were also no interactions with ASIA classification.

FAS responses over time in each of the three conditions are depicted in Table 11 and Figure 19. For FAS, there was a significant Condition x Time interaction with ASIA classification [$F(20.1, 170.7)= 1.80$, $p= .024$. $\eta^2_{part}= .18$; see Table 12]. Decomposing this interaction by examining Condition x Time within each ASIA category revealed that for ASIA-As only (n=9; see Figure 20), there were significant Condition [$F(2, 16)= 4.11$, $p= .036$, $\eta^2_{part}=$ .34] and Time [$F(7.1, 57.5)= 2.57$, $p= .022$, $\eta^2_{part}= .24$] main effects. There were no significant Time effects within Rest or Placebo conditions. However, FAS at the midpoint of the Passive condition (Min11) increased significantly from Pre10 ($M_{diff}= 0.44$, $p= .035$) and then decreased significantly from Min11 to Min20 ($M_{diff} = -0.44$, $p= .035$), Cool-down ($M_{diff} = -0.44$, $p= .035$), Post-0 ($M_{diff} = -0.56$, $p= .013$), and approaching significance at Post-10 ($M_{diff} = -0.56$, $p= .051$).

For ASIA-Bs only (*n*=8; see Figure 21), there was a marginally (*p*= .09) significant Time main effect within the Passive condition [$F(4.8, 38.6)$= 2.09, *p*= .090. η^2_{part}= .21], with Min14 (M_{diff} = 0.56, *p*=.051) being greater than Post-0 (M_{diff}= 0.56, *p*=.051) and Post-10 = M_{diff} = 0.56, *p*=.051). There were no significant effects for ASIA-CDs (see Figure 22).

Table 11

Feeling Scale Before, During, and Following the Conditions

	Time	Rest (*N= 19*)		Passive (*N= 19*)		Placebo (*N= 19*)	
		M	***SD***	***M***	***SD***	***M***	***SD***
Feeling Scale	Pre-10	2.79	1.75	3.11	1.82	3.00	1.76
	Pre-0	3.21	1.72	3.16	1.64	3.00	1.76
	Warm-up	3.42	1.68	3.37	1.46	3.11	1.79
	8 mins	3.37	1.67	3.32	1.64	3.05	1.87
	11 mins	3.32	1.70	3.37	1.64	3.11	1.79
	14 mins	3.37	1.67	3.42	1.54	3.16	1.74
	17 mins	3.53	1.74	3.32	1.64	3.11	1.73
	20 mins	3.47	1.71	3.32	1.64	3.16	1.77
	Cool down	3.47	1.71	3.16	1.61	3.16	1.77
	Post-0	2.67	2.52	3.37	1.67	3.26	1.73
	Post-10	3.53	1.84	3.26	1.70	3.21	1.75
	Time	**Rest (*N= 20*)**		**Passive (*N= 20*)**		**Placebo (*N= 20*)**	
		M	***SD***	***M***	***SD***	***M***	***SD***
Felt Arousal Scale	Pre-10	1.60	0.88	1.30	0.57	1.30	0.47
	Pre-0	1.60	0.75	1.40	0.60	1.30	0.47
	Warm-up	1.50	0.76	1.55	0.61	1.25	0.44
	8 mins	1.40	0.60	1.70	0.66	1.25	0.44
	11 mins	1.35	0.49	1.75	0.64	1.25	0.44
	14 mins	1.35	0.49	1.70	0.73	1.25	0.55
	17 mins	1.35	0.49	1.60	0.75	1.20	0.52
	20 mins	1.30	0.47	1.55	0.76	1.15	0.49
	Cool down	1.30	0.47	1.45	0.61	1.10	0.31
	Post-0	1.30	0.57	1.20	0.41	1.10	0.31
	Post-10	1.35	0.75	1.15	0.37	1.15	0.37

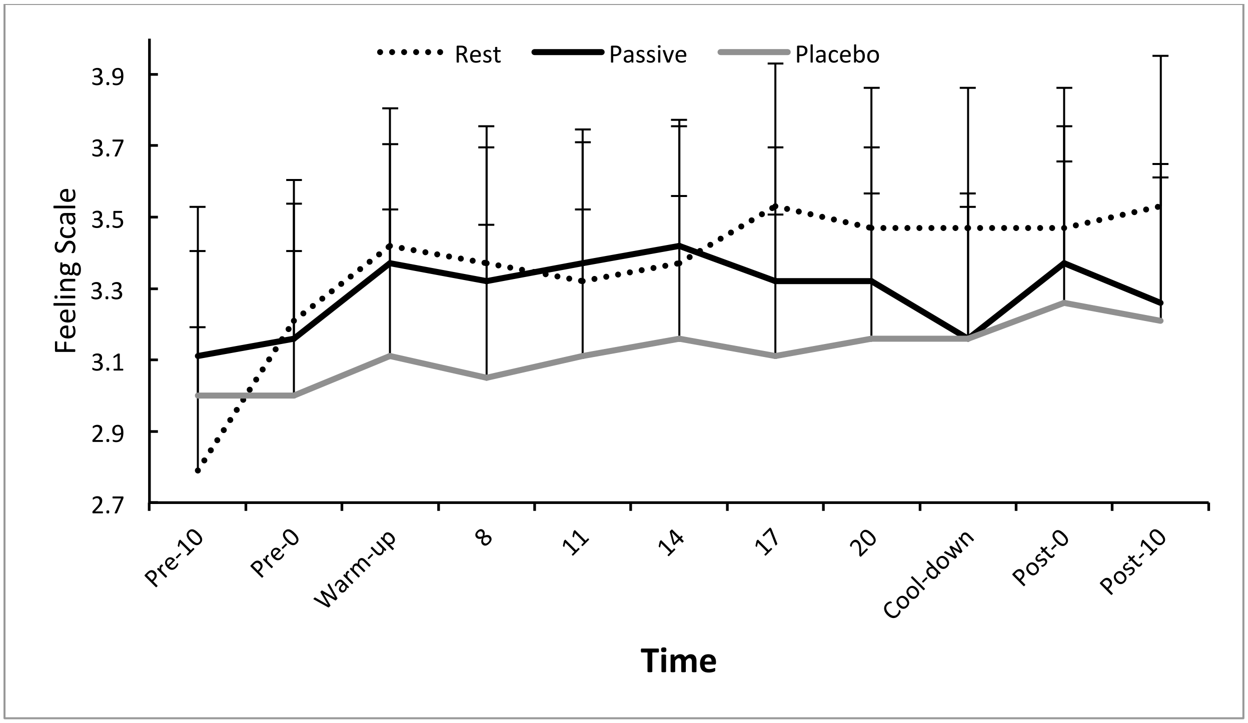


Figure 18. Feeling Scale responses for Rest, Passive, and Placebo conditions.

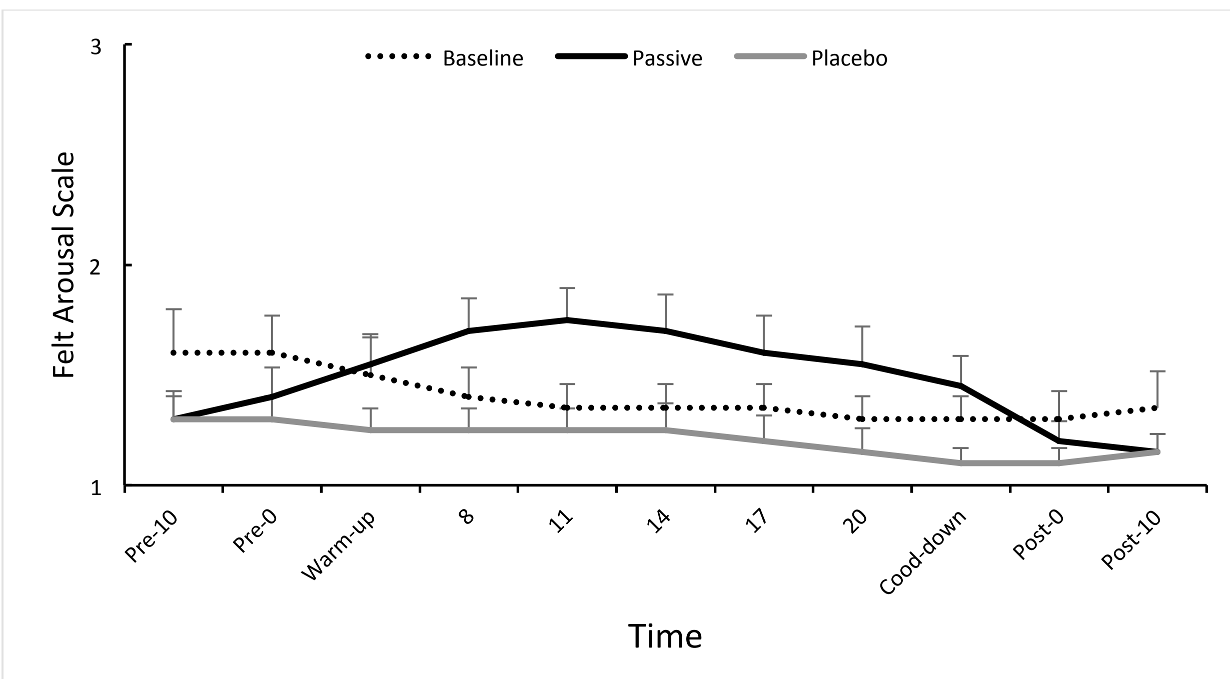


Figure 19. Felt Arousal Scale responses for Rest, Passive, and Placebo conditions.

Table 12

Scores for the Felt Arousal Scale by ASIA classification

	Time	Rest		Passive		Placebo	
		M	***SD***	***M***	***SD***	***M***	***SD***
FAS ASIA-A only (*n* = 9)	Pre-10	1.44	0.73	1.22	0.44	1.22	0.44
	Pre-0	1.44	0.73	1.33	0.50	1.11	0.33
	Warm-up	1.22	0.67	1.56	0.53	1.22	0.44
	8 mins	1.11	0.33	1.56	0.53	1.22	0.44
	11 mins	1.11	0.33	1.67	0.50	1.22	0.44
	14 mins	1.11	0.33	1.33	0.50	1.11	0.33
	17 mins	1.11	0.33	1.33	0.50	1.11	0.33
	20 mins	1.11	0.33	1.22	0.44	1.00	0.00
	Cool down	1.11	0.33	1.22	0.44	1.00	0.00
	Post-0	1.11	0.33	1.11	0.33	1.00	0.00
	Post-10	1.00	0.00	1.11	0.33	1.00	0.00
	Time	**Rest**		**Passive**		**Placebo**	
		M	***SD***	***M***	***SD***	***M***	***SD***
FAS ASIA-B only (*n* = 8)	Pre-10	1.88	1.13	1.38	0.74	1.25	0.46
	Pre-0	1.75	0.89	1.38	0.74	1.38	0.52
	Warm-up	1.63	0.74	1.50	0.76	1.25	0.46
	8 mins	1.50	0.54	1.63	0.74	1.25	0.46
	11 mins	1.50	0.54	1.63	0.74	1.25	0.46
	14 mins	1.50	0.54	1.75	0.71	1.38	0.74
	17 mins	1.50	0.54	1.63	0.74	1.25	0.71
	20 mins	1.50	0.54	1.63	0.74	1.25	0.71
	Cool down	1.50	0.54	1.50	0.76	1.13	0.35
	Post-0	1.38	0.52	1.25	0.46	1.13	0.35
	Post-10	1.38	0.52	1.25	0.46	1.13	0.35

Table 12 (continued)	Time	Rest		Passive		Placebo	
		M	*SD*	*M*	*SD*	*M*	*SD*
FAS ASIA-CD only	Pre-10	1.33	0.58	1.33	0.58	1.67	0.58
(*n* = 3)	Pre-0	1.67	0.58	1.67	0.58	1.67	0.58
	Warm-up	2.00	1.00	1.67	0.58	1.33	0.58
	8 mins	2.00	1.00	2.33	0.58	1.33	0.58
	11 mins	1.67	0.58	2.33	0.58	1.33	0.58
	14 mins	1.67	0.58	2.67	0.58	1.33	0.58
	17 mins	1.67	0.58	2.33	1.16	1.33	0.58
	20 mins	1.33	0.58	2.33	1.16	1.33	0.58
	Cool down	1.33	0.58	2.00	0.00	1.33	0.58
	Post-0	1.67	1.16	1.33	0.58	1.33	0.58
	Post-10	2.33	1.53	1.00	0.00	1.67	0.58

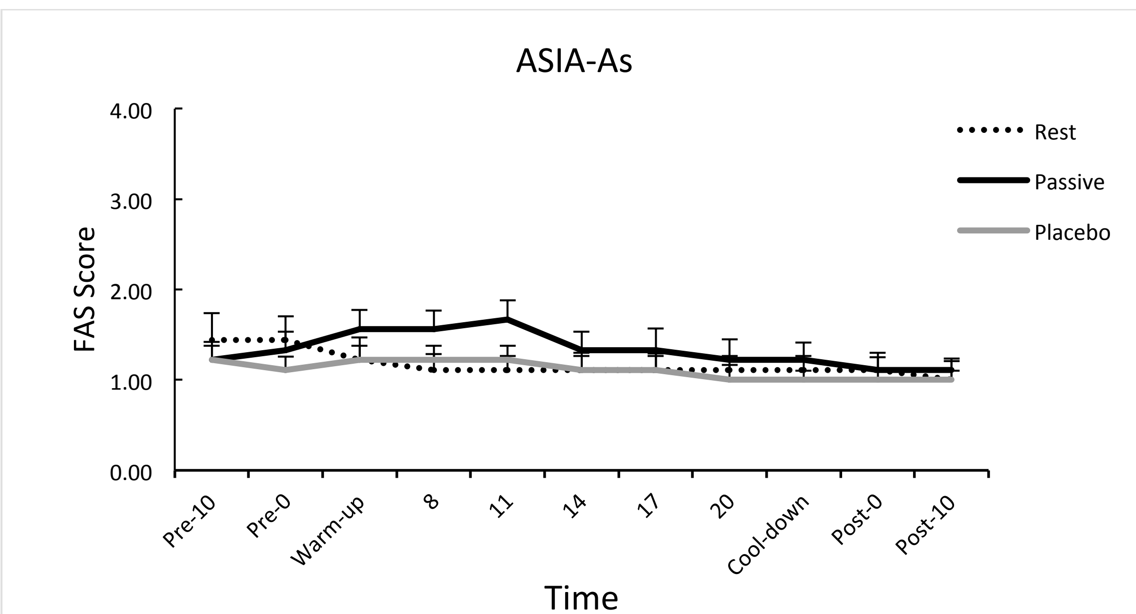


Figure 20. Felt Arousal Scale responses during the three conditions for ASIA-As only (*n*=9).

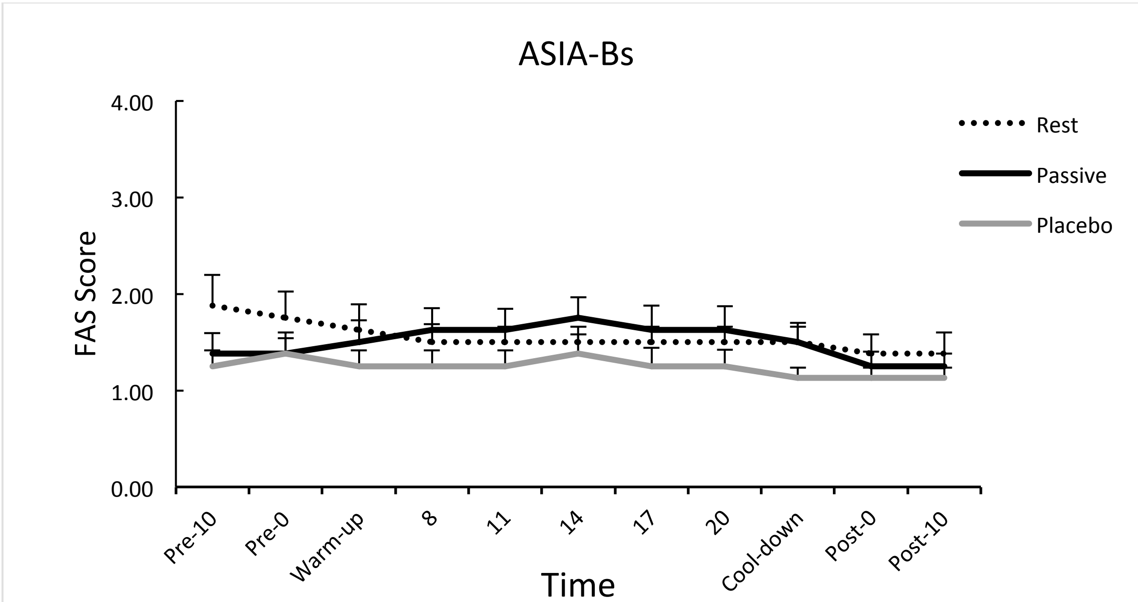


Figure 21. Felt Arousal Scale responses during the three conditions for ASIA-Bs only (*n*=8).

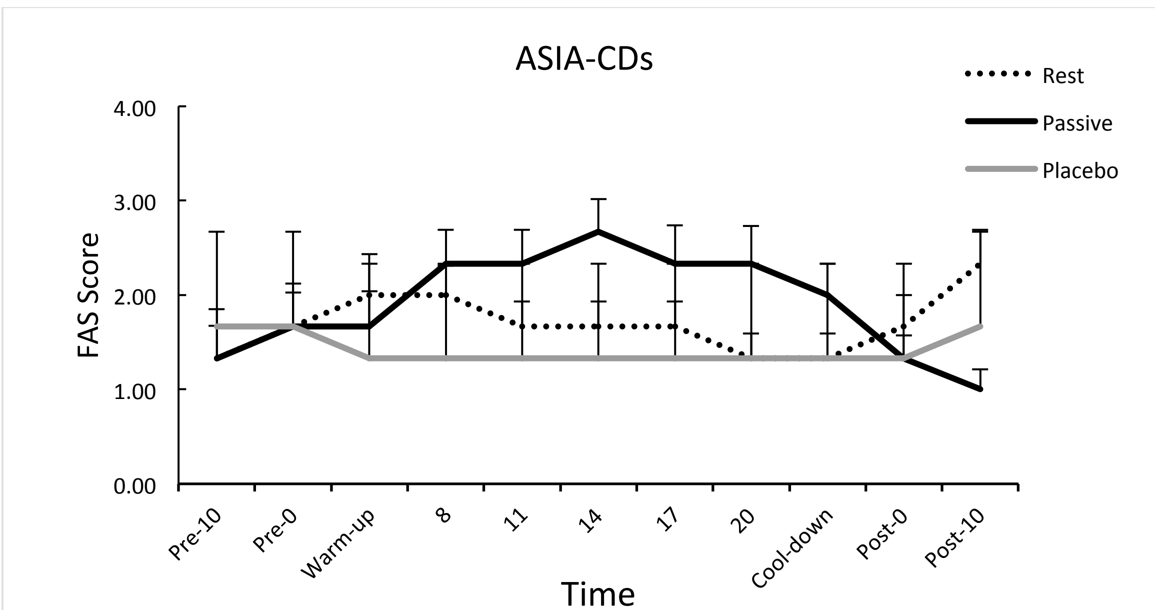


Figure 22. Felt Arousal Scale responses during the three conditions for ASIA-CDs only (n=3).

Enjoyment

Enjoyment responses over time in each of the three conditions are depicted in Table 13 and Figure 23. There was a Condition main effect [$F(2, 36)= 7.907$, $p< .001$, $\eta^2_{part}= 0.31$]. Post hoc comparisons revealed that there was significantly greater enjoyment following the Passive condition when compared to the Placebo condition [$M_{diff}= 14.52$, 95% CI [6.6, 22.4], $t(20)=$

3.83, p=.001] and the Rest condition [M_{diff}= 9.33, 95% CI [2.98, 15.7], $t(20)$= 3.07, p=.006]. Comparing Rest vs Placebo (M_{diff}= 5.19, [CI: -0.5, 10.8], $t(20)$= 1.91, p=.07) revealed Rest to be slightly more enjoyable than Placebo, but not significantly. There were no Condition x Time or Condition x ASIA effects for Enjoyment.

Table 13

Enjoyment Scores from the Physical Activity Enjoyment Scale (PACES) for Each Condition

	Condition	***M***	***SD***
PACES	Rest	70.76	11.90
	Passive	80.10	11.20
	Placebo	65.57	15.04

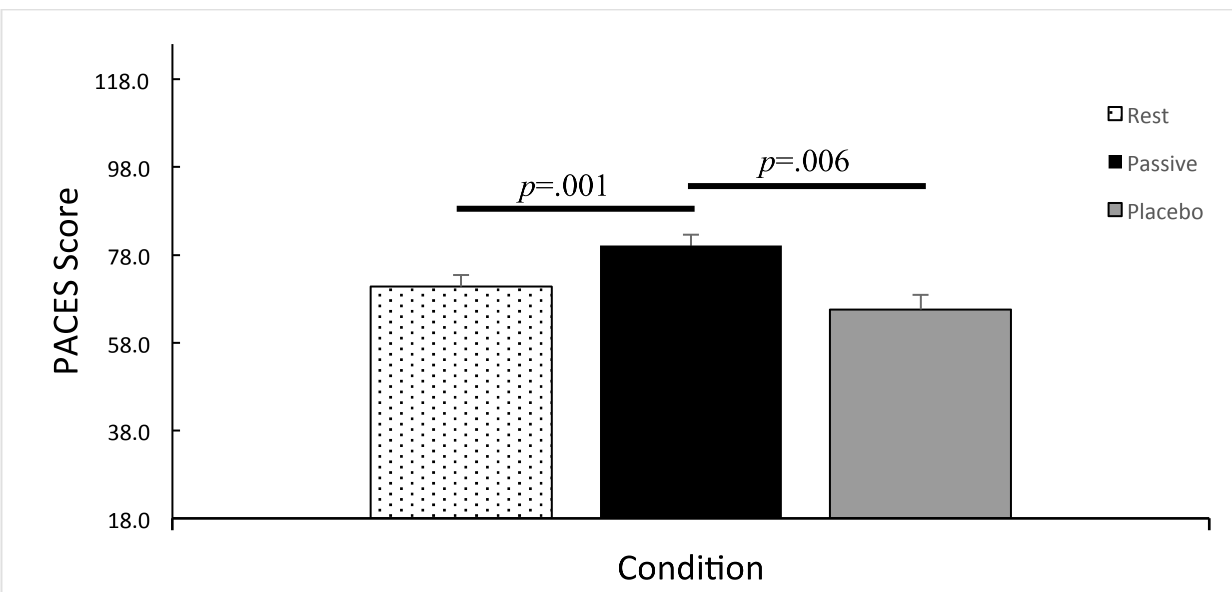


Figure 23. Enjoyment scores for the Rest, Passive, and Placebo conditions.

CHAPTER 4

DISCUSSION

The purpose of this study was to determine the extent to which passive lower limb cycling had an influence on affective and physiological responses in individuals with SCI and whether passive lower extremity cycling could be used as a valid placebo in future exercise trials in this population. The participants were blinded from the chest down with a screen that didn't allow them to see their lower limbs. They were either asked (a) to remain still while a motorized system rotated their legs with their feet attached to pedals at a constant rate of 50 $r \cdot min^{-1}$ for 25-minutes (Passive condition), or (b) to remain still while the motorized system was turned on/running, but disengaged, that is, their feet were attached to the pedals but the pedals did not turn (Placebo condition). Hill (1963) discussed how placebo controls allow for the establishment of a reference point for determining the effectiveness of a new treatment. While it is understood that Passive exercise may not be as effective as active cycling for addressing many of the other potential benefits that excise offers, it may be better than no treatment at all.

Heart Rate (HR) and Rate of Perceived Exertion (RPE)

It was hypothesized that there would be no change in HR or RPE across conditions or participant groups. In the present study, HR decreased during all three conditions from the pre-condition period and then increased during the post-condition period back to pre-condition levels. The decrease from Pre-10 to Pre-0 could be a factor of acclimating to the lab setting. We were unaware and unable to control for activities that may have taken place prior to arrival at the lab for testing. The 10-minute pretest protocol was designed to allow participants to acclimate to the testing environment, and the reduction during the pre-test period seemed to account for that, at least to some extent. It is likely that the decrease in HR could be attributed to the fact that participants transferred from their upright, seated posture to the semi-recumbent, laying posture (see Methods) during the time from Pre-10 to Pre-0 (M_{diff}= 8.76). In other words, this decrease was due to nothing more than a postural change. This is further supported by the subsequent increase in HR as participants moved from the semi-recumbent position following completion of the manipulation back to their upright, seated posture in their wheelchair from Post-0 to Post 10 (M_{diff}= 2.83). Jones et al. (2003) found that a change in posture from supine to seated significantly increased HR (from ~67 to 85 $b \cdot min^{-1}$) in healthy, able-bodied college-aged participants. Miles-Chan et al. (2014) showed a similar effect.

It is hypothesized that the decrease in venous return due to “venous pooling” in the lower limbs is responsible for the increase in HR during standing, due to gravitational effects (Borst, Wieling, vanBrederode & deRijk, 1982). When changing from upright to supine lying, the increase in venous return increases stroke volume, through the Frank Starling mechanism. This leads to a lower HR required to sufficiently maintain cardiac output while lying supine (Jones et al., 2003). Participants were given the option to transfer to their everyday chair during the 10-mintue period post-condition. Most opted to change to an upright, seated position, at a minimum, even if that did not involve transferring to their chair. This decision was based on safety considerations to reduce the risk of skin breakdown and pressure sores from prolonged supine lying. Thus, the changes in HR during the sessions was likely due to nothing more than changes in body position. The conditions did not have any impact on HR responses once body position was stable (i.e., either upright sitting or semi-recumbent laying).

In contrast to the hypothesis, the RPE responses did differ among the conditions. The Passive condition resulted in significantly greater perceptions of exertion when compared to both the Rest and Placebo conditions. Previous research in able-bodied individuals performing upright active or passive cycling showed an average RPE of 7.8 during active (volitional) cycling, and an average of 7.2 for passive cycling (Rougeau, 2015). It was thought that the increase in RPE was related to the necessity of having to use core musculature to stay upright on the bicycle and the inability to completely disengage core and leg muscles to participate in truly passive exercise. However, in the current study, RPE during the Passive (7.7) condition was significantly higher than during both the Rest (6.1) and Placebo (6.30) conditions, respectively. Given the lack of interaction with ASIA classification, it is difficult to reconcile the increased perceptions of effort during the Passive condition (i.e., the sensory function in ASIA-B and CD groups are likely not driving the perception of effort since ASIA-A individuals had similar RPE responses). Marcora (2009) suggests that the afferent feedback from muscle, heart and lungs does not contribute significant input to the perception of effort. The present findings would seem to support that notion. Marcora proposed that other important sources of effort sensation may come from the anterior cingulate cortex, insular cortex, thalamus, dopamine, or endogenous opioids, but these all await confirmation.

The results from the current study give the impression that there is a sensory component associated with physical movement, not necessarily with the act of physical activity itself. Although not all participants had sensation below their injury level (i.e., ASIA-As), it was evident during testing that participants were somehow aware as to whether their legs were or were not being moved based on questions that they asked the research staff. While it was not requested during the study, participants verbalized feedback or gave outbursts regarding each condition such as “This is weird, I feel like I’m actually doing something” for the Passive condition, and “Are my legs supposed to be moving this time?” (in a disappointed tone) during the Placebo condition. This awareness of their legs moving may have led to the report of a higher RPE during the Passive condition. Furthermore, the lack of interaction with ASIA classification leads to the speculation that RPE is not necessarily determined solely by actual motor function, but by a sensory component as well, at some level within the body.

Temperature

It was hypothesized that body temperature would increase significantly during the Passive condition, but not during Rest or Placebo conditions. However, there were no significant changes seen for temperature over time within any condition. It was thought that passive movement could elicit a change in temperature via increased leg blood flow. The lack of change in temperature was likely due to the lack of any physiological changes during the conditions. Temperature was also monitored to check for potential autonomic dysreflexic effects that may have occurred with some participants. The lack of such potential adverse physiological reactions further suggests that the continuous passive movement used in this study could be a useful therapeutic tool for individual with SCI.

Affective Responses

It was hypothesized that there would be no difference in affective responses during the Passive condition compared to the Placebo condition, and no real difference in affect between these two conditions from pre- to post. There were varying levels of support for this hypothesis, depending on the affective construct being considered.

Overall, there were no different responses based on ASIA classification for Tension, Tiredness, State Anxiety, or affective valence (via Feeling Scale). There was a marginal decrease in Tension seen over time, but this was similar across conditions. This lack of change was likely due to the very low Tension scores throughout (i.e., floor effects). The highest mean score for Tension was ~5.8, with the lowest possible score being a 5.0. As such, there was very little room for any meaningful or significant change in Tension. Conversely, it could also be argued that as Tension did not increase, there were no adverse affective changes were seen either. For Tiredness**,** the significant Condition x Time interaction was due to participants reporting feeling more tired following the Placebo condition (effect sizes at Post-0= -0.49 and Post-10= -0.37). Conversely, although not significant, Tiredness decreased from Pre-0 to Post-0 (effect size= 0.29) during the Passive condition. Given that acute bouts of moderate aerobic exercise have been shown to decrease fatigue among regular exercisers (Hoffman & Hoffman, 2008), these findings would support the idea that passive cycling may be useful for either preventing tiredness from increasing or perhaps even as a way for decreasing feelings of tiredness and fatigue (Lindheimer, O'Connor & Dishman, 2015; Rougeau, 2015).

The only significant finding for State Anxiety was that it was significantly lower throughout the Rest condition compared to either the Passive (M_{diff}= 1.71) or Placebo (M_{diff}= 1.60) conditions. While SA levels were not considered high at the onset of each study day (i.e., ~13.7-15.5 on a 10-40 scale), this difference during the Rest condition is notable. The participants were aware that on Rest days, no movement was going to take place and that the motor was not connected to a power source. The Passive and Placebo conditions were randomized and counterbalanced, but the participants knew that on Days 2 and 3, their feet were attached to the pedals and there was the potential for their legs to be moving. This may have led to somewhat higher anxiety levels on these two days relative to the Rest day. In addition, some participants were audibly upset when they deduced that their legs were in fact not going to be moving during the Passive condition. Although the expectations participants had at the onset of the study were not assessed, being aware that Day 1 was a quiet rest day may have eased any potential anxiety that may have occurred on Days 2 and 3 from being unaware of which condition was going to take place.

Acute bouts of active exercise have been routinely shown to reduce State Anxiety (SA) in able-bodied exercisers post-exercise (Ensari et al., 2015; Petruzzello et al., 1991). At this point, very little, if any, work has examined such responses in individuals with SCI. However, such acute bouts of exercise have been shown to sometimes initially increase anxiety during and immediately following exercise prior to seeing the decrease, depending on the intensity of the exercise (Ekkekakis & Petruzzello, 1999). State Anxiety then decreases within 10-minutes post-exercise with a continued decrease below baseline for at least up to an hour post-exercise (Ekkekakis & Petruzzello, 1999; Ensari et al., 2015). This “typical” decrease post-exercise was seen in Rougeau (2015), with Active cycling resulting in a decrease in SA from Pre-0 to Post-10 (M_{diff}= -1.53) and Post-0 to Post-10 (M_{diff}= -1.53; no change Pre0 to Post-0). Passive, motor driven, cycling also resulted in a decrease in SA from Pre-0 to Post-10 (M_{diff}= -1.70) and Post-0 to Post-10 (M_{diff}= -1.53; Rougeau, 2015). However, these changes in SA were not seen in the current study.

It is possible that there was also a floor effect for SA, with relatively low levels of SA at the beginning of each condition. It is not likely that expectancies played any role in that there were no changes seen in SA, regardless of condition. Volitional control, volitional contraction, and self-efficacy are often cited as key components in the reduction of SA. Lacking such control or contractions, the lack of change in SA may be explained for that simple reason. While the distraction/time-out hypothesis (Raglin & Morgan, 1985) has been cited as a possible mechanism for SA reduction, the lack of change could have been due to all three conditions being equally distracting yet not substantively different enough to result in anxiety reduction. The active ingredient in reducing SA may be in the volition associated with creating movement and lacking that, no changes in SA were evident in the current study.

For affective valence, assessed using the Feeling Scale (FS), no significant patterns were present, although there is a tendency for FS responses to increase very slightly from Pre-10 to Post-10 in all three conditions. Participants felt generally pleasant from the beginning to the end of each trial, with no differences across conditions. Perhaps importantly, there were no adverse affective responses (i.e., participants felt no worse) in any of the conditions. There could be a ceiling effect for FS responses, but there was still approximately 1.5 positive units of change available over time in each condition. It is more likely the case that none of the conditions was sufficient to cause any noticeable change in affect over the course of time. In contrast to Tension, Tiredness, State Anxiety, and affective valence, there were significant differences in Energy, Calmness, and Felt Arousal based on ASIA classification.

For Energy, an activated-pleasant affective state, within ASIA-As there were only significant time main effects. This reflected a decrease in Energy over time, regardless of condition. This decrease in Energy may be due in part from participant boredom, lack of engagement, and/or the distraction or time-out from the normal routine. While asking for feedback every 3-minutes to keep participants engaged and awake, there was one instance in which a participant fell asleep briefly. Additionally, as was mentioned with respect to RPE, participants could not move voluntarily, nor did they have sensation below their injury level. However, many were able to determine if the motor was cycling for them based on other sensations occurring in the body.

ASIA-Bs had statistically more Energy following the Passive condition than ASIA-As or ASIA-CDs. The change in Energy in ASIA-Bs was unrelated to RPE as there was no ASIA interaction with RPE. Despite the fact that ASIA-Bs had no voluntary movement, they had maintained some sensation below their injury level. This change in Energy may be indicative of a sensation factor involved in feeling like participants were working during the Passive condition, or a more pleasant-activated state due to a novel, exciting experience.

The small sample size for ASIA-CDs (*n*=3) may have hindered observing significant changes in Energy as this small group showed a small increase in Energy from Pre-10 to Post-0 (M_{diff}= 1.33). However, even with a larger participant group, this change in Energy may not have been capture effects, as was the case in Rougeau (2015), with Active vs Passive cycling in able-bodied participants. Passive, motor driven cycling, in able-bodied participants failed to elicit a change in Energy from Pre-10 to Post-10 (Rougeau et al.)

For Calmness, the interaction with ASIA classifications approached significance. For ASIA-As, Calmness increased from Pre-10 to every other time point, but only in the Placebo condition. During the Passive condition, Calmness decreased, albeit not significantly and there was no change during Rest. For ASIA-Bs, there was greater overall Calmness during the Rest condition compared to Passive and Placebo conditions, with changes over time being similar across conditions. For ASIA-CDs, the Condition x Time interaction between Rest and Passive conditions needs to be viewed cautiously due to the small sample size in this group. Again using Rougeau (2015) as a reference, active cycling resulted in a decrease in Calmness from Pre-10 to Pre-0 and from Pre-0 to Post-0 in able-bodied participants, Passive cycling was shown to increase Calmness following the same intensity and time as the current study.

Finally, for FAS, only ASIA-As reported significantly increased arousal from Pre-10 through 11-minutes followed by decreased arousal from minute 11 through Post-10 in the Passive condition. This increase in arousal could have been due in part from the increased bodily sensations that were present and potentially unfamiliar to the participants. While the participants were blinded from viewing their legs and the motor system, they were able to ascertain whether their limbs were moving during each condition, without aid or priming from the researchers. The increase in arousal may have been due to unfamiliar bodily sensations, but then subsided at minute 11 once the participants were acclimated to the movement. This increased felt arousal is similar to the increase in RPE seen during the Passive condition, yet it is puzzling why the increased felt arousal only occurred in the ASIA As. Given that these individuals have an inability to generate movement and have no sensation, the fact that they reported increased arousal is difficult to explain.

Enjoyment

Immediately following the completion of each condition, participants completed the PACES as a measure of the enjoyment they were experiencing in regards to the session they just completed. It was hypothesized that participants would exhibit similar enjoyment for Passive and Placebo conditions, but both would result in significantly more enjoyment compared to Rest. The results indicated that the Passive condition was significantly more enjoyable than both the Rest and Placebo conditions and that there was no difference between Rest and Placebo conditions. These results are not surprising in that research shows that those who exercise regularly enjoy exercise. These participants regularly participate in, and enjoy, vigorous activity. It can be speculated that these individuals signed up for the study because they wanted to be active participants, and would enjoy exercise over other conditions. A PACES score of ~ 80 is similar to the findings of Rougeau (2015) wherein able-bodied participants reported a PACES score of ~84 to passive cycling. While enjoyment scores were similar for the passive condition of the present study and that of Rougeau (2015), it is important to note that PACES scores ranged from 30 to 100 (possible range of 18 to 126) and while participants found the Passive condition more enjoyable than Rest and Placebo, they did not find it as enjoyable as their able-bodied peers found Active cycling (*M*=92.5; Rougeau, 2015). It is also interesting to note that the range of PACES scores was tighter for both the Rest and Passive conditions (40 and 39, respectively) compared to the Placebo condition (range of 52).

Conclusion

Reflecting on the hypotheses set for this study, it was found that: 1) Passive leg movement elicited psychological changes that varied significantly with respect to perceptions of Energy, Calmness, and valenced (i.e., positive, negative) affect; 2) participants reported more enjoyment following Passive cycling compared to Rest and Placebo conditions; 3) Passive cycling had no significant effects on physiological factors such as HR or temperature; 4) Rating of Perceived Exertion was significantly higher during the Passive condition compared to both Rest and Placebo.

Addressing limitations from Rougeau (2015), this study's primary strength was the ability to have participants perform truly passive physical activity. Although total participant blinding was attempted, it was not possible to truly blind all participants from the stimulus due to other proprioception components that were being signaled within the body. The primary aim of this study was to identify whether passive cycling could be used as a placebo in exercise trials. However, the proprioception of movement throughout the study, particularly with complete SCI participants, defuses the placebo effect.

It is important to note that there was a zero percent dropout rate from the study. However, there were 3 participants who were disqualified from the study, one due to uncontrolled muscle spasticity during the Passive condition, and 2 with inadequate ROM necessary to complete the cycle conditions. None of the data collected for these participants were included in the analyses (i.e., they were not part of the final sample of 21). The researchers put safety as key factor in this study. There were no complaints of tissue break down or abrasions.

No participants experienced any adverse effects throughout the duration of the study. There were no complaints of increased muscle soreness, skin abrasions, pressure sores, or autonomic dysreflexic effects at any point during the study.

Limitations

While blinding was a strength of the study, it also turned into a limitation in that participants were able to discern which condition was occurring. Even those participants without sensation below their injury level were able to identify if the condition was Passive or Placebo. A primary limitation to this study relates to the sample. The current sample is rather narrow in terms of exercise experience in that the majority of the participants were elite athletes and/or regular exercisers. The modality used to complete the conditions was not one the participants were familiar with. However, many were familiar with the feeling after engaging in regular exercise. Additionally, it would have been preferable to add a higher intensity condition to the current study, but due to practical safety limitations, this did not seem possible.

Future Directions

Recommendations for future research include the examination of an active condition (arm ergometry), using non-exercisers, and collecting EEG or other imaging of the brain (e.g., near-infrared spectroscopy). Similar research with a less-fit, less familiar subject pool could prove useful in that they may not have any predetermined expectation or experience with exercise that may influence results. If using passive exercise as a kick-starter for active activities for sedentary individuals is a goal, then testing it in this population is a must. The collection of

EEG data would be ideal in that identifying key neural factors associated with passive exercise may give researchers deeper insight into the mind-body connection, especially comparing active (arm ergometry) to passive lower extremity exercise in those with SCIs.

Future work may also focus on a wider variety of exercise intensities, both above and below VT. This can be done with arm ergometry in SCI participants, or recumbent cycling in able-bodied participants. The addition of a third condition and counterbalancing among all three: 1) Active arm ergometry, 2) Passive cycling, 3) Placebo cycling conditions and adding in an orientation day to familiarize participants to equipment could lead to cleaner research with the ability to draw more inferences from the data.

Third, the addition of priming participants in the Passive and Placebo condition with/without observing leg movement may also be an avenue to explore. We demonstrated in the current study that there were not many significant differences in affective valence following the Passive and Placebo conditions. It would be important to determine what would happen if individuals were told that these conditions were shown to be beneficial in reducing negative affect and improving positive affect prior to having them engage in each of the conditions.

Perhaps one of the most basic and important questions to address is the determination of the affective response to exercise in individuals with SCI. such studies do not appear to have been done to date. While simple in research design, it would be worthwhile to have individuals with SCI perform arm exercise while in their wheelchair on a stationary roller and compare their affective and perceptual responses to either able-bodied counterparts and/or an inactive control condition.

REFERENCES

Alexander, C. J., & Sipski, M. C. (1990). Electrical stimulation bicycle ergometry with spinal cord injured patients: Potential medical and psychological benefits. *SCI Psychosocial Processes, 3*, 18-20.

American Spinal Injury Association (ASIA) (2015). Retrieved from http://www.asia-spinalinjury.org/

Anderson, R. J., & Brice, S. (2011). The mood-enhancing benefits of exercise: Memory biases augment the effect. *Psychology of Sport and Exercise, 12*(2), 79-82.

Bahrke, M., & Morgan, W. (1978). Anxiety reduction following exercise and meditation. *Cognitive Therapy & Research, 2*(4), 323-333.

Bell, H.J., Ramsaroop, D.M., & Duffin, J. (2003). The respiratory effects of two modes of passive exercises. *European Journal of Applied Physiology, 88,* 544-552.

Benjamin, F.B., & Peyser, L. (1964). Physiological effects of active and passive exercise. *Journal of Applied Physiology, 19,* 1212-1214.

Borg, G. A. V. (1998). *Borg's perceived exertion and pain scales*. Champaign, IL: Human Kinetics.

Borst, C., Wieling, W., vanBrederode, J. F. M., & deRijk, L. G., (1982). Mechanisms of initial heart rate response to postural change. *American Journal of Physiology, 243*(5), H676-H681.

Bradley, M.B. (1994). The effect of participating in a functional electrical stimulation exercise program on affect in people with spinal cord injuries. *Archives of Physical Medicine & Rehabilitation, 75*, 676-679.

Brainandspinalcord.org. (n.d.). Spinal Cord Injury Statistics. Retrieved from http://www.brainandspinalcord.org/spinal-cord-injury/statistics.htm

Brooling, J., Pyne, D., Fallon, K., & Fricker, P. (2008). Characterizing the perception of the placebo effect in sports medicine. *Clinical Journal of Sports Medicine, 18*, 432-437.

Burnham, R., Wheeler, G., Bhambani, Y., Eriksson, P., Belanger, M., & Steadward, R. (1994). Intentional induction of autonomic dysreflexia among quadriplegic athletes for performance enhancement: Efficacy, safety and mechanisms of action. *Clinical Journal of Sports Medicine, 4*, 1–10.

CDC, NCHS. Underlying Cause of Death 1999-2013 on CDC WONDER Online Database, released 2015. Data are from the Multiple Cause of Death Files, 1999-2013, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program. Accessed Feb. 3, 2016.

Clark, J.M., Jelbart, M., Rischbieth, H., Strayer, J., Chatterton, B., Schultz, C., & Marshall, R. (2007). Physiological effects of lower extremity functional electrical stimulation in early spinal cord injury: Lack of efficacy to prevent bone loss. *Spinal Cord, 45*, 78-85.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Lawrence Earlbaum.

De Meersman, R.E., Zion, A.S., Weir, J.P., Lieberman, J.S., & Downey, J.A. (1998). Mechanoreceptors and autonomic responses to movement in humans. *Clinical Autonomic Research, 8(4),* 201–205.

Desharnais, R., Jobin, J., Côté, C., Lévesque, L., & Godin, G. (1993). Aerobic exercise and the placebo effect: A control study. *Psychosomatic Medicine, 55,* 149-154.

Dishman, R.K. (1994). The measurement conundrum in exercise adherence research. *Medicine & Science in Sports & Exercise, 26*(11), 1382-1390.

Dishman, R.K. (1995). Physical activity and public health: Mental health. *Quest, 47,* 362-385.

Dixon, M. E., Stewart, P. B., Mills, F. C., Varvis, C. J., & Bates, D. V. (1961). Respiratory consequences of passive body movement. *Journal of Applied Physiology, 16,* 30-34.

Dolbow, D.R., Gorgey, A.S., Cifu, D.X., Moore, J.R., & Gater, D.R. (2012a). Feasibility of home-based functional electrical stimulation cycling: Case report. *Spinal Cord, 50*, 170-171.

Dolbow, D.R., Gorgey, A.S., Moore, J.R., & Gater, D.R. (2012b). Report of practicability of a 6-month homebased functional electrical stimulation cycling program in an individual with tetraplegia. *The Journal of Spinal Cord Medicine, 35*(3), 182-186.

Dolbow, D.R., Gorgey, A.S., Ketchum, J.M., & Gater, D.R. (2013). Home-based functional electrical stimulation cycling enhances quality of life in individuals with spinal cord injury. *Topics in Spinal Cord Injury Rehabilitation, 19*(3), 324-329.

Durstine, J.L., Moore, G.E., Painter, P.L., & Roberts, S.O., Eds. (2008). *ACSM's exercise management for persons with chronic diseases and disabilities* (3rd ed). Champaign, IL: Human Kinetics.

Ekkekakis, P., Hall, E.E., & Petruzzello, S.J. (2004). Practical markers of the transition from aerobic to anaerobic metabolism during exercise: Rationale and a case for affect-based exercise prescription. *Preventive Medicine, 38*, 149-159.

Ekkekakis, P., Hall, E.E., & Petruzzello, S.J. (2005). Some like it vigorous: Measuring individual differences in preference for and tolerance of exercise intensity. *Journal of Sport & Exercise Psychology, 27*, 350-374.

Ekkekakis, P., & Petruzzello, S.J. (1999). Acute aerobic exercise and affect. *Sports Medicine, 28*(5), 337-374.

Ensari, I., Greenlee, T.A., Motl, R.W., & Petruzzello, S.J. (2015). Meta-analysis of acute exercise effects on state anxiety: An update of randomized controlled trials over the past 25 years. *Depression & Anxiety*, *32*(8), 624-634.

Ernst, E., (2007). Placebo: New insights into an old enigma. *Drug Discovery Today, 12(9-10)*, 413-418.

Forman-Hoffman, V.L., Ault, K.L., Anderson, W.L., Weiner, J.M., Stevens, A., Campbell, V.A., & Armour, B.S. (2015). Disability status, mortality, and leading causes of death in the United States community population. *Medical Care, 53*(4), 346-354.

Gauvin, L., Rejeski, W.J., & Norris, J.L. (1996). A naturalistic study of the impact of acute physical activity on feeling states and affect in women. *Health Psychology*, *15*(5), 391-397.

Hill, A.B. (1963). Medical ethics and controlled trials. *British Medical Journal*, *1*(5337), 1043.

Hall, E.E., Ekkekakis, P., & Petruzzello, S.J. (2002). The affective beneficence of vigorous exercise revisited. *British Journal of Health Psychology, 7*, 47-66.

Hardy, C.J., & Rejeski, W.J. (1989). Not what, but how one feels: The measurement of affect during exercise. *Journal of Sport & Exercise Psychology, 11*(3), 304-317.

Health & PA History Form (2010). Department of Kinesiology & Community Health, University of Illinois at Urbana-Champaign.

Hoffman, M.D., & Hoffman, D.H. (2008). Exercisers achieve greater acute exercise-induced mood enhancement than nonexercisers. *Archives of Physical Medicine & Rehabilitation, 89*, 358-363.

Hooker, S.P., Figoni, S.F., Glaser, R.M., Rodgers, M.M., Ezenwa, B.N., & Faghri, P.D. (1990). Physiologic response to prolonged electrically stimulated leg-cycle exercise in the spinal cord injured. *Archives of Physical Medicine and Rehabilitation, 71,* 863-869.

Hu, F.B., Leitzmann, M.F., Stampfer, M.J., Colditz, G.A., Willett, W.C., & Rimm, E.B. (2001). Physical activity and television watching in relation to risk for type 2 diabetes mellitus in men. *Archives of Internal Medicine, 161(12)*, 1542-1548.

Hu, F.B., Li, T.Y., Colditz, G.A., Willett, W.C., & Manson J.E. (2003). Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women. *JAMA, 289*, 1785–1791.

Jacobs, P.L., & Nash, M.S. (2004). Exercise recommendations for individuals with spinal cord injury. *Sports Medicine, 34*(11), 727-751.

Jones, A.Y., Kam, C., Lai, K.W., Lee, H.Y., Chow, H.T., Lau, S.F., Wong, L.M., & He, J. (2003). Changes in heart rate and R-wave amplitude with posture. *Chinese Journal of Physiology, 46*(2), 63-69.

Julious, S.A. (2005). Sample size of 12 per group rule of thumb for a pilot study. *Pharmaceutical Statistics, 4*, 287-291.

Karlsson, A.K. (1999). Autonomic dysreflexia. *Spinal Cord, 37(6),* 383-392.

Kendzierski, D., & DeCarlo, K.J. (1991). Physical activity enjoyment scale: Two validation studies. *Journal of Sport & Exercise Psychology, 13(1)*, 50-64.

Lindheimer, J.B., O'Connor, P.J., & Dishman, R.K. (2015). Quantifying the placebo effect in psychological outcomes of exercise training: A meta-analysis of randomized trials. *Sports Medicine, 45*, 693-711.

Mahoney, E.T., Bickel, C.S., Elder, C., Black, C., Slade, J.M., Apple, D. Jr., & Dudley, G.A. (2005). Changes in skeletal muscle size and glucose tolerance with electrically stimulated resistance training in subjects with chronic spinal cord injury. *Archives of Physical Medicine & Rehabilitation, 86(7),* 1502-1504.

Marcora, S. (2009). Perception of effort during exercise is independent of afferent feedback from skeletal muscles, heart, and lungs. *Journal of Applied Physiology, 106*, 2060-2062.

Martin Ginis, K.A., Jetha, A., Mack, D.E., & Hetz, S. (2010). Physical activity and subjective well-being among people with spinal cord injury: A meta-analysis. *Spinal Cord, 48*, 65-72.

Martin Ginis, K.A., Jörgensen, S., & Stapleton, J. (2012). Exercise and sport for persons with spinal cord injury. *Physical Medicine & Rehabilitation, 4*, 894-900.

McKinley, W.O., Jackson, A.B. Cardenas, D.D., & DeVivi, M.J. (1999). Long-term medical complications after traumatic spinal cord injury: A regional model system analysis. *Archives of Physical Medical Rehabilitation, 80*, 1402-1410.

Miles-Chan, J.L., Sarafian, D., Montani, J.P., Schutz, Y., & Dulloo, A.G. (2014). Sitting comfortably versus lying down: Is there really a difference in energy expenditure? *Clinical Nutrition, 33*(1), 175-178.

Myers, J., Lee, M., Kiratli, J. (2007). Cardiovascular disease in spinal cord injury. *American Journal of Physical Medicine & Rehabilitation, 86*(2), 142-152.

Ojanen, M. (1994). Can the true effects of exercise on psychological variables be separated from placebo effects? *International Journal Sport Psychology, 25*, 63-80.

Peterman, J.E., Kram, R., & Byrnes, W.C. (2012). Factors affecting the increased energy expenditure during passive cycling. *European Journal of Applied Physiology, 122*, 3341-3348.

Peterman, J.E., Wright, Jr., K.P., Melanson, E.L., Kram, R., & Byrnes, W.C. (2016). Motor-driven (passive) cycling: A potential physical inactivity countermeasure? *Medicine & Science in Sports & Exercise, 48*(9), 1821-1828. doi:10.1249/MSS. 0000000000000947

Petrofsky, J.S., Stacy, R., & Laymon, M. (2000). The relationship between exercise work intervals and duration of exercise on lower extremity training induced by electrical stimulation in humans with spinal cord injuries. *European Journal of Applied Physiology, 82(5),* 504–509.

Petruzzello S.J., Landers D.M., Hatfield, B.D., Kubitz, K.A. & Salazar, W. (1991). A meta-analysis on the anxiety-reducing effects of acute and chronic exercise: Outcomes and mechanisms. *Sports Medicine, 11*, 143- 182.

Putnam, M., Geenen, S., Powers, L., Saxton, M., Finney, S., & Dautel, P. (2003). Health and wellness: People with disabilities discuss barriers and facilitators to well being. *Journal of Rehabilitation, 69(1)*, 37-45.

Raglin, J.S., & Morgan, W.P. (1985). Influence of vigorous exercise on mood state. *The Behavior Therapist, 8(9)*, 179-183.

Reger, M., Peterman, J.E., Kram, R., & Byrnes, W.C. (2009). Exercise efficiency of low power output cycling. *Scandinavian Journal of Medicine & Science in Sports, 23*, 713-721.

Rougeau, K.M. (2015). *Passive versus active exercise: An examination of affective change*. IDEALS, http://hdl.handle.net/2142/88226

Salmon, P. (2000). Effects of physical exercise on anxiety, depression, and sensitivity to stress: A unifying theory. *Clinical Psychology Review, 21(1),* 33-61.

Scelza, W.M., Kalpakjian, C.Z., Zemper, E.D., & Tate, D.G. (2005). Perceived barriers to exercise in people with spinal cord injury. *American Journal of Physical Medicine & Rehabilitation, 84*(8), 576-583.

Schulz, K.F., & Grimes, D.A. (2002). Blinding in randomized trials: Hiding who got what. *The Lancet*, *359*(9307), 696-700.

Scremin, A.M., E., Kurta, L., Gentili, A., Wiseman, B., Perell, K., Kunkel, C., & Scremin, O.U. (1999). Increasing muscle mass in spinal cord injured persons with a functional electrical stimulation exercise program. *Archives Physical Medicine Rehabilitation, 80*, 1531-1536.

Sipski, M.L., Delisa, J.A., & Schweer, S. (1989). Functional electrical stimulation bicycle ergometry: Patient perceptions. *American Journal of Physical Medicine & Rehabilitation, 68,* 147-149.

Spielberger, C.D. (1983). *Manual for the State-Trait Anxiety Inventory STAI* (form Y). Palo Alto, CA: Consulting Psychologists Press.

Svebak, S., & Murgatroyd, S. (1985). Metamotivational dominance: A multimethod validation of reversal theory constructs. *Journal of Personality & Social Psychology, 48*, 107–116.

Thayer, R.E. (1986). Activation-deactivation adjective check list: Current overview and structural analysis. *Psychological Reports, 58*, 607–614.

Thomas, S., Reading, J., & Shephard, R.J. (1992). Revision of the Physical Activity Readiness Questionnaire (PAR-Q). *Canadian Journal of Sport Sciences, 17*, 338-345.

Thompson, W.R., Gordon, N.F., & Pescatello, L.S., Eds. (2010). *ACSM's guidelines for exercise testing and prescription (8th ed.)*, Philadelphia, PA: Lippincott Williams & Wilkins.

Twist, D.J., Culpepper-Morgan, J.A., Ragnarrson, K.J., Petrillo, C.R., & Kreek, M.J. (1992). Neuroendocrine changes during functional electrical stimulation. *American Journal of Physical Medicine and Rehabilitation, 71*(3), 156-163.

Vissers, M., van den Berg-Emons, R., Sluis, T., Bergen, M., Stam, H., & Bussmann, H. (2008). Barriers to and facilitators of everyday physical activity in persons with a spinal cord injury after discharge from the rehabilitation centre. *Journal of Rehabilitation Medicine, 40*, 461-467.

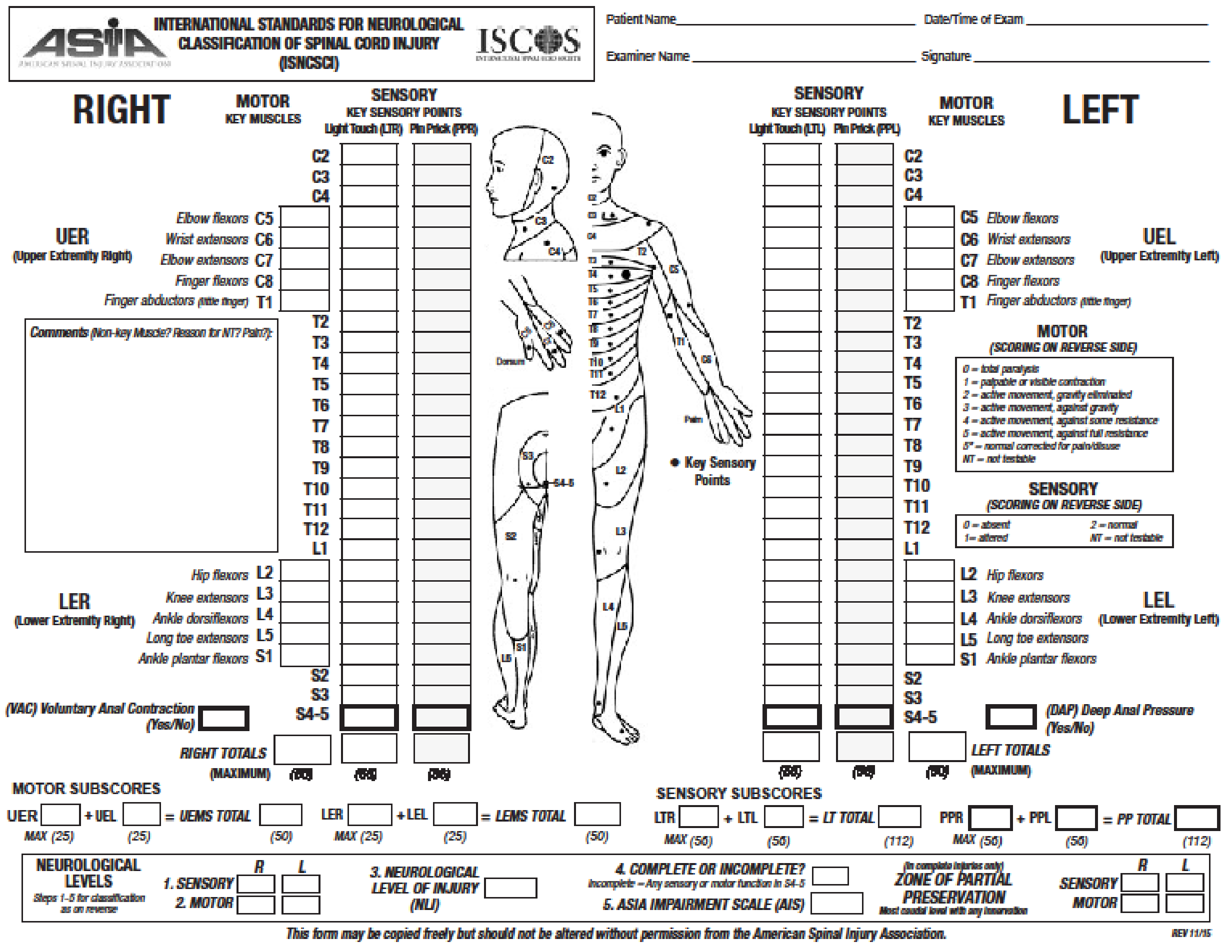
Washburn, R.A., Zhu, W., McAuley, E., Frogley, M., & Figoni, S.F. (2002). The physical activity scale for individuals with physical disabilities: Development and evaluation. *Archives of Physical Medicine & Rehabilitation*, *83*(2), 193-200.

Webborn, A.D.J. (1999). "Boosting" performance in disability sport. *British Journal of Sports Medicine, 33(2),* 74-75.

Williams, D.M., Dunsinger, S., Ciccolo, J.T., Lewis, B.A., Albrecht, A.E., & Marcus, B.H. (2008). Acute affective response to a moderate-intensity exercise stimulus predicts physical activity 6 and 12 months later. *Psychology of Sport & Exercise, 9*, 231-245.

APPENDIX A

ADDITIONAL FIGURES AND TABLES



A = Complete. No sensory or motor function is preserved in the sacral segments S4-5.
B = Sensory Incomplete. Sensory but not motor function is preserved below the neurological level and includes the sacral segments S4-5 (light touch or pin prick at S4-5 or deep anal pressure) AND no motor function is preserved more than three levels below the motor level on either side of the body.
C = Motor Incomplete. Motor function is preserved at the most caudal sacral segments for voluntary anal contraction (VAC) OR the patient meets the criteria for sensory incomplete status (sensory function preserved at the most caudal sacral segments (S4-S5) by LT, PP or DAP), and has some sparing of motor function more than three levels below the ipsilateral motor level on either side of the body.
(This includes key or non-key muscle functions to determine motor incomplete status.) For AIS C – less than half of key muscle functions below the single NLI have a muscle grade ≥ 3.
D = Motor Incomplete. Motor incomplete status as defined above, with at least half (half or more) of key muscle functions below the single NLI having a muscle grade ≥ 3.
E = Normal. If sensation and motor function as tested with the ISNCSCI are graded as normal in all segments, and the patient had prior deficits, then the AIS grade is E. Someone without an initial SCI does not receive an AIS grade.
Using ND: To document the sensory, motor and NLI levels, the ASIA Impairment Scale grade, and/or the zone of partial preservation (ZPP) when they are unable to be determined based on the examination results.

Figure A.1. American Spinal Injury Association (ASIA) international standards for neurological classification of spinal cord injury (reproduced from the American Spinal Injury Association 2015).

Table A1

Physical Characteristics of Traumatic SCI Participants

Participant	Age (yrs)	Weight (kg)	Height (cm)	LOI	ASIA[a]	TSI
2	19	45.45	157.48	T10-11	A	14
3	19	50.00	165.10	T10	C	7
4	22	74.09	172.72	L2-3	B	16
6	39	72.73	185.42	T5-6	A	13
7	41	70.45	180.34	T9	A	22
8	26	90.91	176.64	T6-9	A	15
9	23	60.91	165.10	T11	B	14
10	32	94.55	180.34	L3-5	B	23
11	36	79.55	193.04	T12	A	14
12	20	54.55	172.72	T8-9	A	9
15	25	59.09	180.34	T8-9	A	7
16	23	51.36	162.56	L1-3	A	17
17	30	41.82	149.86	T9-L2	A	26
18	23	68.18	167.64	T6-10	C	9
20	27	48.64	162.56	T10	B	27
21	31	72.73	185.52	T11	B	18
23	24	56.82	175.26	T9	B	24
24	36	54.55	157.48	T10	B	30

Note: ASIA = American Spinal Injury Association Impairment Scale; LOI = level of injury; M = male; TSI = time since injury.
[a]ASIA-A = no motor or sensation below injury; ASIA-B = no motor but some sensation below the level of injury; ASIA-CD = some motor and some sensation below the level of injury.

Table A2

Physical Characteristics of Non-Traumatic SCI Participants

Participant	Age (yrs)	Height (cm)	Weight (kg)	LOI	$ASIA_a$	Acquired (A) or Congenital (C)	Sex
1	27	134.62	37.27	T4	C	C	F
5	22	152.40	54.55	T12-L1/2	B	C	M
13	24	142.24	56.82	T11-12	B	C	F

Note: ASIA = American Spinal Injury Association Impairment Scale; LOI = level of injury; M = male; TSI = time since injury.
[a]ASIA-A = no motor or sensation below injury; ASIA-B = no motor but some sensation below the level of injury; ASIA-CD = some motor and some sensation below the level of injury.