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Effects of upper body HIIT training on recreationally trained wheelchair athletes

Tayler Elizondo
Eastern Washington University

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Tayler Elizondo

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THESIS OF TAYLER T. ELIZONDO APPROVED BY

____ DATE ______

Wendy Repovich, Ph.D., FACSM, Graduate Study Committee

____ DATE________

Nathan Lawton, MS, CSCS, Graduate Study Committee

____ DATE________

Carmen A. Nezat, Ph.D., Graduate Council Representative

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Chapter 1

Introduction

Since the introduction of the Paralympic games there has been an increase in sport participation from those with physical disabilities (International Paralympic Committee, 2012; Keog, 2010; Serefhan, 2002). Athletes with disabilities have shown improvement in both physiological and performance outcomes when undergoing physical training (Bednarczuk, 2007; Ozmen, Yuktasir, Yildirim,Yalcin & Willems, 2013; Yanci et al., 2015). The increase in the number of athletes with disabilities has provided a need for insight into different training parameters and their effects on athletes with disabilities (Klenck & Gebke, 2007). Training protocols that have been primarily used on the able-bodied population likely have positive performance effects on athletes with disabilities as well (Bednarczuk, 2007; Ozmen, et al., 2013; Yanci et al., 2015).

Cardiorespiratory fitness is a component of physical activity that contributes to positive health and performance outcomes. The amount of cardiorespiratory fitness an individual engages in has been associated with lifespan and health benefits (Haskell et al., 2007), as well as positive performance outcomes in sports with an aerobic component (Hawley & Stepto, 2001; Nelson et al., 2007). An individual's aerobic capacity is a contributing factor in all endurance activities. Aerobic capacity varies greatly depending on the demands of the activity one is engaging in and the muscle groups recruited. A person's aerobic capacity during exercise is limited by the amount and size of the muscles that are engaged throughout the activity (Daniels, 2001; McKenzie, 2012). Various methods of aerobic training have been used among populations limited in mobility, such as wheelchair ergometers being utilized for aerobic fitness training among manual wheelchair users (Keyser, Rasch, Finley & Rodgers, 2003). Increasing cardiorespiratory fitness has been shown to lead to positive performance outcomes among sports that have an aerobic component (Hawley & Stepto, 2001). It can be assumed that increasing an athlete's cardiorespiratory fitness will be beneficial for performance outcomes in sports that have an aerobic component.

Engagement in regular aerobic activity is disrupted by many barriers, but one of the most commonly reported is time constraints (Gillen, 2012).This can be seen as true among active populations that are limited in the volume of activity that they engage in throughout the week due to life demands. Parameters of aerobic exercise that require less time than traditional aerobic training have been examined (Bayati, Farzad, Gharakhanlou & Agha-Alinejad, 2011; Gibala, 2007; Gillen, 2009). The results of the alternative methods of aerobic exercise, when compared to traditional aerobic training, have yielded similar physiological adaptations and health benefits (Bayati, Farzad, Gharakhanlou & Agha-Alinejad, 2011; Gibala, 2007; Gillen, 2009). These parameters involve high intensity low volume intervals of exercise followed by moderate to low intensity intervals for recovery. This method is known as high intensity interval training (HIIT) (Gillen, 2012). HIIT is viewed as an effective alternative to traditional aerobic training (Gibala, 2007; Zuhl & Kravitz, 2012).

Subjects with limited lower extremity mobility have demonstrated the benefits of using arm crank ergometers as a method of aerobic training (Dolbow et al., 2010). Using both arm crank ergometers or wheelchair ergometers, resulted in beneficial physiological adaptations and improvement in cardiorespiratory fitness (Dolbow et al., 2010; Keyser et al., 2003). Upper body aerobic training is a practical solution for populations limited in mobility. HIIT has been shown to be an alternate method of cardiorespiratory training that is effective within populations with full mobility (Bayati, Farzad, Gharakhanlou & Agha-Alinejad, 2011; Gibala, 2007; Gillen, 2012). However, current research has not looked at the effectiveness of HIIT on a population that is limited in mobility.

Statement of the Problem

Physiological adaptations can occur when upper body aerobic fitness training is implemented among special populations. However, there is little evidence supporting using alternative aerobic training methods among these populations. It is also not known whether upper body HIIT will show the same physiological adaptations when compared to HIIT in lower extremity aerobic exercise. Therefore, the purpose of this study was to observe the effects of upper body HIIT in a sample of recreational wheelchair athletes.

Null Hypothesis

There would be no significant aerobic adaptations observed after an upper body HIIT intervention on recreationally trained wheelchair athletes, tested at an alpha level of $p \leq .05$.

Delimitations

The participants of the study were delimited to 11 members (7 males & 4 females) of ParaSport Spokane's athletes. Participants ranged in age from 12 to 26 years. The HIIT sessions were held twice a week for eight weeks using a Monarch 881E arm ergometer (Vasbro, Sweden). Participants had at least one day of recovery in between each session.

Limitations

A limitation of the study was the varying fitness levels between participants. This may have caused variations of how the HIIT intervention affected overall adaptations. Another limitation was the potential varying lifestyle and nutritional habits. Due to the broad age range, lifestyle differences may have influenced the effect of the HIIT intervention between participants, differences such as, alcohol consumption, sleep habits, or smoking.

Due to transportation issues and access to facilities, not all participants were able to do HIIT sessions in the same location and some of the equipment varied between participants. The table the ergometer was placed on varied at different locations. This likely led to energy transfer differences during training, due to differences in table stability and surface friction.

Assumptions

All participants refrained from aerobic training aside from the HIIT sessions and the aerobic output required in their basketball practice sessions. Participants understood the RPE scale and reported RPE honestly and to the best of their ability.

Operational definitions

Exercise duration - The amount of time an athlete performed continuous sub-maximal exercise during VO_2 assessment on the Monark 891E upper body ergometer (Vasbro, Sweden).

Resting heart rate - The heart rate after three minutes of resting in a seated position, prior to submaximal testing taken with a Polar heart rate monitor (Polar Inc., Lake Success, NY).

VO_2 - The amount of oxygen consumed at the point of volitional withdraw from exercise testing measured with the Jaeger ™ OxyconPro metabolic cart (CareFusion, Yorba Linda, CA).

Rating of Perceived Exertion (RPE) - The RPE scale is a psychophysiological scale that measures the degree of effort during an activity. The Borg CR10 scale was used during the intervention (Borg, 1998).

Forward Sprint Time - The time it takes participants to push 20 meters while in their sport chairs. Time will be measured using a Brower Test Center Timing System (Draper, Utah).

Backward Sprint Time - The time it takes participants to push 20 meters backward in a sport chair. Time will be measured using a Brower Test Center Timing System (Draper, Utah).

Significance of the Study

With the rise in sport participation among those with physical disabilities, it is important that methods of training and their effectiveness are explored. The ability to implement effective training protocols to produce positive performance outcomes is usually a desire of any coach or trainer. Implementing alternative training equipment and methods will help coaches add variety to training programs among athletes with disabilities.

Summary

Cardiorespiratory fitness training has been shown to result in positive performance outcomes in sports with a cardiorespiratory component. Alternative methods of cardiorespiratory fitness training, such as HIIT, have been observed to be an effective way to improve cardiorespiratory fitness. Although the effectiveness of HIIT has been observed among varying populations, it has not been used as a training method for athletes with physical disabilities that participate in wheelchair sport. The purpose of this study is to observe the effects of an eight-week HIIT protocol on recreationally trained wheelchair athletes. This chapter presented, a declared hypothesis, delimitations, limitations, operational definitions, and stated assumptions.

Chapter 2

Review of Literature

Introduction

The purpose of this study was to observe the effects of an eight-week upper body HIIT training program in a sample of recreational wheelchair athletes. The current review presents the physiological aspects of aerobic training, and the reason and purpose for alternative forms of cardiorespiratory fitness training. The basic principles of HIIT training are reviewed, along with the physiological effects and outcomes. Methods of upper body aerobic fitness training and their outcome are also discussed. Current considerations, outcomes, and goals of adaptive fitness training are presented, along with the need for alternative methods of adaptive aerobic training.

Adaptations to aerobic exercise

The demands of exercise can be met by either the aerobic or anaerobic systems in the body (Katch, McArdle & Katch, 2011). Different adaptations will be observed depending on the metabolic system utilized. Adaptations such as lowered resting heart rate (RHR), improved aerobic capacity, muscle fiber remodeling, and changes in body composition are typical adaptations to exercise that utilizes the aerobic system (Coffey & Hawley, 2007; Katch et al., 2011). No structural adaptations of the lungs have been observed, but the lungs have been shown to improve in functional capacity as a result of aerobic training (McKenzie, 2012).

The ability to perform large muscle group exercise at a moderate to high intensity is how cardiorespiratory fitness is defined (Haskell et al., 2007; Katch et al., 2011;

Nelson et al., 2007). Low levels of cardio respiratory fitness have been associated with cardiovascular disease and early morbidity; however, the opposite is also true, increased fitness is associated with decreased disease. (Nelson et al., 2007). It has also been well documented that moderately fit individuals respond to cardiovascular exercise, and show improvement in fitness and competitive performance outcomes (Daniels, 2001; Hawley & Stepto, 2001; McKenzie, 2012).

The structural changes observed in the heart include an overall increase in heart mass, due to enlargement of the left ventricular wall. A left atrial dimension increase also has been observed along with left ventricle cavity size. The functional improvements of the heart include increased cardiac contractility, increased stroke volume, increased cardiac output, increased diastolic function, and a decrease in peripheral resistance (McKenzie, 2012). The functional and structural changes of the heart observed as a result of aerobic training play a role in the overall efficiency of transporting blood to the muscles. Red blood cells numbers will increase, therefore increasing oxygen carrying capacity to the muscles (McKenzie, 2012). The heart and blood develop structural and functional adaptations that have been observed to contribute to improved performance outcomes (McKenzie, 2012).

Maximal oxygen uptake (VO_{2max} or VO_{2peak}) is considered an accepted measurement of cardiorespiratory fitness and a determinant of aerobic performance (Carter, Rennie, Hamilton, Tarnopolsky, 2001; McKenzie, 2012). It has been shown that when an endurance training protocol is implemented among untrained individuals there are significant improvements in VO_{2max} (Carter et al., 2001). Improvement in VO_{2max} is also associated with an increase in exercise duration performed at submaximal levels

(Holloszy & Coyle, 1984). However, it should be noted that even though adaptations in heart and lung function that contribute to VO_{2max} vary between individuals, they will reach a "plateau." Although elite level athletes typically will reach this plateau, a peripheral improvement is still observed as a result of aerobic training, which will then improve performance during aerobic exercise (Coffey & Hawley, 2007; Warpeha, 2003). These peripheral adaptations include increased capillary density, increased mitochondria density within muscle fibers, muscle fiber adaptations, and phenotypic gene responses as a result of aerobic training (Coffey & Hawley, 2007; Warpeha, 2003). When looking at performance outcomes, the central adaptations observed, compliment the peripheral adaptations and vice versa.

One of the peripheral responses is how muscle fibers accommodate and change function in order to meet the demands of aerobic training. Type IIa muscle fiber adaptation has been shown to be a result of increased mitochondrial biogenesis, which can ultimately be viewed as a response to increased aerobic demands on the muscle fibers, due to the role mitochondria have in oxygen carrying capacity within the cell (Coffey & Hawley, 2007; Scott, Stevens, & Binder-Macleod, 2001). Highly trained endurance athletes have also been shown to have increased glycogen stores, as a result of an increase in Type IIa muscle fibers performing aerobic glycolysis to accommodate for the increased aerobic demands (Hawley & Stepto, 2001).

When endurance training begins it relies primarily on Type I muscle cells (Coffey & Hawley, 2007; Katch et al., 2011). The main subcellular organelle that is utilized during Type I cell activity is the mitochondria. Endurance training has been associated with increased mitochondrial biogenesis. Mitochondrial biogenesis is controlled by a coordinated expression of a large number of genes. These genes are regulated by mitochondrial protein fusion and fission. The peroxisome proliferator activated receptors (PPAR) family has been shown to regulate lipid utilization via genes involved in the expression of mitochondrial fatty acid utilization. Peroxisome proliferator receptor-γ co-activator- 1α (PGC-1α) is a co-activator involved in the transcription of several genes in the PPAR family. Therefore, PGC-1α is an important mitochondrial regulator in skeletal muscle. There is a significant increase in PGC-1α in response to endurance training (Coffey & Hawley, 2007). Increased mitochondrial biogenesis enhances fat utilization in these Type I fibers during prolonged endurance exercise.

Although improvements observed as a result of aerobic training vary, depending on fitness levels and genetics. It can be noted that improvements in performance and oxygen transport efficiency have been observed across most populations when engaging in aerobic training. Alternative methods of aerobic training have been developed for those not able to perform lower extremity exercise and also for those not able to meet the time demands needed for recommended aerobic fitness.

The adaptations to upper body aerobic training (UBT) that have been observed in previous literature coincide with what you would expect with lower body aerobic training. Observed cardiac and pulmonary adaptations have been the result of UBT (Price, Davidoff & Balady, 2000). It is important to note that when compared to lower body aerobic training, VO_{2peak} increases are not as great. This is due to a smaller muscle mass being utilized, therefore a smaller training effect. An individual's functional ability and the amount of muscle mass that is able to be recruited will also alter responses to UBT (Price et al., 2000; Smith et al., 2006; Schrieks, Barnes & Hodges, 2011; Vinet et al., 1997). Even though adaptations to UBT are varied among populations that have differing functional mobility, it is still considered an effective way to train aerobically especially for those who participate in an upper body sport such as rowing, kayaking, or wheelchair sports.

UBT has been utilized within populations where lower extremity mobility is limited, such as individuals with spinal cord injuries (SCI). Much of the previous literature discusses a need for UBT from a clinical perspective. This is because individuals with SCI, and others with physical disability, have a greater risk for developing cardiovascular disease, obesity, diabetes, and osteoporosis due to the lack of mobility (Dolbow et al., 2010; Keyser et al., 2003). However, the effects of UBT have also been examined using athletes with physical disabilities as well as able bodied athletes and shown to be an effective method of training.

Aerobic measurements of the upper body have been examined for those who participate in upper body sports such as canoeing, rowing, and wheelchair racing (Price & Campbell, 1997). Determination of VO_{2peak} has been found to show consistencies in upper body protocols when utilized in healthy active able-bodied subjects (Price & Campbell, 1997). Evaluating VO_{2peak} using an arm crank ergometer (ACE) protocol can help assess the fitness level of an individual, or even determine the effectiveness of an upper body training protocol over time.

It has been recommended that upper body protocols for the determination of VO_{2peak} be performed at crank rates between 50-70 RPMs using an incremental loading protocol. The higher crank rates are used in order to overcome localized fatigue in the upper body. (Price & Campbell, 1997; Van Loan, McCluer, Loftin, Boileau, 1988).

Previous research looking at optimal crank rates for upper body oxygen consumption testing, found that lower RPMs during incremental exercise caused a greater VO_2 slow component. This increase in VO_2 leads to greater values of VO_{2peak}. It was postulated that there seemed to be less mechanical efficiency at the lower RPMs and higher central and localized RPE scores were observed throughout the test at lower RPMs. This was thought to be because of the reduced mechanical efficiency of the arm crank motion (Smith, McCrindle, Doherty, Price & Jones, 2006) though it may not have an effect on VO_{2peak} if upper body trained subjects performed the arm crank protocol.

There have also been differences observed in oxygen consumption among those with varying physical function. Previous literature shows that those with SCI, when compared to able bodied subjects, had lower oxygen consumption during exercise testing, decreased work rates, and lower pulmonary function. This has been speculated to be a result of differences in total muscle mass function and impaired sympathetic innervation (Van Loan et al., 1988). Although the literature is contradictive in the most effective way to measure VO_{2peak} using ACE, it also shows variances depending on functional mobility. ACE has been shown to be a valid and reliable tool to measure upper body aerobic capacity.

Training athletes with disabilities results in improved aerobic and anaerobic power, improved motor skills, and performance outcomes (Bednarczuk, 2007; Ozmen et al., 2014; Yanci et al., 2015). Athletes with disabilities have been observed to have positive performance outcomes when annual plans are developed with performance goals in mind, and traditional training loads and tapering are carried out throughout the annual plan (Bednarczuk, 2007). Although athletes with disabilities will improve as a result of a training stimulus, it is important to note that various disabilities will respond to training stimulus more or less drastically when compared to each other. These outcomes, whether they are aerobic or anaerobic, usually have lower performance outcomes than able bodied athletes and can even be dependent on the nature of the disability (Molik et al., 2006; Montesano et al., 2013; Price et al., 2000; Van Loan et al., 1987).

Although improvements may not be as drastic and can potentially be limited due to the disability, methods of aerobic and anaerobic exercise have shown overall improvements among teams with various disabilities. Attempts to develop physical profiles of wheelchair basketball athletes have been made. The previous literature discusses the key physical characteristics of wheelchair basketball. These characteristics included, sprint, agility, and endurance (Yanci et al., 2015). Research found that an upper extremity explosive strength training program was effective in improving scores in speed and agility among a wheelchair basketball team with various disabilities (Ozmen et al., 2014). The previous literature shows that physical characteristics of wheelchair sport athletes can be determined and that specific training protocols can be utilized among wheelchair athletes to improve specific physical characteristics and performance outcomes.

While the importance of exercise for individuals with lower extremity disability has been expressed, there has also been concern for exercise options among that population. It has been suggested that certain exercise methods may influence motivation and willingness to adhere to an exercise program (Mukherjee, Bohmik, Samanta, 2001). This suggests that the effects of alternative methods of training need to be attempted within populations limited in mobility. This will help develop different methods that will produce similar cardiorespiratory performance outcomes while adding variety to training plans.

HIIT Training

Traditional methods of improving aerobic capacity require an individual to perform high volume continuous moderate intensity endurance exercise (CET), while HIIT training decreases the volume of exercise and increases the intensity (Gibala, 2007; Tschakert & Hofmann, 2013; Zuhl &Kravitz, 2012). In other words, traditional training for aerobic capacity will involve moderate intensity exercise (between 40 and 60% VO_2Reserve) in combination with vigorous intensity exercise (at least 60% VO_2Reserve), for a continuous duration of at least ten minutes or more (Thompson et al., 2009). HIIT training follows a protocol of peak power output over a period of time following a recovery time that is either longer or shorter than the duration of the peak power output (Tschakert & Hofmann, 2013).

HIIT has been utilized to improve aerobic capacity. This form of training involves variable lengths of maximum intensity intervals of exercise separated with variable lengths of rest intervals (Zuhl & Kravitz, 2012). Increased power output and decreased recovery time between bouts of exercise have been elicited as a result of HIIT training (Tschakert & Hoffman, 2013). HIIT training has also been shown to have effects on physiological functions that improve cardiorespiratory fitness. Implementation of HIIT has resulted in improved aerobic performance in both sedentary populations and trained populations (Laursen, & Jenkins, 2002).

This implies that HIIT training may be used effectively in varying populations. High volume low intensity aerobic training has shown to have similar cardiorespiratory improvement outcomes when compared to HIIT training (Gibala, 2007; Laursen, 2010; Zuhl & Kravitz, 2012). Although performance results of aerobic training and HIIT training are similar, the physiological responses during training do differ depending on the population that participates and on the design of the HIIT protocol (Gibala, 2007; Laursen, 2010; Zuhl & Kravitz, 2012).

HIIT training can improve VO_{2max} and can increase the duration of aerobic performance. (Bayati et al., 2011). Evidence shows that there is an increase in heart rate variability (HRV) threshold after three weeks of an implemented HIIT training protocol (Fronchetti, Nakamura, DeOliveira, Lima-Silva & Lima, 2007). An increased HRV threshold suggests that there may be a delay in parasympathetic withdraw as a result of HIIT (Fronchetti et al., 2007). Findings show that HIIT also improves aerobic exercise endurance (Bayati et al., 2011; Tschakert & Hofmann, 2013). This supports the idea that HIIT may have an effect on parasympathetic withdraw due to the direct relationship between efficiency of oxygen uptake and the delay of sympathetic effects on heart rate, which increases exercise duration (Katch et al., 2011). Central and peripheral adaptations leading to improved endurance performance suggests that HIIT is a viable substitute for CET (Bayati et al., 2011; Tschakert & Hofmann, 2013).

Physiological aspects of HIIT training have been compared to the physiological effects of CET. HIIT training has resulted in increased lipid utilization, increases in the resting glycogen storage within the muscle cells, and the decreased overall glycogen depletion during muscle cell activity (Gibala, 2007; 2009; Perry, Heigenhauser, Bonen & Spriet, 2008). The metabolic adaptations to HIIT training are very similar to what has been observed with CET. Significantly increased levels of PGC-1α is one example of this

(Coffey & Hawley, 2007; Gibala, 2009). The increased levels of PGC-1α suggest that there is an increased level of mitochondrial biogenesis, which would result in adaptations comparable to CET.

Adaptations to both CET and HIIT training have also been shown to increase the levels of mitochondrial enzymes that contribute to muscle oxidative capacity, particularly citrate synthase (CS) (Burgomaster, Hughes, Heigenhauser, Bradwell & Gibala, 2005; Gibala, 2007; 2009). Another response to HIIT training includes lactate transport capability which decreases lactate accumulation (Burgomaster, Heigenhauser & Gibala, 2006). There has also been an observed increase in pyruvate dehydrogenase activity which increases the capacity of pyruvate oxidation in the mitochondria (Burgomaster et al., 2006).

The physiological effects of HIIT have been speculated to be a result of increased Type IIa muscle fiber recruitment during a maximal bout of performance. This increased fiber recruitment could be one of the underlying reasons as to why HIIT training shows significant improvements in cardiovascular performance, because improvements in Type IIa muscle fiber function will contribute to aerobic performance, due to the role Type IIa fibers have during endurance activities (Katch et al., 2011; Kohn, Essein-Gustavsson & Myburgh, 2011). The training protocol for HIIT offers a time efficient alternative to traditional cardiovascular training, resulting in similar central and peripheral adaptations seen in CET.

There are some contradicting studies that have shown that these physiological adaptations do not always occur as a result of HIIT (Laursen & Jenkins, 2002), such as when a highly trained individual undergoes a HIIT training protocol central adaptations are not typically observed (Laursen & Jenkins, 2002). However, endurance performance is still improved in the highly trained population after a HIIT intervention, and this is thought to be due to the peripheral adaptions discussed earlier (Laursen & Jenkins, 2002). The physiological adaptations associated with HIIT training are highly comparable to CET. This suggested that HIIT can be used as an alternative form of aerobic training for fitness improvement.

It has been speculated that HIIT training can also be an alternative time efficient exercise strategy for those with time constraints (Gibala, 2007; Zuhl & Kravitz, 2012). One of the criticisms of HIIT is that an individual must be highly motivated for the demanded intensity that HIIT training requires (Gibala, 2007). However, the benefits of HIIT training are nothing to dismiss and the examination of practical applications should be something to consider. It can be speculated that, due to an assumed "competitive nature," an athletic population would be motivated enough to carry out the demands of HIIT.

Summary

Various forms of exercise have been shown to improve aerobic capacity including CET and HIIT. The physiological adaptations that occur in able-bodied athletes using lower body activities appear to be similar to those seen in athletes using upper body activities though the relative improvements may be less. This chapter presented a review of the current literature on aerobic capacity and HIIT training

Chapter 3

Methods

Introduction

The purpose of this study was to observe the effects of an eight-week upper body HIIT training program in a sample of recreational wheelchair athletes. The following methods for the study are presented. Physiological markers and performance markers were assessed prior to and after the HIIT intervention. The HIIT procedures and duration of the protocol are discussed as well as how data was analyzed and interpreted.

Participants

A sample of 11 recreationally trained wheelchair athletes participated in the study. Participants were recruited through ParaSport Spokane in Spokane, WA. The age range for recruitment was 12-30 years and the mean age of those participating was 17.63 ± 4.45 with a range of 12- 26 years. There were seven males and 4 females who volunteered. To meet the criteria for inclusion the athletes were recreationally trained and active participants of the ParaSport Spokane program. They were all members of the wheelchair basketball team that was training at the time of the study. Two participants' data were excluded from data analysis because they missed more than four HIIT sessions. Final data analysis was completed within two weeks following the 8-week HIIT intervention.

Instruments and Measurements

Aerobic capacity was assessed using a continuous submaximal test to exhaustion. The Jaeger ™ OxyconPro metabolic cart (CareFusion, Yorba Linda, CA) was used to determine the aerobic capacity which was reported in $ml \cdot kg^{-1} \cdot min^{-1}$. The test was completed using the Monark 891E upper body ergometer (Vasbro, Sweden) and the intervention was done using the Monark 881upper body ergometer (Vasbro, Sweden). Rate of perceived exertion (RPE) was recorded using The Borg CR10 Scale (Borg, 1998) as a way to measure exercise intensity level during the HIIT intervention. Participants were familiarized with the Borg CR10 scale prior to the study. All heart rates were monitored during testing using a Polar heart rate monitor (Polar Inc., Lake Success, NY). Physical testing completed during training by ParaSport Spokane was also used for data analysis. These tests included a 20 meter wheelchair forward sprint and a 20 meter wheelchair backward sprint. It is important to note that the pre-physical testing done by ParaSport Spokane was done about two months before the HIIT intervention and the post-testing was done within two weeks following the HIIT intervention.

Pilot test

Previous literature supports methodology for determining VO_{2peak} using an upper body arm crank ergometer but the Monark 891E has not been used in any previous aerobic capacity test so it was necessary to determine the test protocol for this study. Existing protocols have found contradictions in the optimal method for testing VO_{2peak} (Forbes & Chilibeck, 2007; Smith, et al., 2001) and most were done with able-bodied athletes. Therefore, a pilot test was implemented before testing the ParaSport athletes. The goal of pilot testing was to determine a protocol that was applicable to the test sample, but a different sample of ParaSport athletes was not available; therefore, participants for pilot testing were recruited based on their recreational participation in upper body intensive activities (e.g. rock climbing, cross-fit, gymnastics, wrestling). The protocol developed by Smith, et al. (2001) was used. However, the protocol differed by using a crank rate of 50 rpms and 60 rpms vs. the 70-80 rpms recommended. This change was due to the fact that during pilot testing participants were not able to maintain 70 rpms or 80 rpms during the first work load at the minimum basket weight. However, pilot test participants were able to go for a longer duration at lower rpms. Due to the diversity in age and function in the test sample it was decided that lower crank rates would be more practical to use for testing.

The ergometer was adjusted so the axis of rotation was in alignment of the glenohumeral joint of each participant. Each participant had 30 degrees of flexion at the elbow when the arm was maximally extended on the ergometer. Before testing, participants performed a 2-minute warm up at a self-selected crank rate and at the minimum resistance of 1.0 kp, the resistance provided by the weight basket.

Following the parameters of the recommended protocol, the load increased by 10 watts every two minutes, this was achieved by increasing the load 0.2 kp every two minutes and keeping the crank rate consistent throughout the protocol. Two test sessions were held; participants performed the protocol at 50 rpms during one session and after at least two days performed the protocol again at 60 rpms. Participants began the testing at the minimum resistance, which was 1 kp, and were loaded with an additional 0.2 kp every two minutes while maintaining their assigned crank rate. The test ended at volitional exhaustion, or when participants were unable to maintain the crank rate within 5 rpms of the assigned cadence. Heart rate (HR), duration of exercise, and VO_2 was measured during pilot testing.

Pilot test results. The pilot sample included eight college-aged participants (3 males and 5 females). Each participant performed the graded exercise test at 50 rpms and again at 60 rpms on separate days. Pilot testing in both males and females resulted in no determination of VO_{2peak}, with the exception of one male. Steady states were not reached within the 2-minute stages, so while VO_2 was recorded it was not a valid aerobic capacity assessment. The work incremental loading at either crank rate was too much to obtain a valid VO_{2peak}, in part due to the starting workload with the 891E when no resistance was still a resistance of 1 kp, the weight created by the basket in the loaded condition. However, participants were able to perform for a longer duration at 50 rpms when compared to 60 rpms; therefore, it was decided to use a submaximal continuous protocol test in place of a VO_{2peak} test for the aerobic component. This was performed at 50 rpms without incremental changes in resistance and at the minimum resistance of 1 kp, until volitional exhaustion.

Procedures

Prior to any contact with the athletes, the study was approved by the Institutional Review Board of Eastern Washington University. Once approval had been granted the researcher approached ParaSport Spokane coaching staff to confirm their willingness to have their athletes participate in the study during their competitive season. A meeting was then held with the ParaSport athletes, and in the case of any minors, with their parents or guardians, to explain the study and solicit their participation. Those who agreed received the informed consent/assent form.

ParaSport Spokane requires all athletes to obtain medical clearance from a doctor before participation; therefore they provided the medical clearance forms for participants of the study. All participants were informed of procedures and possible risks of the study. Participants were required to sign an informed consent prior to the pre-testing period. If the participant was legally dependent then a parent or guardian signed the informed consent and the participant signed an informed assent before any other screening or testing occurred. Familiarization and safety instruction that were given before the pre-testing period included RPE training two weeks prior to data collection, familiarization with the Monark 881 arm crank ergometer that would be used during the training sessions, and instruction on the procedures and duration of the study.

The results of the pilot testing determined the baseline testing protocol for the athletes participating in the study. Measurements of VO_2, RHR, exercise HR, exercise duration, and RPE were taken during the exercise testing. The continuous submaximal testing was performed on the Monark 891E (Vasbro, Sweden). After three minutes of rest a resting heart rate was taken from each participant. Prior to beginning the continuous test a two minute warm up on the Monark 881E (Vasbro, Sweden) was performed at a self-selected pace.

The participants for the current study performed on the ergometer with the same form as the able bodied participants in the pilot test, with the exception being that they were not required to have 30 degrees of flexion when the arm was fully extended. This is because participants with mobility impairments in the upper extremities were not able to crank in that position. Therefore, those with impairments were required to have the most acceptable form that their physical disability allowed. However, all participants had the ergometer adjusted so the axis of rotation was in line with the glenohumeral joint. Participants performed the continuous submaximal exercise test with a load of 1 kp, which was the basket weight of the ergometer in the loaded position. Participants were instructed to maintain 50 rpms while cranking asynchronously until volitional exhaustion, or if they were unable to maintain within 5 rpms below 50 rpms the test was halted by the researcher. An active cool down on the Monark 881E was performed after participation in the submaximal test.

Forward sprint times were assessed using a Brower Test Center Timing System (Draper, Utah). The timing gates were placed 20 meters apart from each other and participants were asked to start directly behind the timing gate and sprint for 20 meters. Participants began the sprint when they were ready without any external cues to start. Time began as soon as participants crossed the first timing gate and ended when they crossed the end timing gate. The same protocol was used for collecting backward sprint times.

HIIT training protocol. The HIIT training consisted of two sessions a week for eight weeks. The training duration was based on what researchers have previously used for lower body HIIT (Zuhl & Kravitz, 2012) as no previous studies had used upper body exercise in a HIIT study. The training protocol was also selected based on the most practical way to integrate sessions during ParaSport Spokane's practice sessions. An RPE was used to determine resistance because a maximal test was not done to determine a percent of VO_2 as was the norm in previous studies (Bayati, et al., 2011; Gillen, 2012; Smith et al., 2001; Zuhl & Kravitz, 2012). Research supports utilizing a self-selected RPE to determine exercise intensity during interval training (Kilpatrick et al., 2014; Sanchez, 2014).

The training consisted of 30 second intervals of a maximal effort asynchronous crank rate on a Monark 881E (Vasbro, Sweden), performed at a resistance that was self-selected to be an RPE of 8-9 (Kilpatrick et al., 2014; Sanchez, 2014). Loading during RPE selection was done by the researcher in response to the athlete's agreement that the resistance was equal to the appropriate RPE. The researcher would steadily increase the resistance on the ergometer with the wattage display covered so participants could not see the load. Participants performed a self-selected low intensity crank rate while the researcher steadily increased the load. When participants verbally indicated that the loading would be an RPE of 8-9 by the end of the 30-sec bout, participants were asked to crank at maximal effort for thirty seconds (Kilpatrick et al., 2014). Resistance was not recorded for any sessions as they were only based on participant perception of RPE meaning the resistance could be different between sessions based on the condition of the athlete in that particular session.

This method followed the parameters of previous HIIT studies with lower body ergometry (Bayati et al., 2011; Gillen, 2012; Smith et al., 2001; Zuhl & Kravitz, 2012), however there was no assigned RPM, this is due to the varied disabilities within the population and the possibility that athletes with disabilities affecting the motor tract were not able to maintain a consistent crank rates during maximal effort. Participants underwent an active warm-up before all HIIT sessions. During the first two weeks of the intervention participants performed four 30-sec sets of HIIT training with 2-min rest intervals, and every two weeks another set was added, ending the intervention with a total of seven 30-sec sets.

All post-testing was completed within two weeks following the 8-weeks of interval training. The post-test protocol was the same as used in the pre-intervention assessment. Participants were reassessed on VO_2, RHR, exercise HR, exercise duration, and physical assessments.

Data Analysis

Descriptive statistics of mean ± SD were recorded for all variables pre and post. After data were collected and analyzed for normality, a two-tailed dependent sample's t-test was used to examine the differences between all variables pre to post. Statistical significance was set at an alpha level of $p \leq .05$.

Summary

The testing procedures attempted to analyze the intervention of a HIIT protocol among a sample of recreational wheelchair basketball athletes. This chapter presented the participants included in the study and all procedures used for testing and the HIIT training. Data analysis was explained.

Chapter 4

Results

Introduction

The purpose of this study was to observe the effects of an eight-week upper body HIIT training program in a sample of recreational wheelchair athletes. This chapter includes the physical characteristics of participants and statistical analysis of all variables.

Participants

Eleven participants (seven males, four females) ages 12 - 26 volunteered. They were all recreationally active wheelchair athletes, participating on the ParaSport Spokane wheelchair basketball team, with the following physical disabilities: cerebral palsy (n=3), spina bifida (n=3), arthrogryposis (n=1), paraplegia (n=2), right leg paralysis (n=1), and above the knee single amputation (n=1). During the 8-weeks of the study, all participants completed an average of 11 ± 3.16 HIIT sessions. Two (one male, one female) participants' data were omitted from the analysis due to the number of sessions missed. The criterion for exclusion was set at missing four or more sessions. Excluding those two athletes the average number of sessions was 12.11 ± 0.78. Complete pre-intervention data was collected on four variables. Two were the performance variables tested at the beginning of the season, two months prior to the intervention, forward sprint (FW sprint), and backward sprint (BW sprint) and two were measured in the pre-test, exercise duration (ED) and resting heart rate (RHR). Steady state VO_2 values were recorded during pre and post testing, but the values never achieved steady-state so were eliminated from the analysis. Out of the four variables that were able to be used for data analysis only five participants were able to provide data for all four variables.

Descriptive Statistics

Means and standard deviations of the four variables, RHR, BW Sprint, and FW sprint times are presented in Table 1.

Table 1

Pre and post intervention data (mean (SD)

	Pre-HIIT		Post-HIIT	
	n	M (SD)	n	M (SD)
RHR (BPM)	11	92.67 (5.34)	9	79.22 (4.45)
BW Sprint (sec)	5	11.94 (1.70)	5	9.64 (1.12)
FW Sprint (sec)	5	6.91 (.46)	5	6.15 (.54)
Exercise Duration (min)	11	5.35 (1.66)	9	1.25 (.280)

Parametric Statistics

Steady state VO_2 values were not able to be obtained during the pre and post submaximal test. The normality assumption for the dependent samples t-test was met using a Shapiro-Wilk test in conjunction with an evaluation of skewness and kurtosis ($p <$ 0.05). Post-intervention results were compared to the pre-intervention using a two-tailed dependent samples t-test. A significantly decrease was found in resting heart rates (t (9) = -2.40, p = .043), forward sprint times (t (5) = -4.44, p =. 011), and in exercise duration (t (9) = -4.72 p = .001). No significant difference was found in backward sprint times (t (5) = -2.060, p = .108)

Summary

This chapter presented the descriptive statistics of the physical characteristics of the participants and a statistical analysis of all variables including backward sprint times, forward sprint times, exercise duration and RHR

Chapter 5

Discussion

Introduction

The purpose of this study was to observe the effects of an eight-week upper body HIIT training program in a sample of recreational wheelchair athletes. This chapter provides a summary of the procedures, a discussion of the results, a comparison of the results to previous research, and recommendations for future research.

Overview

Participants for the study were recruited from the ParaSport Spokane program and were between the ages of 12 and 26. All participants were medically cleared by their physicians. Participants were made familiar with all the testing and training equipment, as well as trained on use of the RPE scale prior to testing. Participants performed a continuous submaximal arm crank test while a breath by breath analysis was taken using a Jaeger ™ OxyconPro metabolic system (CareFusion, Yorba Linda, CA) measured in $ml\cdot kg^{-1}\cdot min^{-1}$, in order to monitor VO_2 during submaximal arm crank exercise. Physical skills testing was also done on the athletes including a 20 meter forward sprint and 20 meter backward sprint. HIIT sessions occurred twice a week for eight weeks and progressed from four to seven 30 second sets, with a set being added every two weeks. Participants were loaded during HIIT sessions based off of an RPE of 8-9 while being able to complete a 30 second set. Within two weeks after the 8-weeks of training participants performed another submaximal test as well as physical skills testing.

Discussion

Improvements in physical skills testing were observed in all athletes that were able to be tested for follow up. The lack of participation in physical skills testing was due to participant schedule conflicts, lack of facilities, and lack of equipment at the time of testing. Although physical testing could only be conducted for a portion of the sample, there were improvements in the forward sprint and non-significant improvements in backward sprint times. The improved sprint times are not able to be fully attributed to the HIIT intervention. The initial sprint times were taken two months prior to HIIT intervention and the HIIT intervention coincided with ParaSport Spokane strength and conditioning, practice, and competition, thus, it is impossible to determine if the effects were due to HIIT or regular training.

Previous studies have found that VO_{2peak} can be determined during incremental arm crank exercise among able-bodied participants and those with disabilities (Price & Campbell, 1997). However, due to the results of pilot testing a decision was made to attempt a continuous submaximal test. During the pre-test the RER values indicated that the participants were working above anaerobic threshold even at the lowest possible resistance for the Monark 891E (Vasbro, Sweden). Therefore, no comparison of VO_2 was done in data analysis. A possible reason for the inability to obtain VO_2 comparisons may be a result of the type of ergometer that was used for submaximal testing. The ergometer used for determination of VO_{2peak} was the Monark 891E upper body ergometer (Vasbro, Sweden). This ergometer was used for submaximal testing because it was thought to be a better machine for the testing sample, due to the adjustable platform it was on, which was designed to accommodate those in wheelchairs. However, The Monark 891E (Vasbro, Sweden) was developed as a tool to measure anaerobic work and has not been utilized for aerobic exercise. The design purpose for anaerobic work of the Monark 891E (Vasbro, Sweden) may have resulted in the inability to obtain steady state VO_2 values during exercise testing. The assumption was made that exercise duration would be another indicator of adaptations in endurance performance, following the HIIT intervention. However, this was not the case due to the results of post- testing data.

A significant decrease in exercise duration during the post-testing is not in agreement with previous literature (Bayati et al., 2011), it is also not in agreement with the other variables measured in this study that would be suggestive of a fitness improvement from HIIT. These findings suggest that there was an equipment error that was altering the function of the Monark 891E (Vasbro, Sweden). This equipment error was potentially increasing the load during performance that was greater than the 1kp of resistance during pre-testing, this would explain why there was a decrease in exercise duration. The Monark 891E (Vasbro, Sweden) was being used for another study during the 8 - week HIIT intervention. It was reported that the researchers for that study had complications with the initial resistance during this time and that the flywheel had to be repaired, and even after repairs there was a perception that the initial load was still too high. Due to the inability to successfully use a submaximal exercise test, this study is not able to provide insight on the effects of upper body HIIT on VO_2 or exercise duration.

Previous literature recommends the use of higher crank rates to determine peak oxygen consumption (Forbes & Chilibeck, 2007; Smith, et al., 2001). However, the current study used lower crank rates due to performance outcomes on the ergometer observed during pilot testing. The performance outcomes observed in pilot testing and during data collection also suggest that the Monark 891E (Vasbro, Sweden) is not an optimal ergometer for VO_2 testing. Therefore, higher crank rates performed on an ergometer more suitable for aerobic testing may be optimal for future research.

It is worth noting that the athletes participating in the HIIT protocol were also casually observed to improve hand speed. This is a desired outcome in many wheelchair sports due to the importance of dynamic movement and multitasking that is reliant on the upper extremities. Future research should explore possible associations with asynchronous hand cranking and effects on tasks with outcomes dependent on hand speed.

Peak power performance is also another result of HIIT training (Bayati, Farzad, Gharakhanlou & Agha- Alinejad, 2001; Laursen & Jenkins, 2002). Future research should explore the effects of an upper body HIIT protocol on peak power output. This could be useful in exercise programming for sprint performance, especially if the HIIT protocol was done in a sport specific manner (e.g. wheelchair racing).

Recommendations

Recommendations for future research include

- Increasing the sample size in order to have higher statistical power with the results and also have a control group so the effects of the intervention are observed with increased internal validity.
- Using an arm crank ergometer that allows participants to perform continuous submaximal testing so oxygen consumption below the AT can be observed before and after intervention.

- Observing the effects of an upper body HIIT training protocol on highly trained wheelchair athletes and untrained individuals that are limited in lower extremity mobility. This could give insight into the effectiveness of HIIT across varying fitness levels within this population.
- Using the same ergometer for HIIT training and for pre and post intervention testing.

Overall Contributions and Summary

The present findings suggest that an upper body HIIT protocol in recreational wheelchair athletes may have positive aerobic effects, as shown by the decreased RHR and decreased forward sprint and backward sprint times. However, the current research was unable to determine whether there was an improvement in peak oxygen consumption during exercise, as the previous literature on HIIT training demonstrates. Due to the lowered RHR and decreased sprint times we can assume that cardiorespiratory adaptations may have occurred.

Despite not being able to test all the desired variables, the current study does show that when a HIIT protocol is implemented on recreationally active wheelchair athletes, the result is improved heart rate adaptations and improved sprint outcomes. Overall, the study contributes to a gap in the body of literature on performance-based training methods for athletes with physical disabilities. Future research should refine HIIT protocol use among this population, and also look into its effects on wheelchair athletes of all performance levels and ages. With the increasing growth of adaptive sport, future literature should focus on performance based outcomes with the implementation of various training methods and protocols.

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Appendix A

Informed Consent

Assent/Consent Form

Effects of HIIT training on recreationally trained wheel chair basketball athletes

In partial fulfillment of the Master's Thesis for Tayler Elizondo

Principal Investigator	Responsible Project Investigator
Tayler Elizondo	Wendy Repovich, Ph.D., FACSM
814 S. Lincoln St. Apt. 7	Physical Education, Health and Recreation Dept.
Spokane, WA 99204	200 Physical Education Bldg
(541) 212-9926	Cheney, WA 99004-2476
telizondo@eagles.ewu.edu	wrepovich@ewu.edu

Purpose and Benefits

Your are invited to take part in a study to test the use of High Intensity Interval Training (HIIT), which is considered an alternative form of aerobic training. The effects of HIIT training have been observed in many different populations. This study can help develop a better understanding of training methods and procedures for wheelchair basketball athletes, which can result in improved performance outcomes in the sport of wheelchair basketball.

Procedures

If you decide to take part, you will be asked:

- To complete a pre-test requiring you to perform a peak aerobic capacity test using an arm crank ergometer, while we measure various physiological parameters including oxygen consumption, heart rate (HR), respiratory rate, and a rating of perceived exertion (RPE).
- HIIT will be part of your training twice a week during regular practice sessions for 8 weeks. This will require performing intervals of maximum effort followed by a rest period and repeating this 4-7 times. Each training session will last 15 – 20 minutes including the warm up and cool down parts of the session.
- After the 8 week HIIT period you will perform post-testing measuring oxygen consumption, respiratory rate, HR, and RPE, will be carried out again while you perform peak aerobic capacity testing using an arm crank ergometer.

We will complete pre- and post-testing at the Eastern Washington University Human Performance Laboratory and it will take your approximately 20-30 minutes in the lab to complete the testing. The training program will be completed your own training location during normal practice times. The principle investigator will be administering all testing and monitoring all of the training sessions.

Risk, Stress, Discomfort

For this study risk, stress and discomfort are minimal. The only thing different from what you are already doing is using HIIT training instead of any regular aerobic training, which would be new to you. There is always the risk of injury with any sport training but you will be trained prior to beginning the program and monitored for any issues during the 8 weeks of the study. You may experience some muscle soreness as you begin the training but supervision and suggestions for any possible mechanical changes occurring with the training will be done regularly to minimize that possibility.

Inquires

Any questions about the procedures used in this study are encouraged. If you have any concerns or questions, or would like more information please contact Wendy Repovich, or Tayler Elizondo prior to signing this informed consent/assent form. We can be reached at (509) 359-7960, wrepovich@ewu.edu or (541) 212-9926, telizondo@eagles.ewu.edu respectively.

Other Information

Your permission to take part is voluntary. You are free to stop at any time if you desire. If you have any concerns about your rights as a participant in this research or any complaints you wish to make, you may contact Ruth Galm, Human Protection Administrator, (509) 359-6567 or rgalm@ewu.edu.

____ ______________________________

Signature of Principal Researcher Date

Participant Statement

I have read this form and I understand what I am being asked to do and the attendant risks and discomforts. Knowing these risks and discomforts and having had an opportunity to ask questions that have been answered to my satisfaction, I agree to be a subject.

____________________ ____

Date Signature of Student

Appendix B

Borg CR10 Scale

1 - 10 Borg Rating of Perceived Exertion Scale

0	Rest
1	Really Easy
2	Easy
3	Moderate
4	Sort of Hard
5	Hard
6	
7	Really Hard
8	
9	Really, Really, Hard
10	Maximal: Just like my hardest race

VITA

Author: Tayler Tomas Elizondo

Place of Birth: Honolulu, HI

Undergraduate Schools Attended: Idaho State University

Degrees Awarded: Bachelor of Science in Physical Education/Exercise Science with a Minor in Psychology, 2013, Idaho State University

Professional Experience: Assistant Athletic Trainer, Pocatello, Idaho, 2012-2013

Physical Therapy Aide, Spokane, Washington, 2013

Internship, Cardiac Rehabilitation Specialist, Coeur d' Alene, Idaho, 2014

Internship, Teaching Assistant, Spokane, Washington, 2015