The Effects of Upper Extremity Functional Electrically Stimulated (FES) Exercise Training on Upper Limb Function in Individuals with Tetraplegia

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ABSTRACT

Functional Electrically Stimulated (FES) arm cycle ergometry is a relatively new technique for exercise in individuals with impairments of the upper limbs. The purpose of this study was to determine the effects of 12 weeks of FES arm cycle ergometry on upper limb function and cardiovascular fitness in individuals with tetraplegia. Five subjects (4M/1F; mean age 43.8 $\pm$ 15.4 years) with a spinal cord injury of the cervical spine (C3-C7; ASIA B-D) participated in 12 weeks of 3 times per week FES arm cycle ergometry training. Exercise performance measures (time to fatigue, distance to fatigue, work rate) were taken at baseline, 6 weeks, and following 12 weeks of training. Cardiovascular measures (MAP, resting HR, average and peak HR during exercise, cardiovascular efficiency) and self reported upper limb function (as determined by the CUE, sf-QIF, SCI-SET questionnaires) were taken at baseline and following 12 weeks of training. Increases were found in time to fatigue (84.4%), distance to fatigue (111.7%), and work rate (51.3%). These changes were non-significant. There was a significant decrease in MAP (91.1 $\pm$ 13.9 vs. 87.7 $\pm$ 14.7 mmHg) following 12 weeks of FES arm cycle ergometry. There was no significant change in resting HR or average and peak HR during exercise. Cardiovascular efficiency showed an increase following the 12 weeks of FES training (142.9%), which was non-significant. There were no significant changes in the measures of upper limb function and spasticity. Overall, FES arm cycle ergometry is an effective method of cardiovascular exercise for individuals with tetraplegia, as evidenced by a significant decrease in MAP, however it is unclear whether 12 weeks of thrice weekly FES arm cycle ergometry may effectively improve upper limb function in all individuals with a cervical SCI.

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LIST OF ABBREVIATIONS

ADL – Activities of Daily Living

ANOVA – Analysis of Variance

ASIA – American Spinal Injury Association

bpm – beats per minute

BWSTT – Body Weight Supported Treadmill Training

CSA – Cross Sectional Area

CUE – Capabilities of Upper Extremity Questionnaire

FES – Functional Electrical Stimulation

HR – Heart Rate

ICC – Intraclass correlation coefficient

MAP – Mean Arterial Pressure

MRC – Medical Research Council

QIF – Quadriplegia Index of Function

ROM – Range of Motion

rpm – revolutions per minute

SCI – Spinal Cord Injury

SCI-SET – Spinal Cord Injury Spasticity Evaluation Tool

sf-QIF – short form of Quadriplegia Index of Function

TSI – Time Since Injury

W - Watts

I. INTRODUCTION

A spinal cord injury (SCI) is a traumatic event that results in a decrease in function. Changes in muscle begin immediately post injury, and include muscle atrophy and muscle fibre type changes. Muscle atrophy, the reduction of cross sectional area (CSA) and weakness in the muscles, can cause many health problems and functional difficulties. SCI also results in a reduction in fatigue resistance. The reduction in fatigue resistance can have a functional effect on individuals with a SCI, as it may limit their ability to perform activities of daily living (ADL) and live independently. Individuals with a SCI may also experience muscle spasticity. Spasticity can have both detrimental and beneficial effects on function.

Functional limitations are a lack of ability to perform an action within the range considered normal that results from impairment (Marino, Shea & Stineman, 1998). The impairment of hand and arm function is one of the consequences of cervical SCI. Generally, individuals with tetraplegia may experience difficulties with the actions of reaching, grasping, and pulling. This may cause functional limitations with activities of daily living. In a study conducted by Anderson (2004), 681 individuals with SCI were surveyed and the results showed that with regards to quality of life, the return of arm and hand function was the highest therapeutic priority to individuals with tetraplegia. Recovery of even partial hand and arm function could potentially have a great impact on independence. Anderson (2004) also found that 96.5% of individuals with a SCI considered exercise to be important for functional recovery, however, only 56.9% had access to exercise, and only 12.2% had access to a trained therapist. These findings demonstrate a need for therapies that will both improve hand and arm function, and exercise techniques that will improve function.

Exercise rehabilitation has been shown to be effective in increasing function and health after spinal cord injury. Arm ergometry has been shown to result in physical and psychological gains. However, not all individuals with SCI have sufficient upper limb function to benefit from manual arm ergometry. Functional Electrical Stimulation (FES) is a therapeutic intervention for individuals with spinal cord injuries. FES uses surface electrodes to activate paralyzed or paretic muscles, and evidence shows that with regular use partial recovery of voluntary muscle control can result (Thrasher, Flett & Popovic, 2006). Recently, FES arm cycle ergometry has become available. FES arm cycle ergometry involves electrical stimulation of the biceps and triceps in a sequential cycling pattern, and the stimulation of the rotator cuff muscles to provide stabilization of the upper limb. The arm cranks that are grasped by the participants are connected to a motor that can either assist as the muscles fatigue or add resistance to create greater cardiovascular challenge. FES arm cycle ergometry can be beneficial to individuals with no arm function or to individuals with some arm function who may benefit from the extra stimulation. A recent study found that 12 weeks of 3 times per week progressive FES arm cycle ergometry resulted in an increase in peak power output in individuals with a C6 spinal cord injury (Coupaud, Gollee, Hunt, Fraser, Allan & McLean, 2008). Coupaud et al. (2008) also looked at peak oxygen uptake (l/min) and found that training effects were different for each individual, indicating the variability of exercise responses between individuals, which may be related to the completeness of the injury.

The benefits of FES arm cycle ergometry are yet to be determined, however it may serve in two capacities; 1) fill a void regarding exercise rehabilitation options, 2) may offer similar adaptations as FES lower extremity cycling, such as increasing muscle function, improving cardiovascular endurance, and reducing spasticity, but in the upper extremities. The purpose of this study is to investigate the effects of twelve weeks of FES arm cycle ergometry at a frequency of 3x/week on upper limb function in individuals with chronic (≥ 1 year post-injury) tetraplegia.

II. REVIEW OF LITERATURE

2.1.0 Background

2.1.1 Epidemiology of Spinal Cord Injury

A spinal cord injury (SCI) is a traumatic event that results in a decrease in function. Approximately 40,000 Canadians are affected by a SCI, with 1,200 new cases occurring each year (Tuszynski, Steeves, Fawcett, Lammertse, Kalichman, Rask, et al., 2007). The life expectancy of individuals with a SCI is increasing. The median survival time for individuals who sustained an injury between the ages of 25-34 years is predicted to be 38 years post injury, with 43% surviving at least 40 years post injury (McColl, Walker, Stirling, Wilkins & Corey, 1997). The ratio of males to females with a SCI is 3.8:1 (McColl et al., 1997). Sekhon and Fehlings (2001) stated that approximately 40% of individuals with a SCI have an injury of the cervical spine.

2.1.2 Classification of Spinal Cord Injury

There are two general ways to classify a spinal cord injury, by its neurological level, and by its severity. The neurological level refers to the most caudal segment of the spinal cord with normal function. Individuals with injuries of the cervical spinal cord are referred to as having tetraplegia because they have upper and lower extremity impairment, as well as impairment of the trunk and pelvic muscles. Individuals with injuries of the thoracic spinal cord and below are referred to as having paraplegia because they have impairment of the lower extremities and pelvic muscles, with possible impairment of the trunk. The severity of the injury refers to whether it is complete or incomplete. A complete injury will have no motor or sensory function at the S4-S5 level. Individuals with a complete injury may have a zone of partial preservation, which refers to dermatomes and myotomes caudal to the neurological level that remain partially innervated. This means that an individual with a complete injury may have some sensory and/or motor function in a few dermatomes and myotomes below the level of injury, but not, by definition, at the S4-S5 level. An incomplete injury will result in partial preservation of sensory and/or motor function below the injury level. The American Spinal Injury Association (ASIA) classifies complete injuries as ASIA A, and incomplete injuries are classified as ASIA B-E, depending on the amount of function maintained below the injury level. Individuals with an ASIA B injury have sensory but not motor function preserved below the injury level. ASIA C injuries display preservation of sensory and motor function below the injury level with more than half the key muscles below the neurological level exhibiting less than anti-gravity strength (i.e. less than 3/5 on the Medical Research Council (MRC) strength scale). ASIA D injuries display sensory and motor function preservation below the injury level with at least half of the key muscles below the neurological level exhibiting at least anti-gravity strength (i.e. ≥ 3/5 on the MRC strength scale). Individuals with an injury classified as ASIA E will have normal sensory and motor function. Thus, the range of function is different for each individual, depending on the level and severity of the injury. Roughly one half of individuals with a SCI have incomplete injuries and therefore some motor and/or sensory function below the level of injury (Sekhon & Fehlings, 2001).

Upper motor neuron injuries refer to injuries of the spinal cord. Lower motor neuron injuries refer to damage to the spinal nerves as they leave the spinal cord. A lower motor neuron injury by itself is not a SCI although individuals with SCI at T10 or lower will often have some lower motor neuron damage as well. Typically, a lower motor neuron injury refers to damage to the cauda equina, which are the peripheral nerves that descend in the vertebral column from the L2 vertebral level and below. Spinal cord injury can be acute (within the first 2 years of injury, changes in function still occur) or chronic (more than 2 years post injury). Spinal cord injury has many effects and often causes loss of muscle function, muscle atrophy, and loss of sensory function, all of which result from damage to the somatic nervous system. However, it is important to note that SCI can result in autonomic dysfunction below the injury level as well (Bloemen-Vrencken, de Witte, Post & van den Heuval, 2007).

2.2.0 Muscle Adaptations after Spinal Cord Injury

Changes in muscle begin immediately post injury, and include both muscle atrophy and muscle fibre type changes.

2.2.1 Muscle Atrophy

Muscle atrophy, the reduction of cross sectional area (CSA) and weakness in the muscles, can cause many health problems and functional difficulties. Skeletal muscle atrophy has been attributed to central activation loss and the consequent unloading that occurs (Castro, Apple, Staron, Campos & Dudley, 1999; Gordon & Mao, 1994). Muscle atrophy occurs rapidly during the first weeks following injury, and then gradually slows. Gorgey and Dudley (2007) found that at six weeks post-injury the CSA of the thigh skeletal muscle was 33% smaller compared to able bodied controls, and decreased slightly but did not change significantly during the following three months. Castro et al. (1999) found that at six weeks post injury muscle fibre size was 60% that of able bodied controls. Average fibre CSA declined further, decreasing by 22% between six and eleven weeks post injury, with a smaller decline of 10% occurring from weeks eleven to twenty-four. A significant atrophy of 27-56% occurred in type I, type IIa, type IIax, and type IIx fibres from six to twenty four weeks post injury, which resulted in a fibre CSA of approximately one-third of that of the able bodied population (Castro et al., 1999). Baldi, Jackson, Moraille and Mysiw (1998) found that six months post injury there was a 9.5% decrease in total body lean mass, a 21.4% decrease in lower limb lean body mass, and a 26.8% decrease in gluteal lean body mass. Muscle atrophy is associated with many health problems. Muscle is the primary site for glucose storage, so atrophy can result in glucose intolerance, insulin resistance, and type II diabetes. Jeon, Weiss, Steadward, Ryan, Burnham, Bell, et al. (2002) found that 22% of individuals with SCI have Type II diabetes compared to only 6% in the able bodied population, and 62% of individuals with tetraplegia have abnormal glucose tolerance. Baldi et al. (1998) associated muscle atrophy with the health concerns of pressure sores, fractures, and deep vein thrombosis. Upper limb atrophy is related to increased risk of pressure sores because upper extremity strength and function is needed in order to shift body weight to relieve pressure. Lower limb and gluteal atrophy is related to increased risk of pressure sores because of the decreased muscle mass/cushion between the skin and bony prominences.

2.2.2 Changes in Muscle Fibre Type Distribution

Spinal cord injury results in a reduction in muscle endurance. Following SCI there is a shift in muscle fibre type towards type IIx muscle fibre dominance. This fibre type shift is, as of yet, unexplained. Type IIx fibres are fast twitch fatigable fibres which, in part, account for the decrease in fatigue resistance. Castro et al. (1999) found that the percentage of type IIa fibres decreased from six to twenty-four weeks post injury, while the percentage of type IIax + IIx fibres increased. The percentage of type I fibres did not change. It was also demonstrated that individuals with a SCI showed greater relative fatigue than able bodied individuals during exercise bouts at both six and twenty four weeks post injury (Castro et al., 1999). The relative fatigability within the SCI participants remained constant from six to twenty four weeks. This shows that individuals with a SCI fatigue faster than able bodied individuals, and this increased fatigability is evident as early as 6 weeks post-injury. It has also been shown that following SCI there is a reduction in Na+/K+ ATPase, which may contribute to the increased fatigability of the paralyzed muscle (Ditor, Hamilton, Tarnopolski, Green, Craven, Parise & Hicks, 2004). The reduction in fatigue resistance can have a functional effect on individuals with a SCI, as it may limit their ability to perform activities of daily living (ADL) and live independently.

2.2.3 Spasticity following Spinal Cord Injury

Individuals with a SCI may experience muscle spasticity. Spasticity can have both detrimental and beneficial results. It is possible that persistent spasticity may preserve the expression of type I muscle fibres (Ditor et al., 2004). Spasticity is an involuntary random increase in muscle tone. More specifically, Lance (1980) defined spasticity as a motor disorder characterized by a velocity dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyperexcitability of the stretch reflex. Spasticity occurs in individuals with an upper motor neuron injury. Individuals with a lower motor neuron injury experience flaccid paralysis, with no spasticity, because there is no neurological connection to the spinal cord. Adams and Hicks (2005) stated that 65-78% of individuals with chronic SCI experience symptoms of spasticity. Bloemen-Vrencken et al. (2007) surveyed 410 individuals with SCI and found that 57.1% had experienced spasms during the prior twelve month period. ASIA classification and level of injury are predictors for the development of spasticity. Skold, Levi, and Seiger (1999) found that 93% of individuals with tetraplegia ASIA A reported spasticity, while 78% of individuals with tetraplegia ASIA B-D reported spasticity.

Spasticity has the potential to negatively affect quality of life in individuals with SCI. Adams and Hicks (2005) state that spasticity may restrict activities of daily living, inhibit walking and self care, cause pain and fatigue, disturb sleep, compromise safety, contribute to the development of contractures, pressure ulcers, and infections, contribute to negative self image, complicate the role of the caretaker, and impede rehabilitation efforts. Skold et al. (1999) found that 20% of individuals with SCI found spasticity to restrict ADL's, and 4% found spasticity to cause pain. Spasticity may also have some beneficial effects, including facilitation of some ADL's and transfers, increases in muscle strength and CSA, and an increase in venous return (Adams & Hicks, 2005).

2.2.4 Contractures following Spinal Cord Injury

Joint contractures are common following SCI, and are characterized by a limitation in the passive range of motion (ROM) of the affected joints. Contractures following immobilization are the result of a chronic lack of stretch across a joint, and in conditions of spasticity, muscle imbalances contribute to contracture development (Moriyama, Yoshimura, Sunahori & Tobimatsu, 2006). Harvey and Herbert (2002), state that contractures are due to a loss of extensibility in the soft tissues spanning joints. Dalyan, Sherman & Cardenas (1998) found that of 482 individuals with SCI, 44 (9%) developed contractures. Individuals with tetraplegia display a significantly increased incidence of contractures than individuals with paraplegia, with 13.3% and 5.5% respectively developing contractures. In individuals with tetraplegia, the shoulder joint was found to be the most affected site for contractures, with 48.7% of individuals with contractures developing them in the shoulders (Dalyan et al., 1998). Contractures can limit the functional use of limbs, and cause a loss of independence. Contractures may delay rehabilitation, and interfere with dressing, transferring, and nursing care (Dalyan et al., 1998). Grover, Gellman and Waters (1996) found that individuals with tetraplegia at the C6 level who developed a flexion contracture at the elbow of 25 degrees or more experienced a loss of functional level and independence with regard to transfer skills and bed mobility.

2.3.0 Functional Limitations following Spinal Cord Injury

Functional limitations are a lack of ability to perform an action within the range considered normal that results from impairment (Marino, Shea & Stineman, 1998). The impairment of hand and arm function is one of the consequences of cervical SCI. Each spinal cord segment is associated with the control of a key muscle: C5 innervates the biceps and brachialis, C6 innervates the extensor carpi radialis and brevis, C7 innervates the triceps, and C8 innervates the flexor digitorum profundus. However, muscles receive innervation from more than one segment, so the strength of a given muscle is a reflection of the functioning of two or more cord segments. Durfee (1999) stated that those with higher level injuries tend to have difficulty positioning their hand in the work space and thus cannot reach or manipulate an object they wish to grasp. Memberg, Crago, and Keith (2003) stated that individuals with an injury at the C5-C6 level typically had some voluntary function of the elbow flexor muscles, but had no function of the triceps, preventing elbow extension against gravity. A lack of voluntary elbow extension limits the ability to reach overhead or push away objects, causing a reduction in the functional workspace. Generally, individuals with tetraplegia may experience difficulties with the actions of reaching, grasping, and pulling. This may cause functional limitations with ADL's, particularly with wheelchair use, catheterization, and transfers.

Limitations in physical activities and problems with work/daily activities as a result of physical health were found to have a significant effect on quality of life (Westgren & Levi, 1998). Hammell (2007) found that quality of life was diminished by functional problems related to the impaired body, including pain, fatigue, and spasticity. Anderson (2004) found that with regards to quality of life, the return of arm and hand function was the highest therapeutic priority to individuals with tetraplegia. A survey was distributed to the SCI community, which asked participants (681) to rank seven functions in order of importance to quality of life. Hand and arm function was stated as most important by 48.7% of individuals with tetraplegia, followed by sexual function (13%), trunk stability (11.5%), bladder/bowel function/autonomic dysreflexia control (8.9%), walking movement (7.8%), normal sensation (6.1%), and relief of chronic pain (4%). Recovery of even partial hand and arm function could potentially have a great impact on independence. Anderson (2004) also found that that majority of individuals with a SCI regard exercise as an important aspect of functional recovery. 96.5% of individuals with a SCI considered exercise to be important for functional recovery, however, only 56.9% had access to exercise, and only 12.2% had access to a trained therapist. This demonstrates a need for therapies that will both improve hand and arm function, and exercise techniques that will improve function.

2.4.0 Exercise Rehabilitation for Individuals with Spinal Cord Injury

Exercise rehabilitation has been shown to be effective in increasing function and health after spinal cord injury. However, exercise options are limited in this population. Available exercise therapies either target the lower extremities (body weight supported treadmill training, functional electrically stimulated leg cycling), or target the upper extremities but require a substantial amount of hand and arm strength and function (wheelchair propulsion, arm ergometry). Body weight supported treadmill training (BWSTT) is an intervention that allows individuals with a SCI to walk supported on a treadmill while therapists aid the lower limbs to produce a walking motion. Giangregorio, Hicks, Webber, Phillips, Craven, Bugaresti, et al. (2005) found that BWSTT partially reversed muscle atrophy following acute (2-6 months post injury) SCI. Following 48 sessions of BWSTT muscle CSA was increased from 60% to 72% in the thigh and 65% to 79% in the calf compared to able bodied controls. However, the upper limbs are left untrained. Arm ergometry has been shown to result in physical and psychological gains. Hicks, Martin, Latimer, Craven, Bugaresti, and McCartney (2003) found that following long-term twice-weekly arm ergometry there was a significant increase in submaximal arm ergometry power output and upper body muscle strength, and higher levels of satisfaction with physical function, perceived health, and overall quality of life. However, upper body therapies such as wheelchair propulsion and arm ergometry involve a specific muscle mass, and therefore may be limited by pain and overuse syndromes (Davoodi, Andrews & Wheeler, 2002), and may not be feasible for individuals with upper limb impairments.

2.5.0 Functional Electrical Stimulation

Functional Electrical Stimulation (FES) is a therapeutic intervention for individuals with spinal cord injuries. The purpose of FES is to activate muscles that have lost function due to an inhibition of the normal pathways of motor control signals from motor areas of the brain through the upper and lower motor neurons to the muscle. When the lower motor neurons are intact, muscle force can be generated with electrical stimulation of the lower motor neurons (Durfee, 1999). Electrical pulses applied to motor nerves create action potentials that propagate along the axons towards the target muscle to cause muscle contraction. To cause continuous muscle contraction the FES system must induce at least twenty action potentials per second, otherwise the muscle would generate twitch, but not a continuous muscle contraction (Popovic, Curt, Keller & Dietz, 2001). FES uses surface electrodes to activate paralyzed or paretic muscles, and evidence shows that with regular use partial recovery of voluntary muscle control can result (Thrasher, Flett, & Popovic, 2006). FES produces complex movements that benefit whole body systems. The main indication for using FES is a deficiency of muscle function (Vitenzon, Mironov & Petrushanskaya, 2004). Vitenzon et al. (2004) state the three main tasks of FES: 1) improving the function of weak muscles, 2) correction of improperly performed movements, and 3) acquisition of a movement habit approximating the normal. Generally, an FES system that restores motion consists of electrodes, a stimulator, a computerized control unit, and sensors (Durfee, 1999). FES lower extremity cycling is a method of facilitating exercise. Muscles are stimulated in a sequential pattern to produce a cycling motion. It has been demonstrated that FES lower extremity cycling has several potential benefits.

2.5.1 Effect of Functional Electrical Stimulation on Muscle Mass

FES lower extremity cycling has been shown to prevent loss of lean body mass in individuals with a SCI. Specifically, Baldi et al. (1998) found that FES lower extremity cycling against progressive resistance prevented a loss and caused moderate increases in lean body mass in individuals with acute SCI (< 1 year post-injury). Losses in lower limb lean body mass and gluteal lean body mass were prevented following both three and six months of training, and losses in total body lean body mass was prevented following 6 months of training. FES lower extremity cycling also significantly increased lower limb lean body mass and gluteal lean body mass following six months of training (Baldi et al., 1998). Chilibeck, Jeon, Weiss, Bell, and Burnham (1999) found that eight weeks of FES lower extremity cycling resulted in a 23% increase in mean fibre area. FES training against no resistance failed to result in changes in muscle fibre area, indicating that training may have to involve work against resistance in order to induce changes in fibre size. Muscle fibre composition was found to be predominantly type II both pre and post training (Chilibeck et al., 1999). Skold, Lonn, Harms-Ringdahl, Hultling, Levi, Nash, et al. (2002) found that leg muscle volume increased 10% as a result of six months of FES lower extremity cycling in motor complete individuals with tetraplegia.

2.5.2 Effect of Functional Electrical Stimulation on Fatigue Resistance

FES lower extremity cycling has also been shown to improve fatigue resistance in individuals with a SCI. Following six weeks of FES lower extremity cycling Gerrits, de Haan, Sargeant, Dallmeijer, and Hopman (2000) found that fatigue resistance improved, as indicated by higher forces maintained when assessed in response to 2 minutes of repetitive electrical stimulation of the quadriceps. The maximal rate of force was found to be unaffected, and speed of relaxation was found to be increased.

2.5.3 Effect of Functional Electrical Stimulation on Cardiovascular Endurance

Cardiovascular endurance has been shown to be increased as a result of FES lower extremity cycling. Heesterbeek, Berkelmans, Thijssen & van Kuppevelt (2005) found that following 4 weeks of FES hybrid cycling VO_2 peak increased 9.3%. FES hybrid exercise refers to FES exercise of the lower extremities paired with voluntary upper extremity training, such as arm ergometry. It was also demonstrated that FES hybrid cycling showed results faster than FES lower extremity cycling alone. Chilibeck et al. (1999) found that 8 weeks of FES lower extremity cycle training resulted in an increase in mean work rate during exercise from 0 watts to 5.1 $\pm$ 2.4 watts. The average total work output increased from 0kJ to 9.2 $\pm$ 4.4kJ. The duration that subjects were able to pedal continuously without assistance increased from 4.3 $\pm$ 0.7 minutes to 21.2 $\pm$ 5.6 minutes. Donaldson, Perkins, Fitzwater, Wood, and Middleton (2000) showed that following 16 months of FES lower extremity cycling the distance to fatigue increased from 1.2km to 12 km. Donaldson et al. (2000) also found that a recovery of voluntary function without stimulation occurred following FES lower extremity cycling in an individual with a chronic incomplete T11/12 injury, in the form of an increased ability to walk short distances and pick up objects off the floor more easily.

2.5.4 Effect of Functional Electrical Stimulation on Spasticity

FES lower extremity cycling may also have an effect on spasticity. Adams and Hicks (2005) stated that FES lower extremity cycling may cause a change in the mechanical properties of the spastic joint by strengthening the antagonists of the spastic muscle, or by decreasing the hyperactivity of spastic muscles through reciprocal inhibition. However, Skold et al. (2002) found no effect of training on deconditioning of spasticity following six months of training.

2.6.0 Functional Electrically Stimulated Training of the Upper Extremities

FES training of the upper extremities has thus far been mainly applied to grasping function as opposed to exercise function. Durfee (1999) stated that the focus of FES systems for the upper extremity has been on restoring hand grasp. Restoration of even a basic grasp can have a significant positive impact on function and independence throughout the day. Recently, FES arm cycle ergometry has become available. FES arm cycle ergometry involves electrical stimulation of the biceps and triceps in a sequential cycling pattern, and the stimulation of the rotator cuff muscles to provide stabilization of the upper limb. The arm cranks that are grasped by the participants are connected to a motor that can either assist as the muscles fatigue or add resistance to create greater cardiovascular challenge. FES arm cycle ergometry can be beneficial to individuals with no arm function or to individuals with some arm function who may benefit from the extra stimulation. A recent pilot study looked at the effect of 12 weeks of thrice weekly progressive FES arm cycle exercise on upper limb strength and cardiopulmonary function in individuals with C6 tetraplegia (Coupaud, Gollee, Hunt, Fraser, Allan & McLean, 2008). Coupaud et al. (2008) found that FES arm cycle ergometry resulted in an increase in peak power output for both participants in the study, and found that only one participant had an increase in peak oxygen uptake, while the other participant had no change. Coupaud et al. (2008) state that the different training effects for each individual indicates the variability of exercise responses between individuals, which may be related to the completeness of the injury. The benefits of FES arm cycle ergometry are yet to be determined, however it may serve in two capacities; 1) fill a void regarding exercise rehabilitation options, 2) may offer similar adaptations as FES cycling, such as increasing muscle function, improving cardiovascular endurance, and reducing spasticity, but in the upper extremities.

III. PURPOSE AND HYPOTHESIS

3.1.0 Statement of Purpose

The purpose of this study is to investigate the effects of twelve weeks of FES arm cycling at a frequency of 3x/week on upper limb function in individuals with chronic (≥ 1 year post-injury) tetraplegia.

3.2.0 Hypothesis

In terms of performance it was hypothesized that 12 weeks of FES upper extremity cycling would increase performance ability in the areas of time and distance cycled as well as kcal/hr expended on an exercise to fatigue cycling test. It was expected that resistance and calories burned would increase throughout the training sessions. In terms of cardiovascular function it was predicted that resting heart rate and blood pressure would decrease and that average and peak heart rate at any given workload would decrease following the twelve week training protocol. In terms of upper limb function, it was hypothesized that upper extremity function and independence levels were expected to increase following the FES training. The CUE scores of function were expected to move towards 7 (not at all limited), and the sf-QIF scores were expected to move towards a score of 4 (independent). Spasticity following twelve weeks of FES upper extremity cycling was expected to become less problematic. SCI-SET scores that started in the negative were expected to move towards 0 (no effect), and scores that started in the positive were expected not to change. Overall, after 12 weeks of FES upper extremity cycling participants were expected to demonstrate improvements in function and independence, as well as endurance.

IV. METHODOLOGY

4.1.0 Subjects

Table 1. Subject details. Age and Time Since Injury (TSI) are as at the start of participation.

Subject	Neurological Level	ASIA Grade	TSI (years)	Age (years)	Sex
1	C4	B	7	26	M
2	C5	D	20	46	M
3	C5	C	11	30	M
4	C3	D	30	58	F
5	C3	B	2	59	M

Five subjects (mean age 43.8 $\pm$ 15.4 years) with chronic SCI were recruited to participate in this study. Participants had a SCI of the cervical level (C3-C7) resulting in either complete or incomplete tetraplegia (ASIA A-D). The details for the subjects are given in Table 1. All individuals were medically stable and were at least one year post injury. Participants were recruited from the patient list of Dr. Richard McMillan of the Hotel Dieu Shaver Hospital in St. Catharines, Ontario, and from the MacWheeler exercise program at McMaster University. All participants received medical clearance by either Dr. Richard McMillan, or their family physician, before beginning the study, and had no FES training or other exercise training in the three months prior to the study. Individuals were excluded from the study if they had documented cardiovascular disease, a tracheostomy, uncontrolled autonomic dysreflexia, or any other medical condition contraindicating exercise. Participants were not asked to discontinue any of their medications during the testing or training sessions, as no medications associated with SCI are contraindicated for FES. Informed consent was obtained following medical clearance.

Participants could decline participation in the study or withdraw from the study at any time without penalty.

4.2.0 Exercise training protocol

The training protocol included a total of twelve weeks of FES arm cycling, at a frequency of three sessions per week, with 30-45 minutes of active exercise per session. A previous study has shown this volume of exercise to increase fatigue resistance in individuals with quadriplegia following 6 weeks of FES lower extremity cycling (Gerrits et al., 2000). There was 48 hours of rest between exercise sessions whenever possible. FES arm cycle ergometry was completed on the RT300 cycle ergometer (Restorative Therapies Inc., Baltimore, MD.). The RT300 consists of a six-channel stimulator. The stimulation pulses were biphasic and charge-balanced. Surface electrodes (PALS Platinum) were placed on the biceps, triceps, deltoids, and supraspinatus muscles. The stimulation pulsewidth was set at 250μs, and the stimulation frequency was set at 50Hz for the biceps and triceps electrodes and 25Hz for the shoulder electrodes. The stimulation current amplitude was variable from 0mA to 140 mA, although this study used a maximum amplitude of 50mA. Each exercise session began with a two minute passive warm up, followed by thirty minutes of active FES arm cycling, and was completed with a two minute passive cool down. Motor support assisted the active therapy when necessary, up to ten minutes in duration.

The exercise was progressed as individually tolerated by increasing the duration of exercise, followed by increasing the resistance of the arm cranks. Arm crank resistance was increased upon the completion of two exercise sessions of at least 30 minutes duration without reaching fatigue. Fatigue was reached when the muscles were no longer able to produce enough force to maintain a set level of pedalling cadence. Fatigue was set at a pedalling rate of less than 35rpm, and a maximum of five runs per session was allotted to complete a 30-45 minute exercise session (Baldi et al., 1998; Gerrits et al., 2000; Skold et al., 2002). Following fatigue a five minute rest session was completed, and then exercise began again. A pulse oximeter was applied to the right ear during exercise sessions to monitor oxygen saturation and heart rate during exercise. Participants had to maintain an exercise adherence of at least 75% for their data to be included in the analysis, meaning they were required to complete the first 18 exercise sessions within 8 weeks or they were excluded from the study, and they were required to complete at least 27 sessions within 12 weeks or their data would not be included in the final results. When sessions were missed, efforts were made to reschedule the training session to maintain three exercise sessions per week.

4.3.0 Outcome Measures

Outcome measures were both performance based and functionally based. Outcome measures pertaining to exercise performance were taken at baseline, six weeks, and upon completion of twelve weeks of FES arm cycle training. Outcome measures pertaining to cardiovascular function and upper limb function were taken at baseline and upon completion of twelve weeks of FES arm cycle training. Pre-testing took place 24-72 hours prior to the first training session. The post-testing session occurred 48-72 hours after the final training session. Post-testing occurred 48-72 hours after the final training session in order to ensure that the results were due to chronic exercise training effects as opposed to acute exercise effects. Exercise performance and cardiovascular measures were collected using the RT300 system and pulse oximeter.

4.3.1 Exercise Performance Measures

Performance based measures were collected via an exercise to fatigue test. This test was conducted at baseline, six weeks, and following the twelve weeks of training, and the resistance used for each individual was held constant for each test. These measures of performance included time to fatigue, distance cycled to fatigue, and work rate (kcal/hr expended). Performance was also measured by tracking the training sessions for changes in resistance, time to fatigue, distance to fatigue, kcal/hr expended, and total work (as measured by total calories burned).

4.3.2 Cardiovascular Performance Measures

Cardiovascular measures were conducted at baseline and following twelve weeks of FES arm ergometry exercise. Cardiovascular measures included resting heart rate, resting blood pressure, average heart rate and peak heart rate during exercise to fatigue tests, and cardiovascular efficiency ([work load] / [heart rate]) for both exercise to fatigue tests and during training sessions. Resting heart rate and blood pressure were taken prior to the exercise to fatigue test using a digital sphygmomanometer. The RT300 system collected average and peak heart rate during the exercise to fatigue tests. Average heart rate was measured as the mean heart rate throughout the exercise bout. Peak heart rate was measured as the highest heart rate achieved during the exercise bout. Cardiovascular efficiency was calculated using the work rate and average heart rate data collected by the RT300 system.

4.3.3 Upper Limb Function Measures

Functional measures included upper extremity function, the ability to use the upper limbs to complete activities of daily living, and resting self-reported muscle spasticity. Upper extremity function was measured with the Capabilities of Upper Extremity Questionnaire (CUE; Marino et al., 1998). The CUE rates 32 items on how well individuals with SCI can perform movements with their arms and hands. The left and right upper extremities are considered separately on a seven point scale, with 1 = totally limited, and 7 = not at all limited. The CUE has a high test-retest reliability (ICC=.94) (Marino et al., 1998). The ability of the upper limbs to complete activities of daily living was measured with a short form of the Quadriplegia Index of Function (sf-QIF; Marino & Goin, 1999). The sf-QIF rates six items on how independent individuals with tetraplegia are when performing activities of daily living that are dependent on upper limb function. Items are rated on a five-point scale, with 0 = dependent and 4 = independent. The interrater reliability of the QIF is good (Pearson's r=0.68 to 0.98), and the sf-QIF score and the QIF score are correlated highly (Spearman correlation = 0.978) (van Tuijl, Janssen-Potten, & Seelen, 2002). Self-reported muscle spasticity was determined by the Spinal Cord Injury Spasticity Evaluation Tool (SCI-SET; Adams, Martin-Ginis & Hicks, 2007). The SCI-SET is a seven day recall self-report questionnaire that rates how problematic or helpful the participant finds spasticity in terms of completing activities of daily living. The SCI-SET rates 35 items using a seven point scale, with – 3 = extremely problematic, 0 = no effect, and +3 = extremely helpful. Internal consistency (α=.90) and test-retest reliability (ICC=.91) are adequate for this measure, and the SCI-SET showed strong correlations with measures of self-report spasticity severity and self-assessed spasticity impact (Adams et al., 2007).

4.4.0 Data Analysis

All of the statistics were calculated using Excel and Statistica. Exercise performance measures were compared within the group using one-way repeated measures ANOVA. Tukey post hoc analysis was used to compare specific differences between means when necessary. Differences in cardiovascular performance measures and upper limb function measures were determined using student's t-tests. Statistical significance was set at $p \leq 0.05$.

V. RESULTS

Participants completed a total duration of 12 weeks of FES arm cycle ergometry training. There was an 85% exercise adherence, with participants completing 28-34 of the 36 possible FES arm ergometry training sessions. Common problems that hindered attendance were illnesses, transportation on holidays, and difficulty scheduling transportation.

5.1.0 Exercise Performance Results

5.1.1 Case Study Participant 1

Participant 1 was a 26 year old male, 7 years post C4 ASIA B spinal cord injury.

Testing Data

Participant 1 completed the FES arm cycle ergometry tests at a resistance of 1.00 Nm. Following 12 weeks of training participant 1 had an 11.7% increase in time to fatigue, 31.4% increase in distance to fatigue, and 77.2% increase in kcal/hr expended.

Training Data

Table 2. Changes in the exercise performance of participant 1 during training sessions.

Session	Active Exercise (min)	Distance (miles)	Total Work (kcal)	Work Rate (kcal/hr)	Resistance (Nm)
1	29.48	3.1	0.6	1.5	1.00
18	30.25	3.7	0.59	1.23	1.00
34	33.25	3.39	0.65	1.22	1.00

5.1.2 Case Study Participant 2

Participant 2 was a 46 year old male, 20 years post C5 ASIA D spinal cord injury.

Testing Data

Participant 2 completed the FES arm cycle ergometry tests at a resistance of 1.00 Nm. Following 12 weeks of training participant 2 had a 10.5% increase in time to fatigue, 30.9% increase in distance to fatigue, and 97.9% increase in kcal/hr expended.

Training Data

Table 3. Changes in the exercise performance of participant 2 during training sessions.

Session	Active Exercise (min)	Distance (miles)	Total Work (kcal)	Work Rate (kcal/hr)	Resistance (Nm)
1	30.24	2.95	0.55	1.25	1.00
18	30.34	3.31	0.84	1.74	1.00
28	33.29	3.68	0.96	1.88	1.00

5.1.3 Case Study Participant 3

Participant 3 was a 30 year old male, 11 years post C5 ASIA C spinal cord injury.

Testing Data

Participant 3 completed the FES arm cycle ergometry tests at a resistance of 4.08 Nm. Following 12 weeks of training participant 3 had a 289.6% increase in time to fatigue, 336.9% increase in distance to fatigue, and 77.2% increase in kcal/hr expended.

Training Data

Table 4. Changes in the exercise performance of participant 3 during training sessions.

Session	Active Exercise (min)	Distance (miles)	Total Work (kcal)	Work Rate (kcal/hr)	Resistance (Nm)
1	45.00	8.06	5.67	7.56	1.98
18	36.13	4.79	4.02	8.18	4.08
28	45.00	7.44	18.28	24.38	7.02

5.1.4 Case Study Participant 4

Participant 4 was a 58 year old female, 30 years post C3-5 ASIA D spinal cord injury.

Testing Data

Participant 4 completed the FES arm cycle ergometry tests at a resistance of 1.00 Nm. Following 12 weeks of training participant 4 had an 87% increase in time to fatigue, 78.3% increase in distance to fatigue, and a 5.5% decrease in kcal/hr expended.

Training Data

Table 5. Changes in the exercise performance of participant 4 during training sessions.

Session	Active Exercise (min)	Distance (miles)	Total Work (kcal)	Work Rate (kcal/hr)	Resistance (Nm)
1	45.00	6.07	2.2	5.2	1.00
18	45.00	8.21	18.6	23.8	6.04
32	38.5	5.13	12.7	16.3	7.16

5.1.5 Case Study Participant 5

Participant 5 was a 59 year old male, 2 years post C3 ASIA B spinal cord injury.

Testing Data

Participant 5 completed the FES arm cycle ergometry tests at a resistance of 1.00 Nm. Following 12 weeks of training participant 5 had a 0.3% decrease in time to fatigue, a 13.3% decrease in distance to fatigue, and no change in work rate.

Training Data

Table 6. Changes in the exercise performance of participant 5 during training sessions.

Session	Active Exercise (min)	Distance (miles)	Total Work (kcal)	Work Rate (kcal/hr)	Resistance (Nm)
1	33.26	2.5	0.5	0.9	1.00
18	33.24	2.15	0.3	0.6	1.00
31	33.26	2.06	0.3	0.5	1.00

5.1.6 Exercise Performance Group Data

Analysis of variance demonstrated no significant main effect for any measure of exercise performance. Figure 1 demonstrates time to fatigue in seconds at the baseline, 6 week, and 12 week exercise to fatigue testing sessions. Time to fatigue showed an increase of 84.4% following 12 weeks of FES arm cycle ergometry training (p=0.22). This was non-significant. Figure 2 demonstrates changes in distance to fatigue in miles at baseline, 6 week, and 12 week exercise to fatigue testing sessions. Distance to fatigue showed an increase of 111.7% following 12 weeks of FES arm cycle ergometry training (p=0.28). This was non-significant. Figure 3 demonstrates changes in work rate in kcal/hr expended at baseline, 6 week, and 12 week exercise to fatigue testing sessions. Work rate showed an increase of 51.3% following 12 weeks of FES arm cycle ergometry training (p=0.35). This was non-significant.

5.2.0 Cardiovascular Performance Results

5.2.1 Case Study Participant 1

Following 12 weeks of training participant 1 had a 2.9% decrease in mean arterial pressure (MAP), and a 6.6% increase in resting HR. Average HR during the exercise to fatigue test did not change following 12 weeks of training. However, Peak HR increased from 79bpm to 89bpm, and cardiovascular efficiency increased 76.5% (0.017kcal/hr/HR to 0.03 kcal/hr/HR) following 12 weeks of training. At both training session 1 and session 34 cardiovascular efficiency reached a highest level of 0.019 kcal/hr/HR.

5.2.2 Case Study Participant 2

Following 12 weeks of training participant 2 had a 2.1% decrease in MAP and no change in resting HR. Average HR during the exercise to fatigue test decreased from 63bpm to 61bpm, peak HR decreased from 68bpm to 65bpm, and cardiovascular efficiency increased 106.7% (0.015kcal/hr/HR to 0.031kcal/hr/HR) following the 12 weeks of training. Throughout the training sessions cardiovascular efficiency changed from 0.02kcal/hr/HR during session 1, to 0.03kcal/hr/HR during session 28.

5.2.3 Case Study Participant 3

Following 12 weeks of training there was a 2.1% decrease in MAP, and a 6.5% increase in resting HR. Average HR during the exercise to fatigue test decreased from 96bpm to 84 bpm, peak HR decreased from 107bpm to 102bpm, and cardiovascular efficiency increased 377.3% (0.044kcal/hr/HR to 0.21kcal/hr/HR) following the 12 weeks of training. Throughout the training sessions cardiovascular efficiency changed from 0.083kcal/hr/HR during session 1, to 0.23kcal/hr/HR during session 28.

5.2.4 Case Study Participant 4

Following 12 weeks of training there was an 8.1% decrease in MAP, and an 11.4% increase in resting HR. Average HR during the exercise to fatigue test decreased from 84bpm to 80bpm, peak HR decreased from 96bpm to 85bpm, and cardiovascular efficiency decreased 1.6% (0.064kcal/hr/HR to 0.063kcal/hr/HR) following the 12 weeks of training. Throughout the training sessions cardiovascular efficiency changed from 0.073kcal/hr/HR during session 1, to 0.24kcal/hr/HR during session 32.

5.2.5 Case Study Participant 5

Following 12 weeks of training there was a 5% decrease in MAP, and no change in resting HR. Average HR during the exercise to fatigue test increased from 80bpm to 92bpm, peak HR increased from 89bpm to 97bpm, and cardiovascular efficiency increased from 0kcal/hr/HR to 0.0054kcal/hr/HR following the 12 weeks of training. Throughout the training sessions cardiovascular efficiency changed from 0.008kcal/hr/HR during session 1 to 0.006kcal/hr/HR during session 31.

5.2.6 Cardiovascular Performance Group Data

Figure 4 shows the change in resting MAP (mmHg) before and after the 12 week training program. There was a significant 3.7% reduction in resting MAP following training ($p=0.027$). Figure 5 shows the changes in resting HR (bpm) at the baseline and at the 12 week exercise to fatigue tests. Resting HR increased 4.8%, but this change was not statistically significant ($p=0.12$). Average HR (79.4 ± 12.19 vs. 78.2 ± 11.63bpm; $p=0.77$) and peak HR (87.8 ± 15.06 vs. 87.6 ± 14.28bpm; $p=0.96$) during the exercise to fatigue tests did not significantly change. Figure 6 shows the change in cardiovascular efficiency (kcal/hr/HR) at baseline and 12 week exercise to fatigue tests. Cardiovascular efficiency increased 142.9% following the 12 weeks of training; however this was not a statistically significant change ($p=0.28$).

5.3.0 Upper Limb Function Results

5.3.1 Case Study Participant 1

Participant 1 showed a 17% increase in the overall CUE scores. When considering the subsets of the CUE by muscle group, participant 1 showed an 84.6% increase in shoulder function scores, a 7.7% decrease in biceps function scores, and a 4.2% increase in triceps function scores. Participant 1 showed a 100.3% increase in the sf-QIF scores, and had a 9.9% increase in SCI-SET total scores, with an 8.8% increase in the questions relating to arm spasticity.

5.3.2 Case Study Participant 2

Participant 2 showed a 15.8% decrease in the overall CUE scores. When considering the subsets of the CUE by muscle group, participant 2 showed a 20.7% decrease in shoulder function scores, a 38.5% decrease in biceps function scores, and a 12.5% decrease in triceps function scores. Participant 2 showed a 100% decrease in the sf-QIF scores, and had a 3.1% increase in SCI-SET scores, with a 4.4% increase in the questions relating to arm spasticity.

5.3.3 Case Study Participant 3

Participant 3 showed a 1.3% increase in the overall CUE scores. When considering the subsets of the CUE by muscle group, participant 3 showed an 8.8% decrease in shoulder function scores, and no change in biceps or triceps function scores. Participant 3 showed a 35.9% increase in the sf-QIF scores, and had a 2.4% decrease in SCI-SET scores, with a 1.1% decrease in the questions relating to arm spasticity. Notable changes in participant 3 included a change from being able to turn supine to side in bed with an assistive device, to turning supine to side in bed without an assistive device. Participant 3 also changed from requiring supervision to transfer from bed to chair to being able to transfer from bed to chair independently without a device.

5.3.4 Case Study Participant 4

Participant 4 showed a 35.9% increase in the overall CUE scores. When considering the subsets of the CUE by muscle group, participant 4 showed a 42.1% increase in shoulder function scores, a 10% increase in biceps function scores, and an 18.2% increase in triceps function scores. Participant 4 showed a 4.7% increase in the sf-QIF scores, and had a 25.2% increase in SCI-SET scores, with a 20.6% increase in the questions relating the arm spasticity. Notable changes in participant 4 included a change from being able to transfer from bed to chair using an assistive device to transferring from bed to chair without an assistive device.

5.3.5 Case Study Participant 5

Participant 5 showed a 5.5% decrease in the overall CUE scores. When considering the subsets of the CUE by muscle group, participant 5 showed a 14.3% decrease in shoulder function scores, a 14.3% decrease in biceps function scores, and a 12.5% decrease in triceps function scores. Participant 5 showed no change in the sf-QIF scores, and had a 1.7% decrease in SCI-SET scores, with a 2.4% decrease in the questions relating to arm spasticity.

5.3.6 Upper Limb Function Group Data

No significant changes were found in upper limb function. Figure 7 shows the change in the total CUE score at baseline and following the 12 weeks of training. The total CUE score increased 6.7% (119.6 $\pm$ 49.4 vs. 127.6 $\pm$ 54.2; p=0.54) following the 12 weeks of FES training. When considering the subsets of the CUE by muscle group, shoulder function showed an increase of 8.8% (20.4 $\pm$ 11.13 vs. 22.2 $\pm$ 9.58; p= 0.61; Fig.8), biceps function decreased 10.5% (p=0.34; Figure 9), and triceps function decreased 3.4% (p=0.59; Figure 10). These changes were non-significant. Figure 11 shows the change in QIF total scores at baseline and following the 12 weeks of training. The QIF scores showed an increase of 18% (7.8 $\pm$ 9.8 vs. 9.2 $\pm$ 10.9; p=0.25). This was non-significant. For the QIF question pertaining to turning from supine to side in bed there was an increase in average score from 1.2 to 1.4 (p=0.37), and for the question pertaining to transferring from bed to chair there was an increase in average score from 1 to 1.6 (p=0.21). Figure 12 shows the change in SCI-SET total scores at baseline and following the 12 weeks of FES training. The SCI-SET scores showed an increase of 5.9% (122.6 $\pm$ 14.9 vs. 129.8 $\pm$ 9.2; p=0.23). This was non-significant. Specifically, there was a 5.4% increase in questions pertaining to arm spasticity. The SCI-SET scores spasticity as having either a negative effect, no effect, or a positive effect on ADL's and quality of life. A desired effect would be for negative scores to move towards having no effect or a positive effect, and for positive scores to remain unchanged. With regards to spasticity having a negative vs. positive effect, the vast majority of scores started in the negative, but only made a non-significant shift towards zero (-0.43 $\pm$ 0.48 vs. -0.29 $\pm$ 0.26; p=0.44), following the 12 weeks of FES arm cycle ergometry. Of the 5 participants, only

2 had any pre-test SCI-SET scores indicating that spasticity had a positive effect on their functioning. A total of 5 scores (of a possible 175) began with a positive score, and following the 12 weeks of FES arm cycle ergometry training these items showed a decrease, which was non-significant (1.0 ± 0.0 vs. 0.8 ± 1.3; $p=0.75$). A shift of this kind indicates a loss in functional spasticity. Participant 1 gave a positive rating to the items pertaining to showering, positioning while lying down, and the ability to change positions in bed. Following the 12 weeks of FES training participant 1 showed an increase in spasticity's assistance to showering, but showed a decrease to the point of spasticity having no effect on his ability to position himself while lying down and change his position in bed. Participant 3 gave a positive rating to the items pertaining to transfers and therapy/exercise. Following the 12 weeks of FES training participant 3 showed no change in spasticity's assistance to transferring, but showed a decrease to the point of spasticity having no effect on his ability to participate in therapy/exercise.

VI. DISCUSSION

The main findings of the present study are a significant decrease in MAP, and increases in exercise performance and upper limb function which were non-significant. The small sample size may be responsible for the non-significant results in exercise performance and upper limb function. Notable changes include an increase in CUE scores and QIF scores following the 12 weeks of FES arm cycle ergometry training, indicating an increase in the functional use of the upper limbs.

6.1.0 Exercise Performance

The mean time to fatigue showed an increase of 84.4% following the 12 weeks of FES arm cycle ergometry training. This was non-significant, but suggests a change in the upper limb muscles fatigue resistance. This finding agrees with previous results of FES leg cycle ergometry training. For example, Chilibeck et al. (1999) found that 8 weeks of FES leg cycle ergometry increased the duration participants were able to pedal, and Gerrits et al. (2000) found that fatigue resistance was improved following 6 weeks of FES leg cycle ergometry training, as indicated by maintaining higher forces in response to repetitive electrical stimulation. In the present study Participant 3 and participant 4 showed a greater increase in time to fatigue than other participants, and also increased the resistance they were pedalling against. These participants had motor incomplete ASIA grades, meaning they had higher functional ability prior to the study, which may have meant they needed less assistance from the FES. These participants may have had been able to pedal longer before fatiguing because they could pedal without assistance from the bike for a portion of the exercise. Participant 2 also had a motor incomplete ASIA score, however only increased his time to fatigue slightly, and did not progress from his initial resistance. This could have been because he had a high level of sensation, which limited how much stimulation he could receive. Participant 1 and participant 5 also only improved their time to fatigue slightly, which may be attributed to the fact that they were graded ASIA B. Individuals with an ASIA score of A or B have the ability to improve muscle mass, however they do not have the ability to activate the muscle, meaning they can only improve involuntary strength. Individuals with an ASIA score of C or D can improve both voluntary and involuntary strength. Both participant 1 and participant 5 needed motor assistance to complete the required bouts of exercise, meaning that the stimulation was not enough to assist them in pedaling against resistance. There was however no correlation between pre-existing functional ability and the results.

The mean distance to fatigue showed an increase of 111.7% following the 12 weeks of FES arm cycle ergometry training. This was non-significant. This agrees with the findings of Donaldson et al. (2000), who showed that 16 months of FES leg cycle ergometry produced an increase in distance to fatigue pedalled. Participant 3 and participant 4 had higher increases in distance pedalled than the other participants. This is consistent with the increase these participants had in time to fatigue, and may be attributed to the participants' ASIA scores (C&D). Participant 1 and participant 2 also experienced an improvement in distance to fatigue following the training protocol, however, their relative increase in distance to fatigue was greater than their relative increase in time to fatigue, indicating that they were pedalling harder or faster during the duration of exercise. Participant 5 had a decrease in distance to fatigue overall. It should be noted that participant 5 was receiving physiotherapy until training session 3, which then was stopped due to a flu outbreak at the hospital. Distance to fatigue then began to decrease, and stiffness in the upper limbs increased. However, there was an increase from the 6 week testing to the post testing, indicating that the FES arm cycle ergometry may have been causing an improvement.

The mean work rate (kcal/hr) showed an increase of 51.3% following the 12 weeks of FES arm cycle ergometry training. This was non-significant. This increase in work rate agrees with previous arm cycle ergometry studies. Hicks et al. (2003) found that following 9 months of exercise training including manual arm ergometry there was a significant increase in submaximal arm ergometry power output of 81%. Arm ergometry without the FES component could produce results similar to FES arm cycle ergometry, however individuals with lower levels of upper limb function may not be able to pedal the bike unassisted. Coupaud et al. (2008) found that power output (W) increased following 12 weeks of FES arm cycle ergometry, which would indicate an increase in work rate. FES leg cycle ergometry also has been found to cause increases in work rate. For example, Chilibeck et al. (1999) found an increase in average total work output (kJ) from 0 to 9.2 $\pm$ 4.4kJ following 8 weeks of FES leg cycle ergometry.

6.2.0 Cardiovascular Performance

The mean resting MAP (mmHg) showed a significant decrease following the 12 weeks of FES arm cycle ergometry. This differs from the findings of Hicks et al. (2003), which showed no change in systolic or diastolic blood pressure following 9 months of exercise training including arm cycle ergometry. The training protocols used in these studies differed in that Hicks et al. (2003) included only 2 training sessions per week, and included strength training along with 15-30 minutes of submaximal arm cycle ergometry, while in the current study participants completed 3 sessions per week of at least 30 minutes of exercise. The higher concentration of exercise bouts in the current study may have been necessary for the change in blood pressure. Individuals with a spinal cord injury are at an increased risk for cardiovascular disease. Heart disease is the second leading cause of death among individuals with a spinal cord injury (Devivo, Black, & Stover, 1993). The risk of cardiovascular disease is increased by high blood pressure, and decreased by lowering blood pressure. FES arm cycle ergometry decreases MAP, thus may be effective at reducing the risk of developing cardiovascular disease in individuals with tetraplegia. Devivo et al. (1993) suggested that increasing exercise participation would have a greater impact on the life expectancy of individuals with a spinal cord injury than the general population, due to the effect exercise has on assisting in the prevention of heart disease. FES arm cycle ergometry could provide a means of cardiovascular exercise for individuals who have limited arm function, and has the potential to increase the life expectancy of individuals with tetraplegia due to its effect on blood pressure.

The mean resting HR (bpm) showed an increase following the 12 weeks of FES arm cycle ergometry. This was non-significant. This agrees with the findings of Hicks et al. (2003) which found no change in resting HR following 9 months of exercise training. Average and peak HR during the exercise to fatigue tests did not significantly change. This differs from the findings Hicks et al. (2003), which found a significant increase in HR during the 9 month arm cycle testing session. Average and peak HR during the exercise to fatigue tests may have remained constant due to the fact that while the heart may have been more efficient, the work they were doing was increasing, so no effect was seen. This relates to cardiovascular efficiency. Mean cardiovascular efficiency (kcal/hr/HR) showed an increase following the 12 weeks of FES arm cycle ergometry training. This was non-significant. This indicates that participants could perform more work at a given HR after the 12 weeks of FES arm cycle ergometry training than at baseline. Hicks et al. (2003) looked at the relationship between HR and power output and also found that 9 months of exercise training produced greater cardiovascular efficiency (as measured by a significant decline in the HR/W ratio), and also found that individuals with tetraplegia experienced a greater decrease in the HR for a given power output than individuals with paraplegia.

6.3.0 Upper Limb Function

The mean total CUE score showed an increase of 6.7% following the 12 weeks of FES arm cycle ergometry. This was non-significant. This finding could indicate an increase in upper limb strength, which would agree with Hicks et al. (2003) finding that arm cycle ergometry paired with resistance training increased upper body muscle strength following 9 months of training. Hicks et al. (2003) also found that participants had higher levels of satisfaction with their physical functioning following the exercise training. Donaldson et al. (2000) found an increase in voluntary muscle function following FES leg cycle ergometry, in terms of an increased ability to walk. FES arm cycle ergometry may therefore increase voluntary muscle function in the upper limbs, leading to an increase in function, as indicated by the large but non-significant increase in CUE scores in the present study. There has been evidence that FES leg cycle ergometry causes changes in muscle (Skold et al., 2002; Baldi et al., 1998; Chilibeck et al., 1999), however these studies did not investigate putative functional changes. The mean shoulder function as indicated by the CUE showed an increase of 8.8% following the 12 weeks of FES arm cycle ergometry, while biceps CUE scores showed a decrease of 10.5%, and triceps CUE scores showed a decrease of 3.4%. These changes were non-significant. This is an unexpected result, as the shoulder stimulation with the RT300 is intended for support of the shoulder joint during FES arm cycle ergometry, as opposed to the biceps and triceps stimulation which is used for the actual pedalling of the bike against resistance. It was hypothesized that limb function would increase, as was indicated by the overall CUE score, however it was also expected that biceps and triceps function would show relatively more improvement than the deltoids.

The mean total QIF scores showed an increase of 18% following the 12 weeks of FES arm cycle ergometry. This was non-significant. Participant 2 showed a decrease in QIF scores, and participant 5 showed no change. As stated before, participant 2 had high sensation levels, and could not handle high levels of stimulation, so may not have seen changes in muscle strength and function. Participant 5 has a high level ASIA score, which could decrease his capacity for improvement. Participant 1 and participant 3 had a greater level of improvement than participant 4. Looking at the initial scores for the QIF it is apparent that participant 4 had a high level of functioning before the training began. This means that there may not have been a lot of room for improvement, indicating a possible ceiling effect. Participant 1 and participant 3 experienced greater increases in QIF scores than the other participants perhaps because they were at the optimal level for improvement, such that they had both the capacity and room for improvement. Looking specifically at the questions pertaining to upper limb function, participant 3 experienced an increase in the ability to turn from supine to side in bed, and participant 3 and participant 4 experienced an increase in the ability to transfer from bed to chair. Functionally, even a small improvement in the ability to reposition in bed or transfer from bed to chair can cause a large improvement in quality of life. Repositioning in bed is important for pressure relief, and could prevent the complications associated with pressure sores, while going from the need for a transfer device to being able to transfer by oneself would increase independence.

The mean total scores on the SCI-SET showed an increase of 6.7%. This was non-significant. Previous studies involving FES training have found no effect on spasticity (Skold et al., 2002); however Adams and Hicks (2005) suggested that FES leg cycle ergometry may have an effect. Adams and Hicks (2005) predicted that properties of the spastic joint may be changed by strengthening the antagonist muscle. The current study cannot discount this theory, as no measures of strength were included, and the necessary gains in strength may not have been accomplished. As spasticity can have either a negative or positive effect on functional ability, it was hypothesized that the baseline SCI-SET scores indicating a negative effect would increase, and scores indicating a positive effect would stay the same. The mean total scores for the SCI-SET did show an increase in those items that were initially negative (thus moving towards the result of spasticity having no effect), however, the few scores that were initially positive also showed a decrease towards the result of spasticity having no effect. These changes were non-significant. Specifically, before the FES arm cycle ergometry training, participant 1 indicated that spasticity assisted with his positioning while lying down, and his ability to change positions while in bed, while after the training he found that his spasticity had no effect on these functions. Participant 3 found that prior to the FES training his spasticity assisted with his ability to participate in therapeutic and exercise activities, and after training he found that his spasticity had no effect on his ability to complete these functions. Both the positive and negative effects of spasticity were found to move towards spasticity having no effect on function. To our knowledge this is the first use of the SCI-SET before and after an exercise intervention. It suggests that exercise may not always change muscle spasticity in a way that improves function, and more research is warranted. It is also important to note that the individual changes on certain items of the SCI-SET could be due to an actual exercise-induced decrease in spasticity, or just a change in the way spasticity interacted with functional movements (such as a change in timing or predictability of spasms). As no measure of spasticity was included in this study, we cannot determine which was the main cause for the observed changes.

6.4.0 Relevance to the Current Literature & Clinical Relevance

As FES arm cycle ergometry is a relatively new technology, there is little evidence of its effects. Coupaud et al. (2008) did a pilot study that looked only at individuals with a C6 spinal cord injury. The aim of the study was to determine the effects of FES arm cycle ergometry training on upper limb strength and cardiopulmonary fitness. Coupaud et al. concluded that FES arm cycle ergometry training had the potential to improve upper limb strength and cardiopulmonary fitness in some individuals with tetraplegia. Coupaud et al. (2008) stated that "The completeness of the injury, degree of disuse and denervation atrophy of the upper limb muscles prior to training, and the level of motivation behind the individual, are all likely to influence the potential for training effects in this group". The findings of the current study are complement to the findings of Coupaud et al. (2008) as they both suggest that FES arm cycle ergometry may be more beneficial for some participants than others based on the completeness of the injury and pre-existing function.

The results of the present study are important for individuals with tetraplegia due to the implications for the prevention of secondary health complications. The findings of this study show that FES arm cycle ergometry can be a beneficial form of cardiovascular exercise for individuals with tetraplegia. This is important for decreasing the risk of developing cardiovascular disease in this population. FES arm cycle ergometry may have the potential to improve upper limb function in individuals who have the capacity for improvement, depending on the completeness and level of injury, and pre-existing function. By improving upper limb function, individuals with tetraplegia could experience an increase in quality of life, based on their increased mobility, which results in a decrease in the risk for pressure sores, and increased independence.

6.5.0 Limitations

The main limitation of this study was the small number of participants. The current study included a good distribution of participants, and future large scale studies should continue to include a range of participants with regards to sex, age, level of injury, and completeness of injury. This would have given a better field for determining whether there was is a correlation between injury level and completeness and increases in upper limb function. This study did not include any participants with an ASIA A classification, so the results of this study may not be valid for these individuals. Another limitation of the study was that a duration of 12 weeks of training was used as the completion point, as opposed to the completion of 36 training sessions. This was done because of the need to complete the training of some participants before holidays where lab access was not available, and the participants were not available. It would have been beneficial to have an equal number of sessions for each participant for analysis purposes, and some participants may not have reached the levels of improvement they had the potential to reach. With regards to upper limb function, the measures used were self-reporting questionnaires. This creates the potential for over or under reporting the benefits of function on spasticity. Questionnaires also are limited by ceiling effects, meaning that no improvement will be seen in individuals who have high scores to begin with, which limits the potential for significant change. The SCI-SET questionnaire was the only measure pertaining to spasticity in this study, and it only looked at the effect of spasticity on function. A limitation is that we have no data on whether the participants had any pre-existing spasticity, and if they did not experience spasticity at any point, this would also limit the potential for significant change.

6.6.0 Future Directions

Further study is needed to determine the potential benefits of FES arm cycle ergometry on the upper limbs. Measures to determine changes in the upper limb muscles, such as manual muscle testing and muscle biopsies to look for changes in the muscle fibres would determine if FES arm cycle ergometry has effects on muscle similar to FES leg cycle ergometry. A measure of muscle spasticity, such as the Ashworth scale, should also be done in conjunction with the SCI-SET to determine if FES arm cycle ergometry elicits changes in the spastic muscle, not just the effect on function. Further study to determine which specific groups would benefit from FES arm cycle ergometry should be done, as individuals should be aware before beginning an exercise program what positive or negative effects to expect. While Coupaud et al. (2008) showed changes in cardiopulmonary function following 12 weeks of FES arm cycle ergometry, these results were specific to individuals with a C6 spinal cord injury. Further study should be done into the effects of FES arm cycle ergometry on cardiopulmonary measures.

VII. CONCLUSION

The current study shows that 12 weeks of FES arm cycle ergometry results in a significant decrease in resting MAP in individuals with an incomplete spinal cord injury. FES arm cycle ergometry could be an effective exercise technique for decreasing the risk of cardiovascular disease in this population, due to the decrease in MAP. Exercise performance showed a non-significant increase in the areas of time to fatigue, distance to fatigue, and work rate. These results could have been found to be non-significant due to the small sample size. FES arm cycle ergometry may also result in improvements in upper limb function and spasticity, depending on the level and completeness of injury. Future research into the effect of FES arm cycle ergometry on muscle and strength in the upper limbs should be done, and large scale studies should be done on the effect of FES arm cycle ergometry on cardiovascular health in individuals with tetraplegia.

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XI. FIGURES

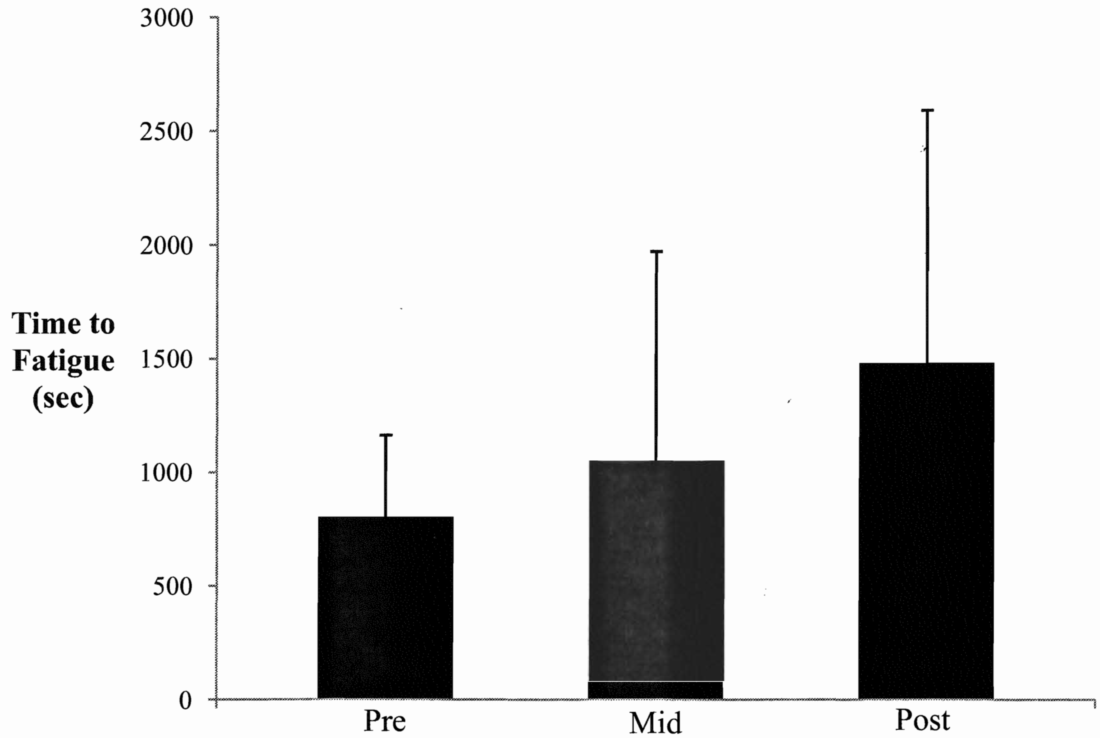


Fig. 1. Time to fatigue (sec) during exercise to fatigue tests taken at baseline (pre), 6 weeks (mid), and following 12 weeks (post) of FES arm cycle ergometry training in individuals with tetraplegia.

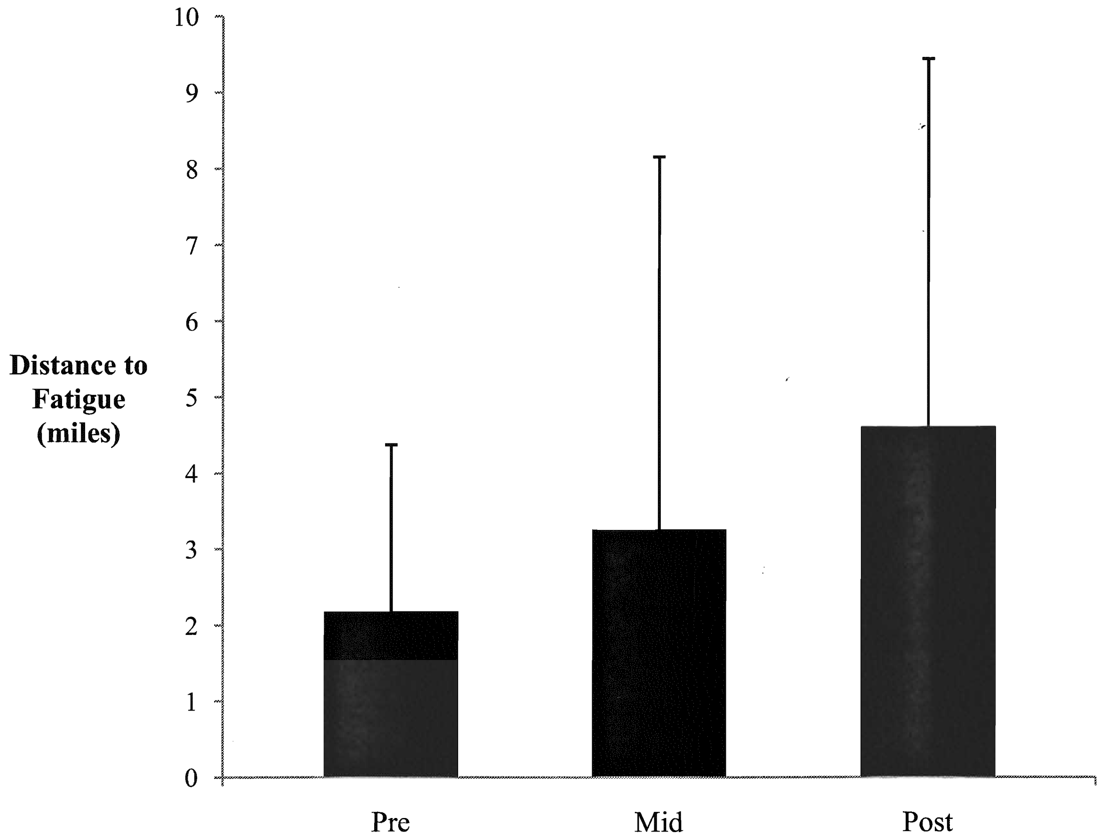


Fig. 2. Distance to fatigue (miles) during exercise to fatigue tests taken at baseline (pre), 6 weeks (mid), and following 12 weeks (post) of FES arm cycle ergometry training in individuals with tetraplegia.

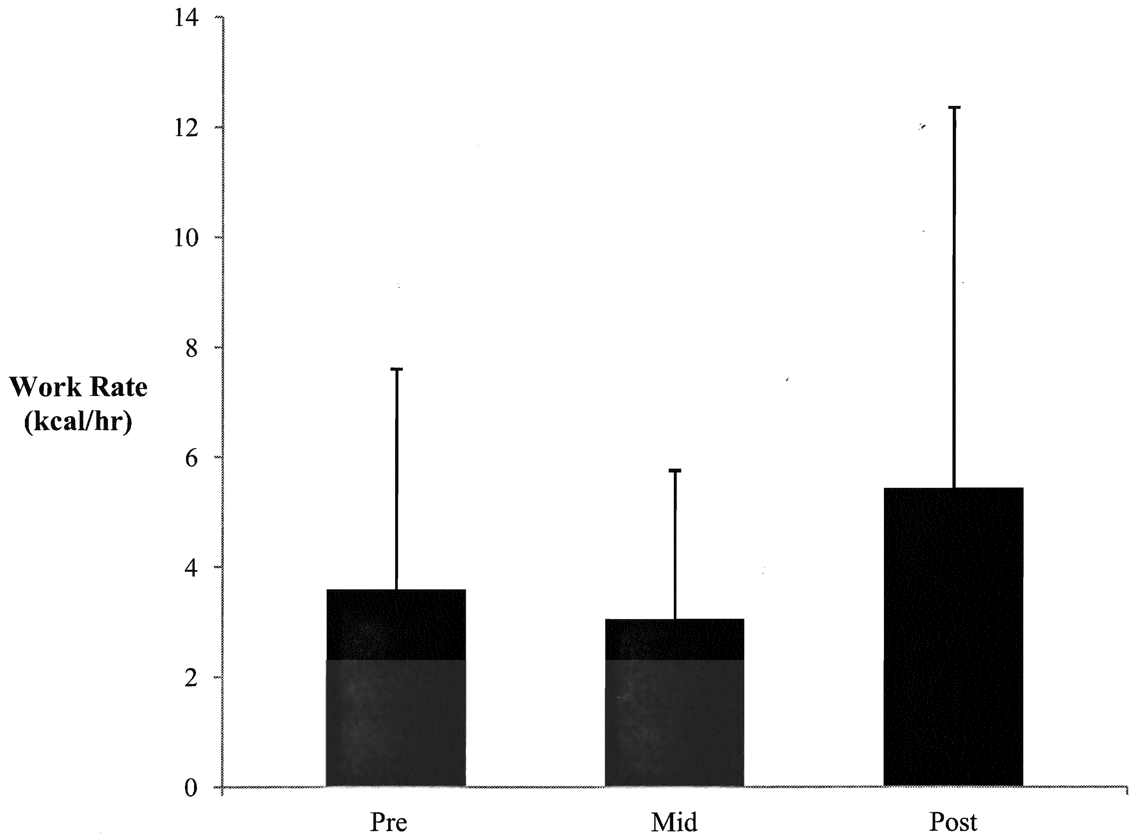


Fig. 3. Work rate (kcal/hr) during exercise to fatigue tests taken at baseline (pre), 6 weeks (mid), and following 12 weeks (post) of FES arm cycle ergometry training in individuals with tetraplegia.

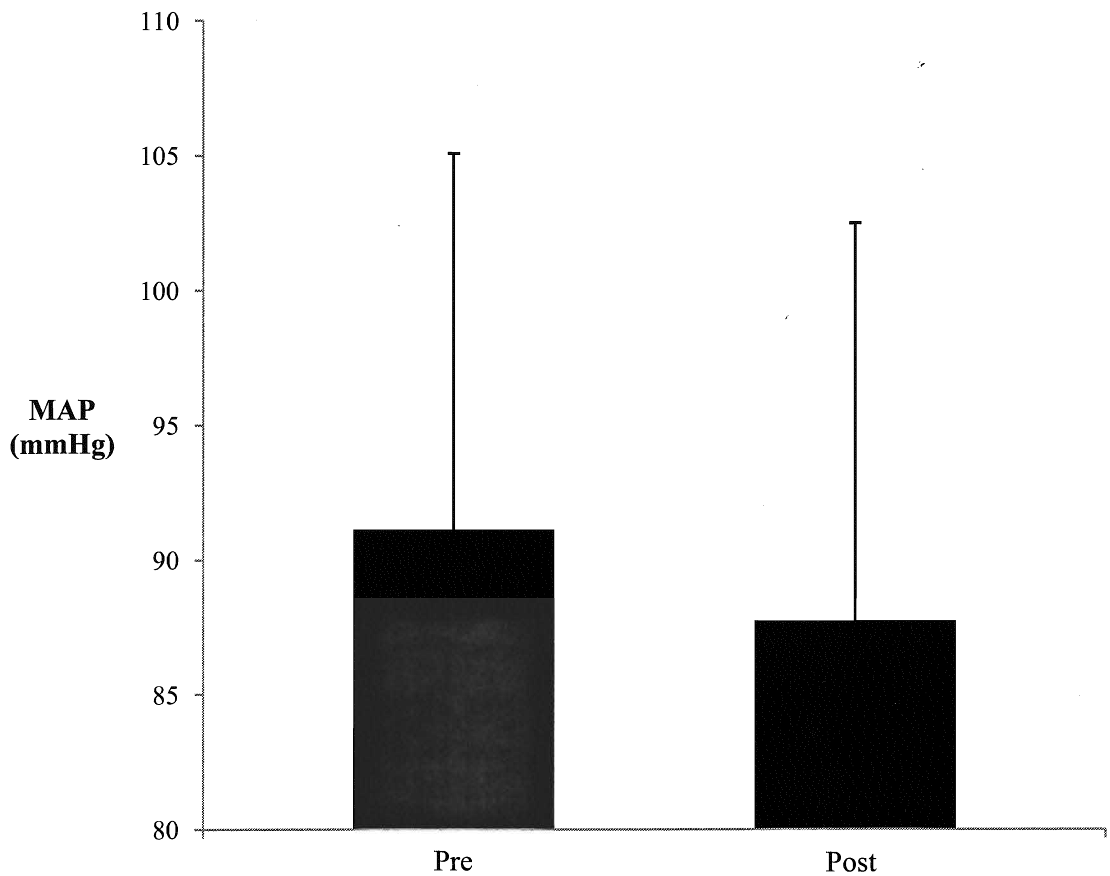


Fig. 4. Mean Arterial Pressure (mmHg) at exercise to fatigue tests taken at baseline and following 12 weeks (post) of FES arm cycle ergometry training in individuals with tetraplegia.

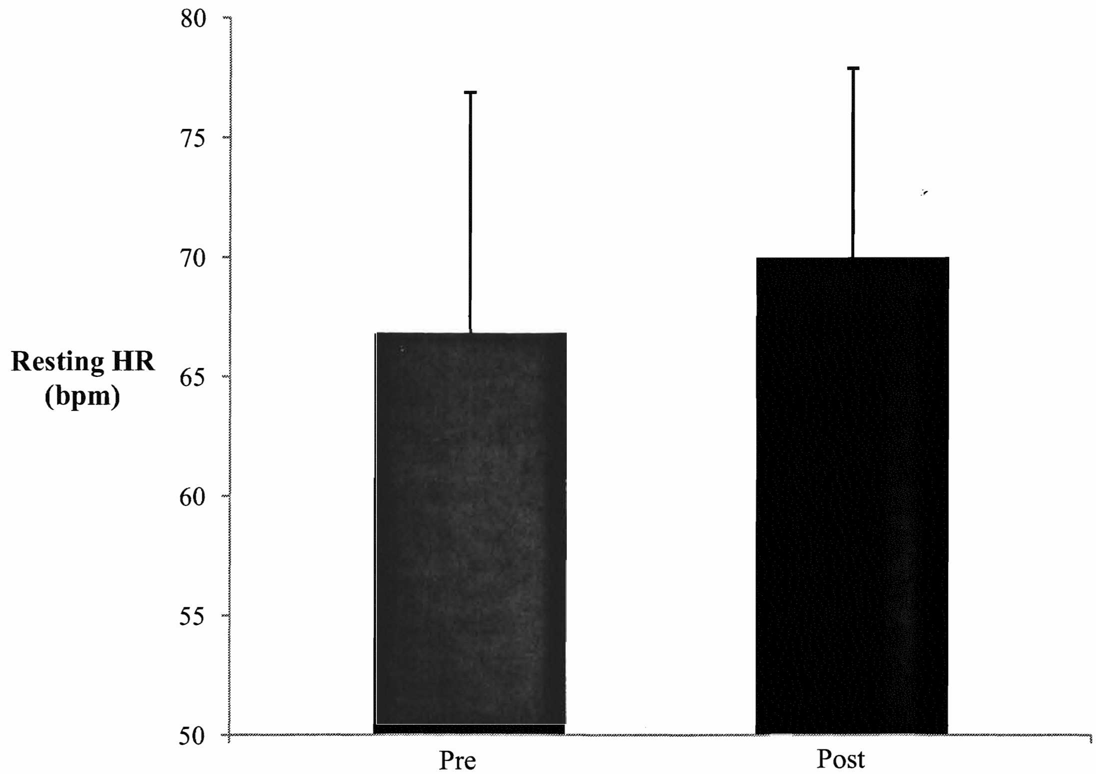


Fig. 5. Resting heart rate (bpm) at exercise to fatigue tests taken at baseline (pre), and following 12 weeks (post) of FES arm cycle ergometry in individuals with tetraplegia.

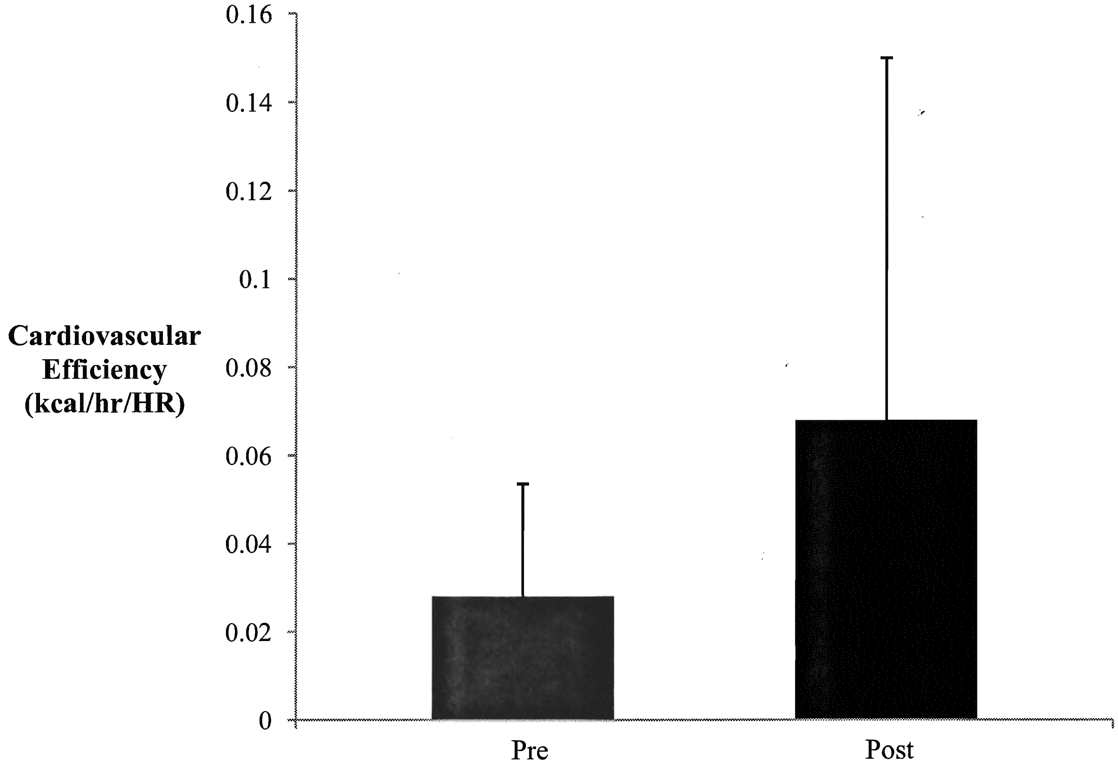


Fig. 6. Work intensity (kcal/hr/HR) during exercise to fatigue tests taken at baseline (pre) and following 12 weeks (post) of FES arm cycle ergometry training in individuals with tetraplegia.

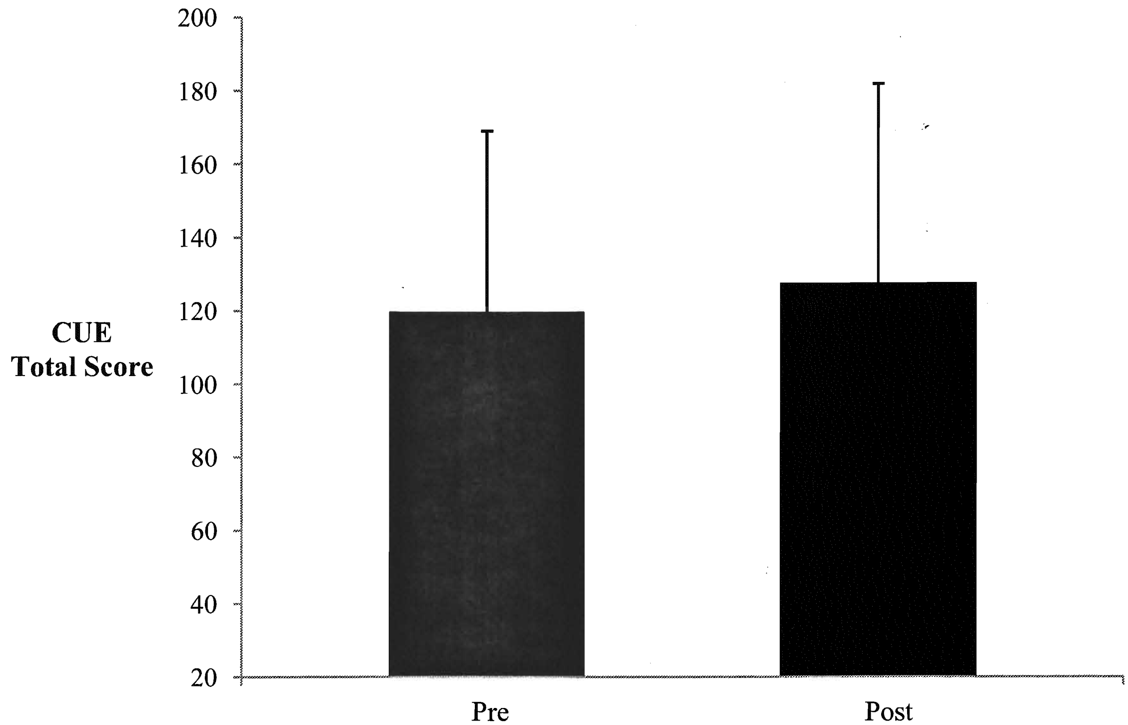


Fig. 7. Capabilities of Upper Extremity Questionnaire scores taken at baseline (pre) and following 12 weeks (post) of FES arm cycle ergometry in individuals with tetraplegia.

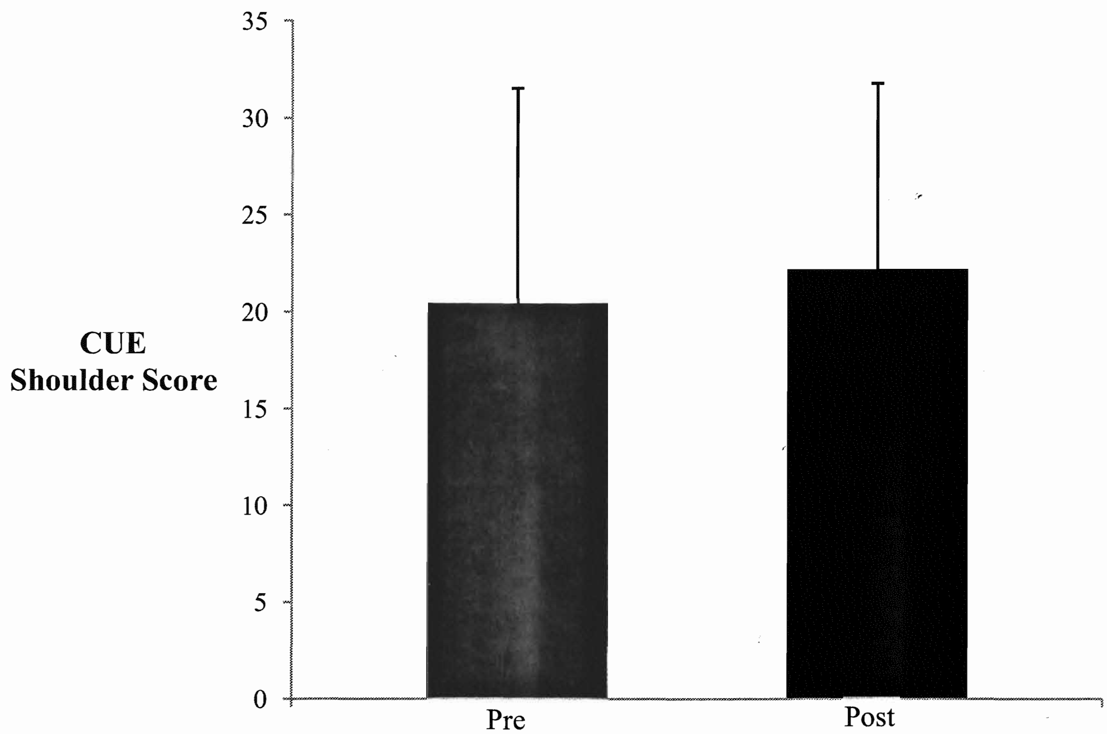


Fig. 8. Capabilities of Upper Extremity Questionnaire shoulder function scores taken at baseline (pre) and following 12 weeks (post) of FES arm cycle ergometry in individuals with tetraplegia.

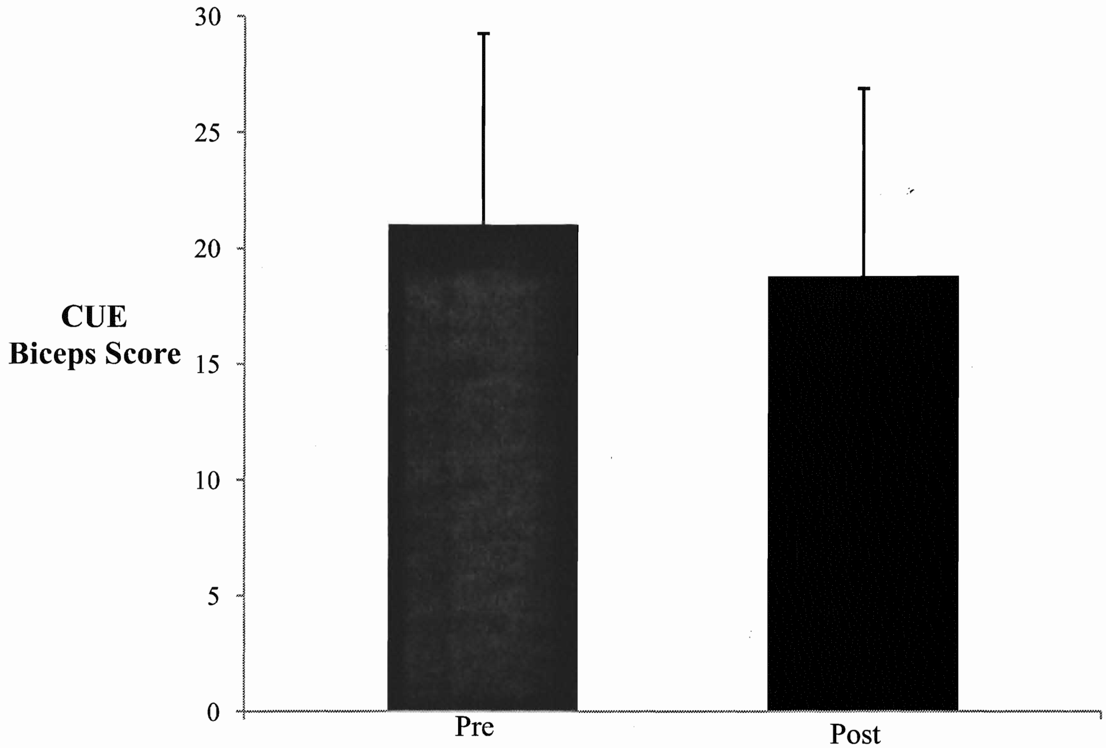


Fig. 9. Capabilities of Upper Extremity Questionnaire biceps function scores taken at baseline (pre) and following 12 weeks (post) of FES arm cycle ergometry in individuals with tetraplegia.

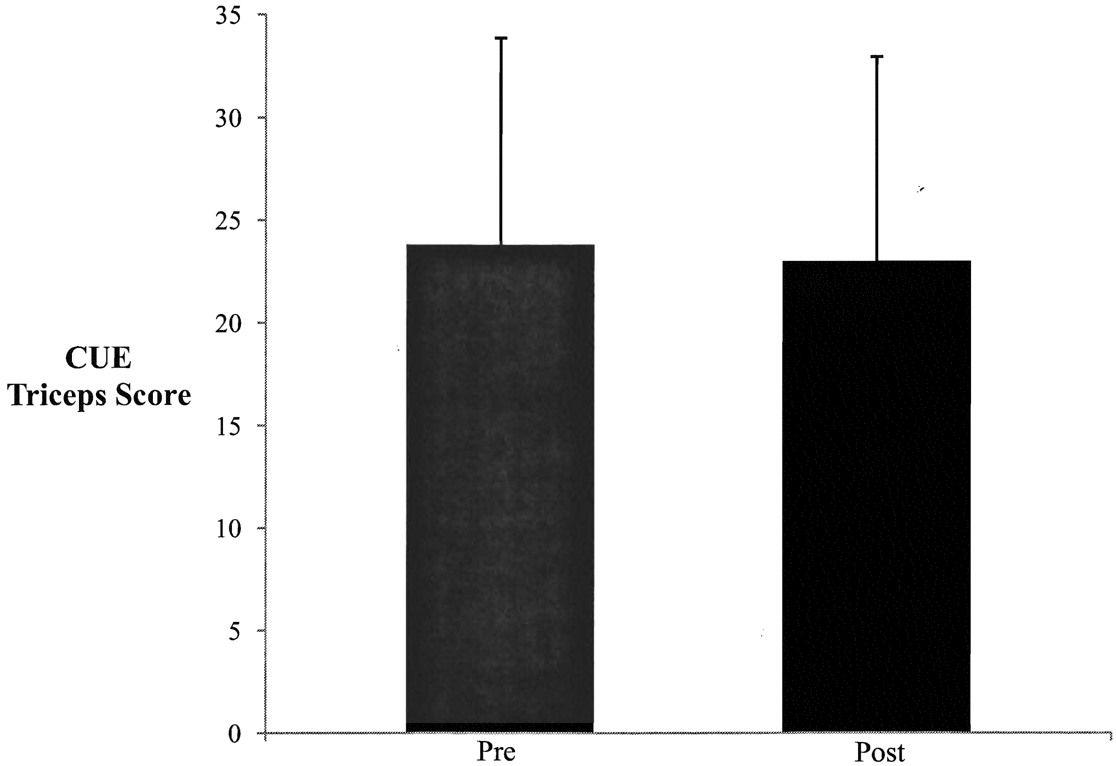


Fig. 10. Capabilities of Upper Extremity Questionnaire triceps function scores taken at baseline (pre) and following 12 weeks (post) of FES arm cycle ergometry in individuals with tetraplegia.

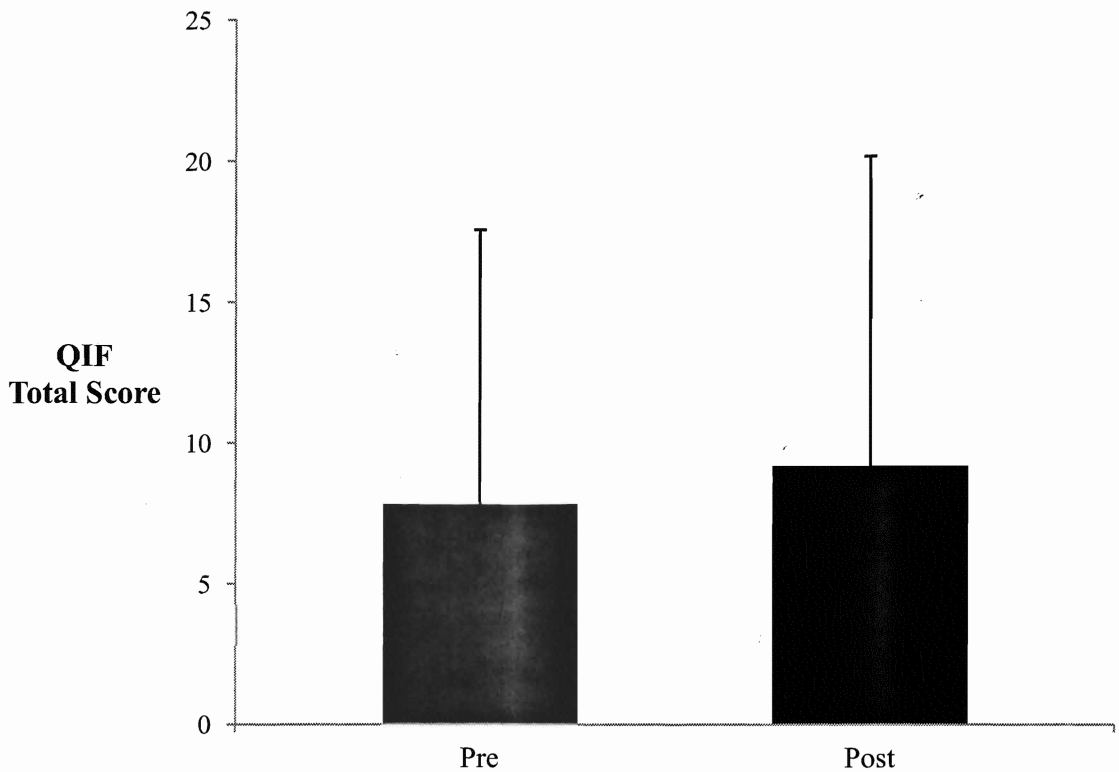


Fig. 11. Quadriplegia Index of Function total scores taken at baseline (pre) and following 12 weeks (post) of FES arm cycle ergometry in individuals with tetraplegia.

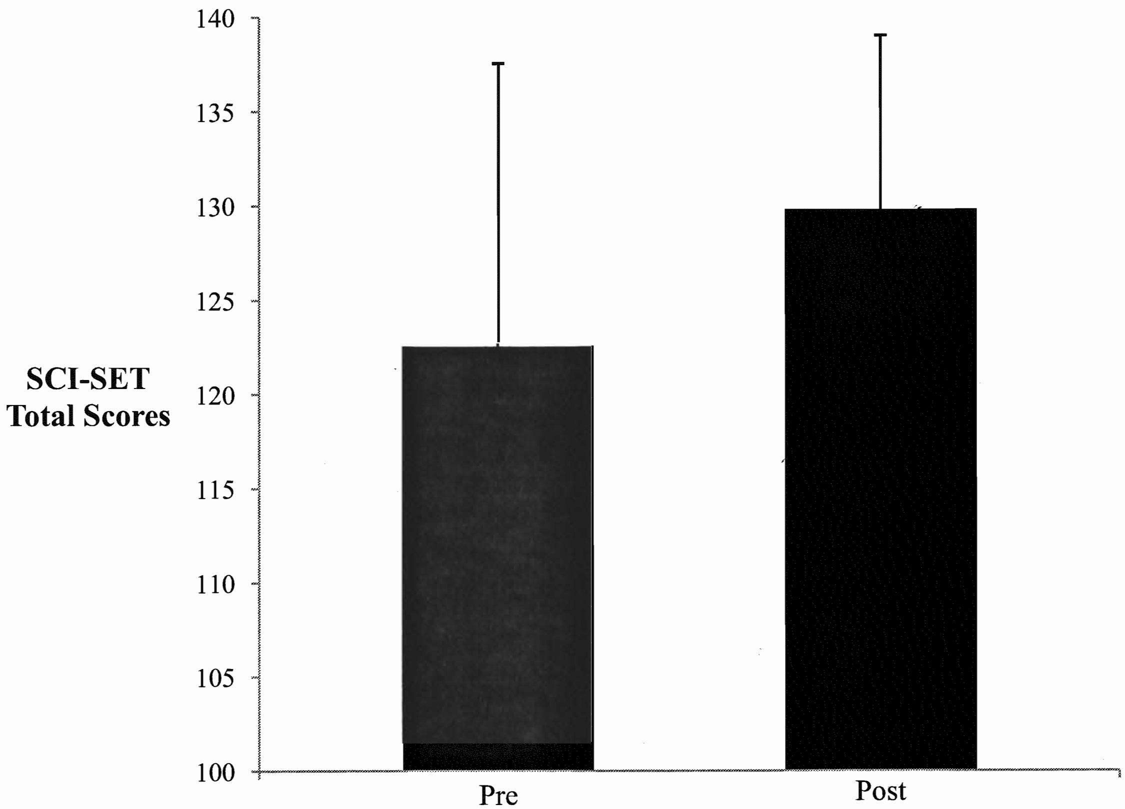


Fig. 12. Spinal Cord Injury Spasticity Evaluation Tool total scores taken at baseline (pre) and following 12 weeks (post) of FES arm cycle ergometry in individuals with tetraplegia.

APPENDIX A:

Standard Neurological Classification of Spinal Cord Injury

13-10

STANDARD NEUROLOGICAL CLASSIFICATION OF SPINAL CORD INJURY

MOTOR

KEY MUSCLES

	R	L	
C2			
C3			
C4			
C5			Elbow flexors
C6			Wrist extensors
C7			Elbow extensors
C8			Finger flexors (distal phalanx of middle finger)
T1			Finger abductors (little finger)
T2			
T3			
T4			
T5			
T6			
T7			
T8			
T9			
T10			
T11			
T12			
L1			
L2			Hip flexors
L3			Knee extensors
L4			Ankle dorsiflexors
L5			Long toe extensors
S1			Ankle plantar flexors
S2			
S3			
S4-5			

0 = total paralysis
1 = palpable or visible contraction
2 = active movement, gravity eliminated
3 = active movement, against gravity
4 = active movement, against some resistance
5 = active movement, against full resistance
NT = not testable

☐ Voluntary anal contraction (Yes/No)

TOTALS ☐ + ☐ = ☐ **MOTOR SCORE**

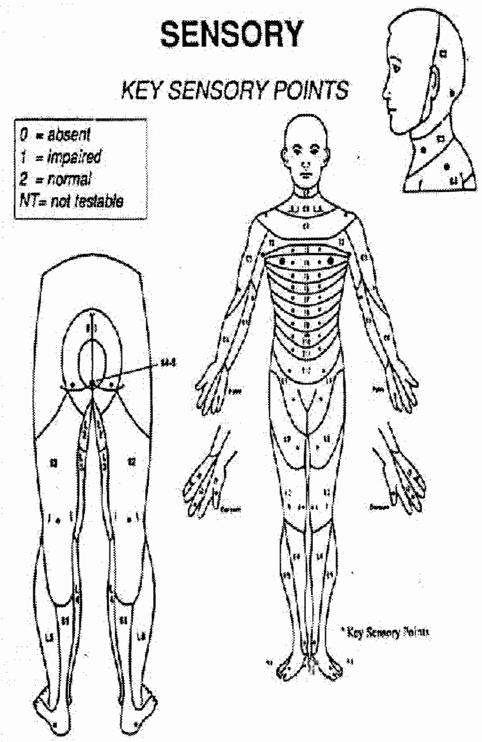
(MAXIMUM) (50) (50) (100)

SENSORY

KEY SENSORY POINTS

	LIGHT TOUCH R	LIGHT TOUCH L	PIN PRICK R	PIN PRICK L
C2				
C3				
C4				
C5				
C6				
C7				
C8				
T1				
T2				
T3				
T4				
T5				
T6				
T7				
T8				
T9				
T10				
T11				
T12				
L1				
L2				
L3				
L4				
L5				
S1				
S2				
S3				
S4-5				

0 = absent
1 = impaired
2 = normal
NT = not testable



☐ Any anal sensation (Yes/No)

TOTALS ☐ + ☐ = ☐ **PIN PRICK SCORE** (max: 112)

☐ + ☐ → = ☐ **LIGHT TOUCH SCORE** (max: 112)

(MAXIMUM) (56) (56) (56) (56)

NEUROLOGICAL LEVELS

The most caudal segment with normal function

	R	L
SENSORY		
MOTOR		

COMPLETE OR INCOMPLETE? ☐

Incomplete = Any sensory or motor function in S4-S5

ASIA IMPAIRMENT SCALE ☐

ZONE OF PARTIAL PRESERVATION

Partially innervated segments

	R	L
SENSORY		
MOTOR		

Version 4

APPENDIX B:

Upper Extremity Capability Questionnaire

UPPER EXTREMITY CAPABILITY QUESTIONNAIRE

Read the following instructions to the patient and be sure he/she understands the responses before proceeding to the questions.

This questionnaire is designed to find out how well you are able to use your arms and hands. I will ask you about a number of actions which some people with spinal cord injury have limitations performing. Please consider whether, on an average day, you have difficulties or limitations performing these actions. By this I mean difficulty doing the action, or trouble doing it as often as you would like or need in order to complete everyday activities. Consider only the specific part of your arm or hand asked about in each question. For example, if asked about pulling something with your arm, do not worry about whether or not you can grab it with your hand.

Pick one of the following responses to indicate how much, if any, limitation you have:

7. Not at all limited
6. A little limited
5. Some limitation
4. Moderately limited
3. Very limited
2. Extremely limited
1. Totally limited, can't do it at all

The following questions are about your ability to reach or lift:

1. Think about reaching out with your arm to touch something directly in front of you that is at shoulder level:

a. How limited are you doing this using your RIGHT ARM?

b. How limited are you doing this using your LEFT ARM?

2. Think about raising your arm directly over your head, with your arm straight:

a. How limited are you doing motion using your RIGHT ARM?

b. How limited are you doing motion using your LEFT ARM?

3. Think about reaching down to touch the floor and sitting back up straight, without hooking with your other arm or using it to pull yourself up:

a. How limited are you doing this with your RIGHT HAND?

b. How limited are you doing this with your LEFT HAND?

4. Think about raising a 5-pound object like a heavy blanket over your head using both arms. (Don't worry about whether you could grab it with your hands, just if you could raise something that heavy over your head.):

How limited are you doing this using BOTH ARMS?

The following questions are about your ability to pull and push with your arms:

5. Think about pulling or sliding (without grasping) a light object such as a can of soda, that is on a table, towards you:

a. How limited are you doing this kind of thing using
your RIGHT ARM?
b. How limited are you doing this kind of thing using
your LEFT ARM?
Think about pulling or sliding (without grasping) a
heavy object (up to 10 lbs.), that is on a table, towards
you:
a. How limited are you doing this kind of thing using
your RIGHT ARM?
b. How limited are you doing this kind of thing using
your LEFT ARM?
Think about pushing a light object such as a can of soda
on a table, away from you:
a. How limited are you doing this kind of thing using
your RIGHT ARM?
b. How limited are you doing this kind of thing using
your LEFT ARM?
Think about pushing a heavy object (up to 10 lbs.) on a
table, away from you:
a. How limited are you doing this kind of thing using
your RIGHT ARM?
b. How limited are you doing this kind of thing using
your LEFT ARM?
Think about pushing down with both arms into your
chair enough to lift your buttocks (both sides) off the seat
(do a push-up weight shift):
How limited are you doing this?
The following questions are about moving and positioning your
arm and wrist:
10. With your hand on your lap palm down, think about
curling your wrist upwards, keeping your arm on your
lap:
a. How limited are you doing this motion using your
RIGHT HAND?
11
b. How limited are you doing this motion using your
LEFT HAND?
Think about turning your hand over-from your palm
facing up to facing the floor, keeping your elbow bent at
your side (the arm motion someone would make when
turning a doorknob or a dial):
a. How limited are you doing this motion using your
RIGHT ARM?
b. How limited are you doing this motion using your
LEFT ARM?
The following questions are about using your hands and fingers:
12. Think about grasping and holding an object like a
hammer with your hand:
a. How limited are you doing this kind of thing using
your RIGHT HAND?
b. How limited are you doing this kind of thing using
your LEFT HAND?
13. Think about picking up a small object such as a paper
clip or the cap of a tube of toothpaste with the tips of
your thumb and first two fingers:
a. How limited are you doing this kind of thing using

your RIGHT HAND?
b. How limited are you doing this kind of thing using your LEFT HAND?
14. Think about pinching and holding an object between your thumb and the side of your index finger, such as holding a key:
a. How limited are you doing this kind of thing using your RIGHT HAND?
b. How limited are you doing this kind of thing using your LEFT HAND?
15. Think about grasping a large object like the lid of a 2 pound jar of mayonnaise with the tips of the fingers hard enough to pick the jar up or open the lid:
a. How limited are you doing this kind of thing using your RIGHT HAND?
b. How limited are you doing this kind of thing using your LEFT HAND?
16. Think about using your fingers to manipulate objects, such as holding a coin and turning it over and over with your fingers:
a. How limited are you doing this kind of thing using your RIGHT HAND?
b. How limited are you doing this kind of thing using your LEFT HAND?
17. Think about pressing something with the tip of your index finger (not knuckle) such as dialing a touch-tone phone or ringing a doorbell:
a. How limited are you doing this kind of thing using your RIGHT HAND?
b. How limited are you doing this kind of thing using your LEFT HAND?

APPENDIX C:

Short-form of the Quadriplegia Index of Function Scale

Short-form of the Quadriplegia Index of Function Scale

Please indicate your level of independence for the following activities of daily living.

1. Opening a carton/jar
   - 0 = Dependent
   - 1 = Assistance needed
   - 2 = Supervision required
   - 3 = Independent with devices
   - 4 = Independent

2. Washing/drying your hair
   - 0 = Dependent
   - 1 = Assistance needed
   - 2 = Supervision required
   - 3 = Independent with devices
   - 4 = Independent

3. Dressing your lower body
   - 0 = Dependent
   - 1 = Assistance needed
   - 2 = Supervision required
   - 3 = Independent with devices
   - 4 = Independent

4. Turning from supine to your side in bed
   - 0 = Dependent
   - 1 = Assistance needed
   - 2 = Supervision required
   - 3 = Independent with devices
   - 4 = Independent

5. Transferring from bed to wheelchair
   - 0 = Dependent
   - 1 = Assistance needed
   - 2 = Supervision required
   - 3 = Independent with devices
   - 4 = Independent

6. Locking your wheelchair wheels
   - 0 = Dependent
   - 1 = Assistance needed
   - 2 = Supervision required
   - 3 = Independent with devices
   - 4 = Independent

APPENDIX D:

Spinal Cord Injury Spasticity Evaluation Tool

For each of the following, please choose the answer that best describes how your spasticity symptoms have affected that area of your life **during the past 7 days**. When I talk about "spasticity symptoms", I mean: a) uncontrolled, involuntary muscle contraction or movement (slow or rapid; short or prolonged), b) involuntary, repetitive, quick muscle movement (up and down; side to side), c) muscle tightness, and d) what you might describe as "spasms". Please let me know when a question is not applicable to you.

Extremely problematic	Moderately problematic	Somewhat problematic	No effect	Somewhat helpful	Moderately helpful	Extremely helpful
- 3	- 2	- 1	0	+ 1	+ 2	+ 3

DURING THE **PAST 7 DAYS**, HOW HAVE YOUR SPASTICITY SYMPTOMS AFFECTED:

1. your showering?	-3	-2	-1	0	+1	+2	+3	N/A
2. your dressing/undressing?	-3	-2	-1	0	+1	+2	+3	N/A
3. your transfers (to and from bed, chair, vehicle, etc.)?	-3	-2	-1	0	+1	+2	+3	N/A
4. your sitting positioning (in your chair, etc.)?	-3	-2	-1	0	+1	+2	+3	N/A
5. the preparation of meals?	-3	-2	-1	0	+1	+2	+3	N/A
6. eating?	-3	-2	-1	0	+1	+2	+3	N/A
7. drinking?	-3	-2	-1	0	+1	+2	+3	N/A
8. your small hand movements (writing, use of computer, etc.)?	-3	-2	-1	0	+1	+2	+3	N/A
9. your ability to perform household chores?	-3	-2	-1	0	+1	+2	+3	N/A
10. your hobbies/recreational activities?	-3	-2	-1	0	+1	+2	+3	N/A
11. your enjoyment of social outings?	-3	-2	-1	0	+1	+2	+3	N/A
12. your ability to stand/weight-bear?	-3	-2	-1	0	+1	+2	+3	N/A
13. your walking ability?	-3	-2	-1	0	+1	+2	+3	N/A
14. your stability/balance?	-3	-2	-1	0	+1	+2	+3	N/A
15. your muscle fatigue?	-3	-2	-1	0	+1	+2	+3	N/A
16. the flexibility of your joints?	-3	-2	-1	0	+1	+2	+3	N/A
17. your therapy/exercise routine?	-3	-2	-1	0	+1	+2	+3	N/A
18. your manual wheelchair use?	-3	-2	-1	0	+1	+2	+3	N/A

Extremely problematic	Moderately problematic	Somewhat problematic	No effect	Somewhat helpful	Moderately helpful	Extremely helpful
- 3	- 2	- 1	0	+ 1	+ 2	+ 3

DURING THE **PAST 7 DAYS**, HOW HAVE YOUR SPASTICITY SYMPTOMS AFFECTED:

19. your power wheelchair use?	-3	-2	-1	0	+1	+2	+3	N/A
20. your lying positioning (in bed, etc.)?	-3	-2	-1	0	+1	+2	+3	N/A
21. your ability to change positions in bed?	-3	-2	-1	0	+1	+2	+3	N/A
22. your ability to get to sleep?	-3	-2	-1	0	+1	+2	+3	N/A
23. the quality of your sleep?	-3	-2	-1	0	+1	+2	+3	N/A
24. your sex life?	-3	-2	-1	0	+1	+2	+3	N/A
25. the feeling of being annoyed?	-3	-2	-1	0	+1	+2	+3	N/A
26. the feeling of being embarrassed?	-3	-2	-1	0	+1	+2	+3	N/A
27. your feeling of comfort socially?	-3	-2	-1	0	+1	+2	+3	N/A
28. your feeling of comfort physically?	-3	-2	-1	0	+1	+2	+3	N/A
29. your pain?	-3	-2	-1	0	+1	+2	+3	N/A
30. your concern with falling?	-3	-2	-1	0	+1	+2	+3	N/A
31. your concern with getting injured?	-3	-2	-1	0	+1	+2	+3	N/A
32. your concern with accidentally injuring someone else?	-3	-2	-1	0	+1	+2	+3	N/A
33. your ability to concentrate?	-3	-2	-1	0	+1	+2	+3	N/A
34. your feelings of control over your body?	-3	-2	-1	0	+1	+2	+3	N/A
35. your need to ask for help?	-3	-2	-1	0	+1	+2	+3	N/A

Number of (+) items: ________

Number of (-) items: ________

Number of (0) items: ________

Negative score: ________

Positive score: ________

Total score: ________

Applicable items (#): ________

Average score: ________

APPENDIX E:

ANOVA TABLES

	df effect	MS effect	df error	MS error	F	p-level
MAP	2	114.902	8	242.1262	0.474554	0.638618

	df effect	MS effect	df error	MS error	F	p-level
Resting HR	2	114.2	8	55.61666	2.053341	0.19066

	df effect	MS effect	df error	MS error	F	p-level
Time to Fatigue	2	592000.8	8	327206.2	1.809259	0.22478

	df effect	MS effect	df error	MS error	F	p-level
Distance to fatigue	2	7.4115	8	5.058925	1.465035	0.286991

	df effect	MS effect	df error	MS error	F	p-level
Kcal/hr expended	2	7.76958	8	6.45168	1.204272	0.34898

	df effect	MS effect	df error	MS error	F	p-level
Avg HR	2	5.066667	8	27.06667	0.187192	0.832815

	df effect	MS effect	df error	MS error	F	p-level
Peak HR	2	6.066667	8	24.65	0.246112	0.787543

	df effect	MS effect	df error	MS error	F	p-level
CUE Total	2	176.2667	8	350.4333	0.502996	0.622635

	df effect	MS effect	df error	MS error	F	p-level
QIF Total	2	11.26667	8	22.35	0.504101	0.622024

	df effect	MS effect	df error	MS error	F	p-level
SCI-SET	2	72.86667	8	51.36666	1.418559	0.296965

	df effect	MS effect	df error	MS error	F	p-level
CUE 1,2,4	2	4.2	8	18.03333	0.232902	0.79742

	df effect	MS effect	df error	MS error	F	p-level
CUE 3	2	6.066667	8	2.566667	2.363636	0.156106

	df effect	MS effect	df error	MS error	F	p-level
CUE 5,6	2	7.4	8	7.566667	0.977974	0.416898

	df effect	MS effect	df error	MS error	F	p-level
CUE 7,8,9	2	0.8	8	4.383333	0.18251	0.836551

	df effect	MS effect	df error	MS error	F	p-level
CUE 10,11	2	0.866667	8	6.533333	0.132653	0.877656

	df effect	MS effect	df error	MS error	F	p-level
CUE 12-17	2	75.26667	8	48.6	1.548697	0.27007

	df effect	MS effect	df error	MS error	F	p-level
QIF 1	2	2.066667	8	1.733333	1.192308	0.352207

	df effect	MS effect	df error	MS error	F	p-level
QIF 2	2	0.466667	8	1.05	0.444444	0.6561

	df effect	MS effect	df error	MS error	F	p-level
QIF 3	2	0.6	8	1.266667	0.473684	0.639114

	df effect	MS effect	df error	MS error	F	p-level
QIF 4	2	0.466667	8	1.633333	0.286714	0.758835

	df effect	MS effect	df error	MS error	F	p-level
QIF 5	2	0.6	8	0.35	1.714286	0.2401

	df effect	MS effect	df error	MS error	F	p-level
QIF 6	2	0.6	8	1.266667	0.473684	0.639114

APPENDIX F:

Group Data

Exercise Performance Data

Time to Fatigue (seconds)	Pre	Mid	Post
1	608	608	679
2	608	615	672
3	693	650	2700
4	1444	2700	2700
5	670	668	668
AVG	804.6	1048.2	1483.8
STDEV	359.4117	923.71489	1110.241

Distance to Fatigue (miles)	Pre	Mid	Post
1	1.02	1.02	1.34
2	0.97	1.18	1.27
3	2.06	1.44	9
4	6	12	10.7
5	0.83	0.64	0.72
AVG	2.176	3.256	4.606
STDEV	2.19311	4.89664	4.83065

Kcal/Hr Expended	Pre	Mid	Post
1	1.27	1.03	2.25
2	0.95	1.84	1.88
3	9.84	6.22	17.44
4	5.4	5.7	5.1
5	0.5	0.5	0.5
AVG	3.592	3.058	5.434
STDEV	4.007452	2.698059	6.916804

Cardiovascular Performance Data

MAP	Pre	Mid	Post
1	79.3	64.3	77.7
2	112.3	96	110
3	97.7	112	95.7
4	86.3	133	79.3
5	80	80.7	76
AVG	91.12	97.2	87.74
STDEV	13.9507	26.72443	14.73713
	p=	0.027197	

Resting HR	Pre	Mid	Post
1	61	74	65
2	57	83	57
3	77	89	82
4	70	73	78
5	69	62	68
AVG	66.8	76.2	70
STDEV	7.886698	10.32957	10.07472
	p=	0.125355	

AvgHR	Pre	Mid	Post
1	74	70	74
2	63	60	61
3	96	95	84
4	84	90	80
5	80	86	92
AVG	79.4	80.2	78.2
STDEV	12.19836	14.669697	11.62755
	p=	0.7724458	

PeakHR	Pre	Mid	Post
1	79	77	89
2	68	65	65
3	107	103	102
4	96	94	85
5	89	90	97
AVG	87.8	85.8	87.6
STDEV	15.05656	14.92314	14.27585
	p=	0.962449	

Kcal/hr/HR	Pre	Mid	Post
1	0.017	0.015	0.03
2	0.015	0.03	0.031
3	0.044	0.065	0.21
4	0.064	0.063	0.063
5	0	0.0056	0.0054
AVG	0.028	0.03572	0.06788
STDEV	0.025622	0.027252	0.082038
	p=	0.276411	

Upper Limb Function Data

CUE TOTAL	Pre	Mid	Post
1	106	107	124
2	158	179	133
3	162	193	164
4	131	138	178
5	41	39	39
AVG	119.6	131.2	127.6
STDEV	49.40951	61.718717	54.21531
	p=	0.5391849	

CUE q1,2,4	Pre	Mid	Post
1	13	24	24
2	29	23	23
3	34	33	31
4	19	19	27
5	7	6	6
AVG	20.4	21	22.2
STDEV	11.12654	9.8234414	9.576012
	p=	0.6120552	

CUE q5,6	Pre	Mid	Post
1	26	24	24
2	26	16	16
3	26	28	26
4	20	20	22
5	7	7	6
AVG	21	19	18.8
STDEV	8.246211	8.0622577	8.074652
	p=	0.3455239	

CUE q7,8,9	Pre	Mid	Post
1	24	25	21
2	32	28	28
3	33	35	33
4	22	21	26
5	8	8	7
AVG	23.8	23.4	23
STDEV	10.05982	10.014989	9.924717
	p=	0.5964759	

QIF TOTAL	Pre	Mid	Post
1	2	9	4
2	1	0	0
3	14	15	19
4	22	7	23
5	0	0	0
AVG	7.8	6.2	9.2
STDEV	9.757049	6.379655	10.98636
	p=	0.245492	

QIF q2	Pre	Mid	Post
1	0	1	0
2	0	0	0
3	3	0	4
4	3	3	3
5	0	0	0
AVG	1.2	0.8	1.4
STDEV	1.643168	1.30384	1.949359
	p=	0.373901	

QIF q5	Pre	Mid	Post
1	0	1	0
2	0	0	0
3	2	4	4
4	3	3	4
5	0	0	0
AVG	1	1.6	1.6
STDEV	1.414214	1.81659	2.19089
	p=	0.208	

SCI-SET TOTAL	Pre	Mid	Post
1	131	140	144
2	129	128	133
3	130	143	127
4	96	110	120
5	127	121	125
AVG	122.6	128.4	129.8
STDEV	14.94323	13.61249	9.20326
	p=	0.22886	

APPENDIX G:

Participant 1 Data

Exercise Performance Data

Time to Fatigue:	
Pre	10:08
Mid	10:08
Post	11:19

Distance to Fatigue:	
Pre	1.02
Mid	1.02
Post	1.34

Kcal/hr Expended:	
Pre	1.27
Mid	1.03
Post	2.25

Cardiovascular Performance Data

	MAP	Resting BP	Resting HR
Pre	79.3	90/58	61
Mid	64.3	85/54	74
Post	77.7	84/65	65

Avg HR:		Peak HR:	
Pre	74	Pre	79
Mid	70	Mid	77
Post	74	Post	89

Upper Limb Function Data

QIF			
?	Pre	Mid	Post
1	2	4	4
2	0	1	0
3	0	1	0
4	0	1	0
5	0	1	0
6	0	1	0
AVG	0.333333	1.5	0.666667
STD	0.816497	1.224745	1.632993
SUM	2	9	4

CUE			
?	Pre	Mid	Post
1a	5	6	7
1b	3	3	4
2a	2	5	6
2b	1	2	3
3a	1	1	1
3b	1	1	1
4	2	5	4
5a	7	7	7
5b	6	5	5
6a	6	5	7
6b	7	3	5
7a	7	7	7
7b	6	5	6
8a	6	5	7
8b	4	3	4
9	1	1	1
10a	1	1	1
10b	1	1	1
11a	7	6	7
11b	7	6	4
12a	1	1	1
12b	1	1	1
13a	4	1	6
13b	3	1	3
14a	1	1	1
14b	1	1	1
15a	1	1	1
15b	1	1	1
16a	1	6	6
16b	1	2	3
17a	6	7	7
17b	4	6	5
AVG	3.3125	3.34375	3.875
SD	2.455245	2.322532	2.432972
SUM	106	107	124

SCI-SET			
?	Pre	Mid	Post
1	5	4	7
2	3	4	4
3	4	3	4
4	3	4	4
5	4	4	4
6	4	4	4
7	4	4	4
8	4	4	4
9	4	4	4
10	3	4	4
11	4	4	4
12	1	4	4
13	4	4	4
14	4	4	4
15	4	4	5
16	3	3	4
17	3	4	4
18	3	4	4
19	4	4	4
20	5	5	4
21	5	6	4
22	4	4	4
23	4	4	4
24	4	4	4
25	3	4	4
26	3	3	4
27	4	4	4
28	4	4	4
29	4	4	4
30	4	4	4
31	4	4	4
32	4	4	4
33	4	4	4
34	3	4	4
35	4	4	4
AVG	3.742857	4	4.114286
SD	0.741337	0.485071	0.529785
SUM	131	140	144

Training Data 1		Resting BP	Resting HR	Resistance	Distance	Time	Peak HR	Avg HR	BP Post	Cal	Cal/hr
Pre		90/58	61	1	1.02	10.08	79	74	89/52	0.2	1.3
1		85/62	69	1	1	9.28	98	84	70/58	0.2	1.1
				1	1.1	10.12	97	89	93/82	0.2	1.4
				1	1.1	10.08	88	76	131/69	0.2	1.5
1a		82/62	71	1	0.97	10.08	93	83	75/50	0.13	0.75
				1	0.96	10.08	86	76	90/53	0.15	0.87
				1	0.98	10.08	79	70	95/48	0.15	0.87
2		89/48	67	1	1	9.38	86	77	90/51	0.11	0.67
				1	1.13	10.08	89	80	130/62	0.27	1.58
				1	1.1	10.1	84	74	95/55	0.25	1.48
3		63/54	72	1	1.09	10.08	81	75	75/50	0.21	1.24
				1	1.06	10.1	81	73	72/50	0.19	1.09
				1	1.07	10.09	91	76	70/50	0.21	1.27
4		103/61	64	1	1.1	10.09	88	74	120/90	0.19	1.15
				1	1.07	10.11	83	74	129/74	0.23	1.36
				1	1.13	10.08	84	75	90/49	0.3	1.76
5		81/61	70	1	1.13	10.1			150/115	0.28	1.66
				1	1.15	10.2	83	75	80/62	0.29	1.7
				1	1.15	10.42	78	70	73/52	0.25	1.42
6		73/54	80	1	1.21	10.13	99	86	96/65	0.31	1.85
				1	1.05	10.08	92	83	79/55	0.19	1.13
				1	1.19	10.18	102	85	79/59	0.33	1.93
7		106/65	63	1	1.19	10.31	83	73	77/45	0.32	1.82
				1	1.11	10.11	79	70	74/48	0.25	1.45
				1	1.23	10.25	98	67	116/49	0.38	2.21
8		82/61	55	1	1.11	10.12	70	63	87/47	0.21	1.21
				1	1.11	10.14	76	68	86/52	0.24	1.4
				1	1.06	10.08	70	65	100/82	0.21	1.24
9		119/105	97	1	1.12	10.48	90	79	80/61	0.23	1.26
				1	1.05	10.11	85	79	81/41	0.17	1.02
				1	1.2	11.17	86	78	78/44	0.27	1.43
10		88/54	71	1	1.04	10.08	82	73	90/54	0.18	1.09
				1	1.05	10.08	78	66	126/60	0.2	1.17
				1	1.1	10.1	77	66	90/38	0.21	1.4
11		118/66	71	1	1.14	10.09	93	77	70/51	0.29	1.69
				1	1.2	10.34	87	73	95/55	0.34	1.91
				1	1.18	10.08	93	66	92/58	0.32	1.92
12		87/62	63	1	1.03	10.08	83	78	86/53	0.18	1.09
				1	1.02	10.08	72	66	106/50	0.16	0.93
				1	1.07	10.17	88	73	84/38	0.17	1.02
13		98/67	72	1	1.11	10.12	87	78	110/66	0.26	1.55
				1	1.08	10.08	90	73	137/71	0.21	1.26
				1	1.03	10.1	76	68	76/41	0.17	1.01
14		102/61	49	1	1.08	10.1	78	69	107/55	0.22	1.32
				1	1.02	10.08	78	66	82/60	0.15	0.86
				1	0.96	10.08	66	57	92/52	0.15	0.91
		85/54	74	1	1.02	10.08	77	70	79/51	0.17	1.03

Mid											
				1	1.01	10.08	70	58	86/50	0.15	0.92
				1	1.01	10.08	70	60	76/42	0.17	0.99
16		83/51	60	1	0.94	10.08	83	68	75/46	0.14	0.83
				1	0.98	10.1	72	66	78/51	0.15	0.88
				1	0.98	10.08	72	62	77/37	0.14	0.86
17		86/48	73	1	0.98	10.08	92	75	103/63	0.15	0.9
				1	0.98	10.08	88	68	61/40	0.18	1.09
				1	1	10.08	89	72	93/72	0.17	1
18		99/66	63	1	1.03	10.08	69	62	98/58	0.21	1.23
				1	1.01	10.08	67	58	94/62	0.19	1.1
				1	1.03	10.09	63	57	90/66	0.19	1.12
19		70/46	65	1	0.99	10.08	74	70	80/54	0.17	0.99
				1	0.99	10.08	73	63	75/62	0.17	0.99
				1	1	10.08	74	64	77/57	0.16	0.92
20		128/47	72	1	0.98	10.08	83	71	158/81	0.18	1.07
				1	1.03	10.08	69	60	88/73	0.17	0.99
				1	1	10.08	68	58	88/51	0.13	0.76
21		84/54	71	1	0.95	10.08	84	78	70/46	0.18	1.04
				1	0.98	10.08	76	70	77/62	0.14	0.82
				1	0.98	10.08	75	68	64/54	0.14	0.82
22		90/54	64	1	1.04	10.08	74	70	86/47	0.17	1
				1	1.01	10.08	73	73	78/42	0.18	1.09
				1	1.03	10.08	80	64	82/42	0.19	1.12
23		102/58	50	1	1.01	10.07	69	63	78/50	0.15	0.89
				1	1.04	10.08	59	54	89/48	0.18	1.1
				1	1.07	10.08	64	56	90/54	0.23	1.39
24		82/66	65	1	1.09	10.12	74	64	71/54	0.23	1.35
				1	1.07	10.08	74	61	83/62	0.22	1.28
				1	1.09	10.08	78	56	98/54	0.24	1.41
25		90/61	60	1	1.02	10.13	66	56	81/42	0.23	1.35
				1	1.08	10.08	61	54	86/60	0.21	1.24
				1	1.07	10.08	63	54	112/93	0.18	1.07
26		97/30	63	1	1.05	10.08	83	71	134/92	0.22	1.33
				1	1.07	10.09	73	63	84/54	0.19	1.1
				1	1.15	10.17	85	67	85/58	0.3	1.78
27		95/67	74	1	1.13	10.11	71	60	82/49	0.29	1.72
				1	1.05	10.08	73	58	87/50	0.23	1.35
				1	1.05	10.09		59	105/37	0.22	1.27
28		111/81	69	1	1.12	11.08	77	57	82/54	0.22	1.21
				1	1.11	11.08	76	59	86/68	0.21	1.13
				1	1.08	11.08	71	57	138/113	0.18	0.96
29		92/66	65	1	1.09	11.08			66/54	0.18	0.96
				1	1.06	11.09	69	63	122/56	0.21	1.15
				1	1.08	11.08	69	63	52/42	0.22	1.21
30		98/62	68	1	1.14	11.08	72	62	73/61	0.2	1.09
				1	1.12	11.08	78	64	94/56	0.22	1.17
				1	1.14	11.08	91	70	86/52	0.23	1.24

31		86/55	60	1	1.11	11.09	72	66		0.17	0.94
				1	1.11	11.08	66	59	144/125	0.19	1.01
				1	1.07	11.08	76	58	130/103	0.2	1.08
32		85/62	59	1	1.07	11.08	75	63	86/53	0.19	1.04
				1	1.07	11.08	67	56	90/48	0.19	1.04
				1	1.06	11.08	71	57	70/56	0.19	1.04
33		100/66	52	1	1.15	11.12	66	56	90/58	0.2	1.07
				1	1.11	11.09	60	50	83/58	0.2[illegible]	1.17
				1	1.13	11.07	66	51	84/53	0.19	1.04
34		94/56	65	1	1.13	11.09	81	72	74/43	0.19	1
				1	1.13	11.08	80	63	84/53	0.23	1.21
				1	1.13	11.08	81	69	81/51	0.23	1.22

APPENDIX H:

Participant 2 Data

Exercise Performance Data

Time to Fatigue:	
Pre	10:08
Mid	10:15
Post	11:12

Distance to Fatigue:	
Pre	0.97
Mid	1.18
Post	1.27

Kcal/hr Expended:	
Pre	0.95
Mid	1.84
Post	1.88

Cardiovascular Performance Data

	MAP	Resting BP	Resting HR
Pre	112.3	126/85	57
Mid	96	109/70	83
Post	110	124/82	57

Avg HR:		Peak HR:	
Pre	63	Pre	68
Mid	60	Mid	65
Post	61	Post	65

Upper Limb Function Data

QIF			
?	Pre	Mid	Post
1	0	0	0
2	0	0	0
3	0	0	0
4	1	0	0
5	0	0	0
6	0	0	0
AVG	0.166667	0	0
STD	0.408248	0	0
SUM	1	0	0

CUE			
?	Pre	Mid	Post
1a	6	6	4
1b	6	6	4
2a	5	7	5
2b	5	6	4
3a	4	5	4
3b	4	6	4
4	7	6	6
5a	7	7	4
5b	7	7	4
6a	6	6	4
6b	6	6	4
7a	7	7	6
7b	7	7	6
8a	6	7	6
8b	6	7	6
9	6	6	4
10a	7	7	4
10b	7	7	4
11a	6	7	6
11b	6	7	6
12a	4	5	4
12b	4	5	3
13a	3	5	4
13b	4	5	4
14a	3	6	3
14b	5	6	3
15a	2	6	4
15b	5	6	3
16a	2	4	3
16b	3	3	3
17a	1	2	2
17b	1	2	2
AVG	4.9375	5.78125	4.15625
STD	1.830521	1.385044	1.167003
SUM	158	179	133

SCI-SET			
?	Pre	Mid	Post
1	4	4	4
2	4	4	4
3	4	3	4
4	3	3	4
5	4	4	4
6	4	4	4
7	4	4	4
8	3	4	4
9	4	4	4
10	4	4	4
11	4	4	4
12	3	3	4
13	3	3	4
14	3	3	4
15	4	3	3
16	4	4	3
17	4	4	4
18	4	4	4
19	4	4	4
20	3	3	3
21	3	3	3
22	4	4	3
23	4	4	3
24	4	4	4
25	4	4	4
26	4	4	4
27	4	4	4
28	4	4	4
29	3	3	3
30	3	3	4
31	3	3	4
32	3	3	4
33	4	4	4
34	4	4	4
35	4	4	4
AVG	3.685714	3.657143	3.8
STD	0.471008	0.481594	0.40584
SUM	129	128	133

Training Data 2		Resting BP	Resting HR	Resistance	Distance	Time	Peak HR	Avg HR	BP Post	Cal	Cal/hr
Pre		126/85	57	1	0.97	10.08	68	63	112/66	0.16	0.95
1		102/57	58	1	1.01	10.08	71	66	101/62	0.18	1.07
				1	0.98	10.08	74	66	99/60	0.16	0.93
				1	0.96	10.08	67	62	102/62	0.21	1.25
2		115/65	53	1	1	10.08	64	58	107/69	0.2	1.16
				1	1	10.08	57	52	114/72	0.19	1.14
				1	1.04	10.08	58	52	105/68	0.22	1.29
3		99/67	65	1	0.93	10.08	72	67	104/58	0.17	1.03
				1	0.95	10.08	68	63	98/61	0.12	0.71
				1	0.98	10.08	66	60	111/64	0.13	0.77
4		118/59	56	1	0.99	10.08	62	57	105/68	0.16	0.95
				1	1.12	10.42	58	55	109/58	0.21	1.16
				1	1.09	10.41	64	56	112/72	0.22	1.26
5		106/70	58	1	1.02	10.08	64	60	98/62	0.23	1.35
				1	1.02	10.08	66	60	95/66	0.17	0.98
				1	1.04	10.08	64	58	104/62	0.19	1.14
6		91/67	59	1	1.02	10.08	63	59	115/64	0.22	1.3
				1	1.03	10.08			103/62	0.18	1.09
				1	1.04	10.08	59	56	111/82	0.22	1.28
7		110/67	54	1	0.96	10.08	61	59	108/70	0.14	0.81
				1	1	10.08	56	54	110/70	0.15	0.91
				1	1.07	10.08			112/70	0.25	1.49
8		99/78	57	1	0.96	10.08	63	60	91/70	0.22	1.28
				1	0.99	10.08	61	57	111/69	0.19	1.11
				1	1.02	10.08	60	57	109/69	0.2	1.19
9		124/73	80	1	1.06	10.08			108/47	0.25	1.47
				1	1.02	10.08			110/70	0.26	1.54
				1	1.05	10.08			122/69	0.24	1.44
10		107/61	58	1	0.98	10.08	68	64	117/70	0.17	1
				1	1.02	10.08			111/70	0.27	1.59
				1	1.02	10.08	61	58	112/73	0.24	1.39
11		116/70	53	1	1.03	10.08	61	56	110/62	0.17	1
				1	1.02	10.08	59	53	119/74	0.22	1.29
				1	1.06	10.08	59	54	111/71	0.24	1.4
12		116/73	60	1	1.06	10.08	65	60	106/69	0.25	1.5
				1	1.04	10.08	64	57	108/75	0.25	1.5
				1	1.04	10.08	62	57	118/69	0.25	1.48
13		93/62	56	1	1.15	10.08	63	56	105/64	0.3	1.75
				1	1.11	10.1	57	53	109/69	0.26	1.51
				1	1.07	10.08	60	54	113/76	0.23	1.38
14		106/87	59	1	1.12	10.1	64	59	98/64	0.27	1.58
				1	0.98	10.08	62	58	109/64	0.23	1.34
				1	1.14	10.09	59	55	110/73	0.29	1.73
Mid		109/70	83	1	1.18	10.15	65	60	111/75	0.31	1.84
15		96/74	59	1	0.36	3.15	61	58	83/66	0.07	1.25
				1	1.1	10.09	62	55	100/70	0.2	1.4
				1	1.1	10.08			112/72	0.2	1.4

					1	1.2	10.08	58	56	104/74	0.3	2
16		118/65	61		1	1.15	10.11	64	60	113/68	0.32	1.88
					1	1.09	10.08	59	56	110/74	0.26	1.52
					1	1.07	10.11	61	58	108/70	0.24	1.41
17		104/70	63		1	1	10.09	67	65	123/68	0.23	1.36
					1	1.03	10.07	64	62	122/78	0.21	1.24
					1	1.06	10.08			120/83	0.25	1.45
18		118/67	54		1	1.11	10.07	61	57	102/70	0.26	1.55
					1	1.09	10.08	58	55	101/69	0.29	1.74
					1	1.11	10.19	57	54	114/72	0.29	1.7
19		110/70	63		1	1.07	10.08	73	65	107/71	0.25	1.5
					1	1.11	10.1	69	63	108/66	0.29	1.73
					1	1.17	10.15	67	63	106/69	0.37	2.16
20		147/78	57		1	1.22	11.08	63	59	119/74	0.33	1.76
					1	1.18	11.09	61	56	113/69	0.28	1.51
					1	1.2	11.12	63	59	107/70	0.27	1.45
21		130/82	61		1	1.41	12.2	68	64	88/66	0.38	1.87
					1	1.17	11.08	65	60	108/70	0.28	1.52
					1	1.2	11.07	64	58	98/69	0.31	1.69
22		116/72	59		1	1.16	11.14	67	62	101/65	0.22	1.2
					1	1.13	11.08	64	60	106/69	0.24	1.31
					1	1.13	11.13	61	58	110/75	0.28	1.49
23		102/65	61		1	1.2	11.12	67	63	102/67	0.27	1.47
					1	1.25	11.31	63	60	105/68	0.28	1.45
					1	1.32	11.57	63	60	98/66	0.35	1.78
24		126/73	51		1	1.28	11.28	58	56	106/66	0.35	1.86
					1	1.15	11.13	58	55	111/69	0.25	1.35
					1	1.57	13.08	55	53	97/86	0.51	2.35
25		130/74	63		1	1.36	11.21	67	61	109/66	0.44	2.34
					1	1.15	11.07	64	58	119/72	0.27	1.46
					1	1.24	11.11	62	57	162/83	0.29	1.54
26		112/70	61		1	1.19	11.08	70	66	149/66	0.27	1.48
					1	1.15	11.08	66	62	114/67	0.26	1.4
					1	1.28	11.16	63	59	114/73	0.39	2.06
27		124/82	58		1	1.29	11.1	65	61	114/78	0.35	1.88
					1	1.23	11.09	63	60	120/50	0.34	1.82
					1	1.19	11.08	63	60	120/78	0.27	1.47
28		124/82	57		1	1.27	11.12	65	61	113/73	0.35	1.88
					1	1.23	11.09	63	60	118/49	0.34	1.82
					1	1.18	11.08	63	60	120/78	0.27	1.47

APPENDIX I:

Participant 3 Data

Exercise Performance Data

Time to Fatigue:	
Pre	11:33
Mid	10:50
Post	45:00:00

Distance to Fatigue:	
Pre	2.06
Mid	1.44
Post	9

Kcal/hr Expended:	
Pre	9.84
Mid	6.22
Post	17.44

Cardiovascular Performance Data

	MAP	Resting BP	Resting HR
Pre	97.7	141/76	77
Mid	112	130/76	89
Post	95.7	106/75	82

Avg HR:		Peak HR:	
Pre	96	Pre	107
Mid	95	Mid	103
Post	84	Post	102

Upper Limb Function Data

QIF			
?	Pre	Mid	Post
1	1	2	4
2	3	0	4
3	1	1	1
4	3	4	2
5	2	4	4
6	4	4	4
AVG	2.333333	2.5	3.166667
STD	1.21106	1.760682	1.32916
SUM	14	15	19

CUE			
?	Pre	Mid	Post
1a	7	7	7
1b	7	7	7
2a	7	7	7
2b	7	7	7
3a	2	5	3
3b	2	5	3
4	6	5	3
5a	7	7	7
5b	7	7	7
6a	6	7	6
6b	6	7	6
7a	7	7	7
7b	7	7	7
8a	6	7	6
8b	6	7	6
9	7	7	7
10a	7	7	7
10b	7	7	7
11a	7	7	7
11b	7	7	7
12a	6	5	5
12b	6	4	5
13a	2	4	3
13b	2	3	2
14a	4	6	5
14b	2	6	4
15a	3	5	4
15b	2	4	3
16a	2	6	1
16b	2	4	1
17a	4	6	4
17b	2	6	3
AVG	5.0625	6.03125	5.125
STD	2.16925	1.230903	1.995964
SUM	162	193	164

SCI-SET			
?	Pre	Mid	Post
1	3	5	3
2	3	5	3
3	5	5	5
4	3	5	3
5	4	4	4
6	4	4	4
7	4	4	4
8	3	5	3
9	4	4	3
10	4	4	3
11	4	4	4
12	4	4	4
13	4	4	4
14	3	5	3
15	4	5	3
16	3	5	4
17	5	4	4
18	3	5	4
19	4	4	4
20	3	3	3
21	3	3	3
22	4	3	3
23	4	3	3
24	4	4	4
25	3	3	4
26	4	4	4
27	4	4	4
28	4	4	3
29	4	4	4
30	3	3	3
31	4	4	4
32	3	4	4
33	4	4	4
34	4	4	4
35	4	4	4
AVG	3.714286	4.085714	3.628571
STD	0.572478	0.658493	0.546955
SUM	130	143	127

Training Data 3		Resting BP	Resting HR	Resistance	Distance	Time	Peak HR	Avg HR	BP Post	Cal	Cal/hr
Pre		141/76	77	1	8.84	45	109	94	126/85	3.14	4.19
1		129/72	82	1.98	8.06	45	104	91	131/91	5.67	7.56
2		136/79	86	3.1	7.84	45	101	90	129/75	8.66	11.55
3		128/74	75	4.08	2.06	11.33	107	96	103/82	2.22	9.84
4		138/82	67	4.08	1.4	10.14	100	93	119/62	1.28	7.51
				4.08	1.57	11.22	99	88	118/88	2.19	11.58
				4.08	3.78	27.23			136/71	5.39	11.8
5		135/65	89	4.08	1.8	13.19	110	99	111/70	2.6	11.9
				4.08	1.4	11.16			138/69	1.2	6.3
				4.08	1.2	10.1	94	80	146/74	1	5.7
6		133/70	76	4.08	1.82	12.09	109	93	118/54	2.57	12.67
				4.08	1.42	10.29	97	87	120/72	1.22	6.97
				4.08	1.52	11.22	101	88	95/76	1.18	6.23
7		132/73	81	4.08	1.44	10.38	95	88	118/78	1.61	9.06
				4.08	1.38	10.37	97	85	118/76	0.89	5.04
				4.08	1.29	10.1	91	80	124/78	0.57	3.37
8		129/78	73	4.08	1.69	10.27	105	91	126/75	2.04	11.7
				4.08	1.28	10.13	97	84	119/81	0.6	3.55
				4.08	1.41	10.2	92	84	118/63	1.19	6.88
9		142/74	77	4.08	3.03	20.26	97	89	123/77	4.35	4.42
				4.08	3.03	23.51	98	86	121/74	12.76	11.12
10		143/79	71	4.08	3.09	18.4	113	99	104/78	4.43	14.25
				4.08	1.43	10.27	109	87	139/73	1.34	7.72
11		143/77	76	4.08	1.36	10.21	99	92	122/75	1.2	6.99
				4.08	1.42	10.18	100	87	114/78	1.56	9.08
				4.08	2.63	18.56	97	87	122/71	3.44	10.89
12		143/80	88	4.08	1.4	10.22	102	92	137/71	1.2	6.93
				4.08	3.2	17.11	130	102	126/72	4.63	16.17
				4.08	1.38	10.12	93	86	126/78	1.13	6.63
13		123/72	94	4.08	2.12	15.25	105	96	126/81	2.61	10.14
				4.08	2.51	18.18	99	90	137/82	3.07	10.08
14		130/79	85	4.08	1.44	10.29			142/85	1.41	8.07
				4.08	1.47	11.15	100	84	147/93	1.11	5.95
				4.08	2.08	15.18	92	80	134/82	2.13	8.34
Mid		130/76	89	4.08	1.44	10.5	103	95	132/80	1.12	6.22
				4.08	1.28	10.54	92	86	132/83	0,28	1.53
				4.08	1.21	10.11	93	86	113/64	0,36	2.11
16		134/69	80	4.08	1.46	11.18	103	96	124/75	1.1	5.86
				4.08	1.38	10.28	99	91	122/71	1.03	5.92
				4.08	1.46	10.55	99	88	156/106	1.2	6.6
17		154/70	81	4.08	4.15	22.41	109	98	119/71	6.02	15.92
				4.08	1.43	11.05	96	89	116/87	0.62	3.37
18		130/76	87	4.08	1.3	10.27	100	90	114/70	0.55	3.14
				4.08	2.05	15.14	98	88	110/74	2.08	8.18
				4.08	1.44	10.32	100	88	115/71	1.39	7.9
19		133/77	92	4.08	6.84	45	118	99	146/98	9.9	13.21
20		138/78	81	4.08	6.96	45	103	90	138/86	10.07	13.43

21		135/71	84	5.06	2.53	16.15	111	99	126/77	4.47	16.49
				5.06	4.44	29.29	109	91	119/75	7.74	15.75
22		136/72	82	5.06	6.66	40.34	103	94	127/73	12.01	17.76
23		142/90	77	5.06	8.62	45	122	96	138/85	15.51	20.68
24		126/74	76	5.06	7.83	45	103	90	117/88	14.07	18.75
25		98/81	84	6.04	8.66	45	112	94	125/82	18.54	24.72
26		132/98	85	6.04	9.73	45	104	87	117/71	20.94	
27		138/62	95	7.02	5.05	29.13	116	99	118/62	12.51	25.7
28		135/84	86	7.02	7.44	45	114	104	126/75	18.28	24.38

APPENDIX J:

Participant 4 Data

Exercise Performance Data

Time to Fatigue:	
Pre	24:04:00
Mid	45:00:00
Post	45:00:00

Distance to Fatigue:	
Pre	6
Mid	12
Post	10.7

Kcal/hr Expended:	
Pre	5.4
Mid	5.7
Post	5.1

Cardiovascular Performance Data

	MAP	Resting BP	Resting HR
Pre	86.3	111/74	70
Mid	133	165/69	73
Post	79.3	96/71	78

Avg HR:		Peak HR:	
Pre	84	Pre	96
Mid	90	Mid	94
Post	80	Post	85

Upper Limb Function Data

QIF			
?	Pre	Mid	Post
1	4	0	4
2	3	3	3
3	4	0	4
4	4	0	4
5	3	3	4
6	4	0	4
AVG	3.666667	1	3.833333
STD	0.516398	1.549193	0.408248
SUM	22	7	23

CUE			
?	Pre	Mid	Post
1a	4	5	6
1b	4	4	6
2a	4	4	6
2b	4	4	6
3a	5	6	7
3b	5	6	7
4	3	2	3
5a	6	6	7
5b	6	6	7
6a	4	4	4
6b	4	4	4
7a	5	6	7
7b	5	6	7
8a	3	3	3
8b	3	3	3
9	6	3	6
10a	3	3	6
10b	3	3	6
11a	4	6	7
11b	4	6	7
12a	4	6	6
12b	4	6	6
13a	3	2	5
13b	4	3	6
14a	4	3	5
14b	4	3	6
15a	3	3	5
15b	4	4	6
16a	2	2	2
16b	2	3	3
17a	6	6	6
17b	6	7	7
AVG	4.09375	4.3125	5.5625
STDEV	1.117583	1.533233985	1.457738
SUM	131	138	178

SCI-SET			
?	Pre	Mid	Post
1	3	3	4
2	3	4	4
3	2	3	3
4	3	3	4
5	2	4	3
6	4	4	4
7	4	4	4
8	4	4	3
9	3	4	3
10	2	3	3
11	3	3	4
12	2	2	3
13	4	4	4
14	2	3	4
15	1	3	3
16	3	3	3
17	3	3	4
18	4	4	4
19	4	4	4
20	2	2	3
21	1	2	1
22	2	1	2
23	2	1	4
24	4	4	4
25	3	2	4
26	4	4	4
27	4	3	3
28	2	3	3
29	2	3	3
30	1	3	3
31	1	3	3
32	4	4	4
33	3	4	4
34	2	3	3
35	3	3	4
AVG	2.742857	3.142857143	3.428571
STDEV	1.010034	0.845154255	0.698137
SUM	96	110	120

Training Data 4		Resting BP	Resting HR	Resistance	Distance	Time	Peak HR	Avg HR	BP Post	Cal	Cal/hr
Pre		111/74	70	1	6	24.04	96	84	116/81	2.2	5.4
1			60	1	6.07	26.21	88	71	120/82	2.2	5.2
				1		19.39	99		114/78		
2		94/62	94	1	10.36	45	87	75			
3		124/73	85	1	10	45	80	68	98/70	3.6	4.8
4		111/78	79	1.98	10.04	45		82	108/83	7.1	9.5
5		102/70	82	1.98	10.32	45			107/86	7.3	9.7
6		111/83	85	1.98	10.42	45	102	94	114/85	7.4	9.8
7		114/82	87	2.98	9.98	45	101	95	112/74	10.6	14.1
8		116/82	87	2.96	10.3	45	102	94	106/68	10.9	14.6
9		99/67	88	2.96	10.74	45	72	66	128/66	11.4	15.2
10		101/67	84	3.94	10.43	45	100	89	105/71	14.7	19.6
11		102/69	81	3.94	10.45	45			100/68	14.7	19.6
12		110/68	83	4.92	7.9	45	101	89	99/66	13.8	18.4
13		113/69	91	4.92	8.18	45	106	97	90/62	14.4	19.2
14		108/70	90	4.92	7.4	45	115	101	94/62	13	17.3
15		125/77	81	5.62	8.9	45	109	65	91/66	17.8	23.8
16		105/69	93	5.62	11.47	45	112	70	103/69	25	30.7
Mid		165/69	73	1	12	45	94	90	122/78	4.3	5.7
18		121/71	90	6.04	5.1	27.3	90	87	94/61	10.9	23.8
				6.04	3.11	19.3	90	87	97/64	7.7	23.8
19		111/74	78	6.04	8.06	45	87	61	98/66	17.4	23.2
20		99/67	88	6.04	8.54	45	102	89	83/67	18.4	24.5
21		94/72	95	6.6	3.6	25.26	93	81	97/61	8.4	21.5
				6.6	4.51	21.34	109	87	106/70	8.3	22.3
22		106/66	87	6.6	7.09	45	103	99	83/67	16.6	22.2
23		99/70	83	6.6	7.03	45	153	131	81/71	16.6	22.1
24		83/73	86	7.16	3.7	24.15			98/62	8.9	24.1
				7.16	2.1	11.07			101/65		25.2
25		112/72	89	7.16	3.3	24.26			94/64	7.8	21
				7.16	3.16	22.34			102/69	7.9	21.4
26		100/73	81	7.16	3.3	22.19	89	74	101/72	7.9	21.1
				7.16	2.99	20.25			86/63	7.2	21.5
27		111/66	90	6.6	3	19.5			154/57	6.4	20.3
				6.6	2.98	20.1			96/64	6.3	19.1
28		95/66	70	6.6	3.5	22.14			92/60	7.7	20
				6.6	3.4	21.03			87/58	7.2	19.5
29		95/66	75	7.02	4.4	26.05			99/66	10.2	22.5
				7.02	4.67	19.55			98/69	10.3	21.4
30		102/68	91	7.02	3.5	25.23	102	96	82/56	8	6.3
				7.02	2.87	20			90/57	20.6	20.1
31		96/74	90	7.16	2.3	19.28	90	86	92/56	4.9	19
				7.16	2.1	14.18			114/54	4.2	17.8
32		98/72	80	7.16	3	18.49	94	89	95/70	7	21.2
				7.16	1.6	9.32			100/60	2.6	15
				7.16	1.7	10.29			98/68	3.1	16.3

APPENDIX K:

Participant 5 Data

Exercise Performance Data

Time to Fatigue:	
Pre	11:10
Mid	11:08
Post	11:08

Distance to Fatigue:	
Pre	0.83
Mid	0.64
Post	0.72

Kcal/hr Expended:	
Pre	0.5
Mid	0.5
Post	0.5

Cardiovascular Performance Data

	MAP	Resting BP	Resting HR
Pre	80	102/69	69
Mid	80.7	100/71	62
Post	76	98/65	68

Avg HR:		Peak HR:	
Pre	80	**Pre**	89
Mid	86	**Mid**	90
Post	92	**Post**	97

Upper Limb Function Data

QIF			
?	**Pre**	**Mid**	**Post**
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
AVG	0	0	0
STD	0	0	0
SUM	0	0	0

CUE			
?	Pre	Mid	Post
1a	1	1	1
1b	3	2	2
2a	1	1	1
2b	1	1	1
3a	1	1	1
3b	1	1	1
4	1	1	1
5a	1	1	1
5b	4	4	3
6a	1	1	1
6b	1	1	1
7a	1	1	1
7b	4	4	3
8a	1	1	1
8b	1	1	1
9	1	1	1
10a	1	1	1
10b	1	1	1
11a	1	1	1
11b	1	1	2
12a	1	1	1
12b	1	1	1
13a	1	1	1
13b	1	1	1
14a	1	1	1
14b	1	1	1
15a	1	1	1
15b	1	1	1
16a	1	1	1
16b	1	1	1
17a	1	1	1
17b	2	1	2
AVG	1.28125	1.21875	1.21875
STDEV	0.812578	0.750672	0.552669
SUM	41	39	39

SCI-SET			
?	Pre	Mid	Post
1	4	1	4
2	3	2	4
3	3	3	3
4	4	3	3
5	4	1	4
6	4	1	4
7	4	4	4
8	4	4	4
9	4	4	4
10	4	4	4
11	4	4	4
12	4	4	4
13	4	4	4
14	4	4	4
15	4	4	3
16	3	4	5
17	3	3	3
18	4	4	4
19	3	3	3
20	3	3	3
21	4	4	4
22	4	4	4
23	4	4	4
24	4	4	4
25	3	4	3
26	3	4	3
27	3	4	3
28	3	4	3
29	3	3	2
30	4	4	4
31	4	4	3
32	3	3	3
33	4	4	4
34	3	3	3
35	4	4	3
AVG	3.628571	3.457143	3.571429
STDEV	0.490241	0.91853	0.608069
SUM	127	121	125

Training Data 5		Resting BP	Resting HR	Resistance	Distance	Time	Peak HR	Avg HR	BP Post	Cal	Cal/hr
Pre		102/69	69	1	0.83	11.1	89	80	90/59	0	0
1		102/69	69	1	0.8	11.08	107	95	103/67	0.2	0.8
				1	0.9	11.1	98	85	121/66	0.2	0.9
				1	0.8	11.08	105	83		0.1	0.3
2		90/62	56	1	1	11.2	89	83	90/59	0	0
				1	1.1	11.09	80	79	114/74	0	0.1
				1	0.8	11.08			100/70	0	0.1
3		86/69	69	1	0.83	11.1			86/64	0.1	0.5
				1	0.9	11.1			111/74	0.1	0.6
				1	0.9	11.08			114/78	0.1	0.6
4		78/54	73	1	0.9	11.08	93	90	94/68	0.1	0.8
				1	0.9	11.08	94	86	108/72	0.1	0.8
				1	0.9	11.08	91	87	107/66	0.1	0.6
5		102/69	66	1	0.8	11.08	96	91	100/67	0.1	0.5
				1	0.8	11.08	94	87	107/66	0.1	0.6
				1	0.9	11.09	95	89	94/66	0.1	0.6
6		94/65	61	1	0.9	11.2	88	80	102/66	0.1	0.8
				1	0.9	11.08	88	82	96/62	0.1	0.8
				1	0.9	11.08	85	75	102/67	0.1	0.9
7				1	0.7	11.08	80	74	101/65	0.1	0.4
				1	0.8	11.08	84	78	92/67	0.1	0.4
				1	0.8	11.08	88	82	94/62	0.1	0.5
8		77/63	60	1	0.81	11.08	87	79	95/66	0.1	0.6
				1	0.8	11.08	83	78	97/63	0.1	0.6
				1	0.8	11.09	84	77	95/66	0.1	0.6
9		101/70	65	1	0.7	11.08	96	90	109/71	0.1	0.3
				1	0.8	11.08	95	87	100/66	0.1	0.6
				1	0.84	11.08	98	84	98/69	0.1	0.7
10		96/68	64	1	0.8	11.02	93	79	104/66	0.1	0.5
				1	0.79	11.02	88	76	111/70	0.1	0.5
				1	0.9	11.02	93	73	125/70	0.1	0.8
11		83/59	56	1	0.72	11.08	88	76	87/64	0.1	0.5
				1	0.83	11.08	93	72	110/63	0.1	0.7
				1	0.74	11.08	89	76	102/67	0.1	0.6
12		95/65	60	1	0.63	11.02	85	82	86/55	0.1	0.3
				1	0.7	11.08	90	80	88/56	0.1	0.3
				1	0.8	11.08	93	80	82/54	0.1	0.5
13		102/75	61	1	0.7	11.08	89	82	98/63	0.1	0.5
				1	0.82	11.08	85	75	83/66	0.1	0.6
				1	0.8	11.08	86	79	98/66	0.1	0.7
14		90/65	63	1	0.67	11.08	83	79	94/56	0.1	0.4
				1	0.69	11.08	85	78	94/62	0.1	0.4
				1	0.74	11.08	88	77	88/57	0.1	0.6
15		102/68	59	1	0.6	11.08	93	88	108/66	0.1	0.4
				1	0.69	11.08	89	81	72/56	0.1	0.4
				1	0.67	11.08	89	81	122/74	0.1	0.5
16		86/69	58	1	0.71	11.08	90	82	101/66	0.1	0.5

				1	0.69	11.09	90	81	121/73	0.1	0.5
				1	0.7	11.08	95	83	118/74	0.1	0.5
17		112/80	57	1	0.59	11.08	93	88	102/66	0	0.3
				1	0.61	11.08	94	90	112/70	0.1	0.4
				1	0.6	11.08	88	82	118/77	0	0.3
Mid		100/71	62	1	0.64	11.08	90	86	114/69	0.1	0.5
18		102/70	62	1	0.69	11.08	96	86	107/66	0.1	0.5
				1	0.74	11.08	104	88	112/56	0.1	0.5
				1	0.72	11.08	94	82	121/70	0.1	0.6
19		106/79	59	1	0.55	11.08	99	91	121/65	0.1	0.4
				1	0.65	11.08	106	92	118/74	0.1	0.5
				1	0.7	11.08	114	95	128/75	0.1	0.4
20		82/59	66	1	0.7	11.08	102	95	82/66	0.1	0.4
				1	0.61	11.08	100	94	108/75	0.1	0.4
				1	0.56	11.08	90	81	109/70	0.1	0.4
21		101/70	60	1	0.6	11.08	106	93	114/71	0.1	0.4
				1	0.65	11.08	99	84	113/75	0.1	0.3
				1	0.71	11.08	85	77	129/86	0.1	0.4
22		91/64	69	1	0.6	11.09	111	95	114/70	0.1	0.4
				1	0.71	11.08	107	89	119/69	0.1	0.5
				1	0.75	11.09	108	88	124/76	0.1	0.5
23		112/78	61	1	0.62	11.08	96	87	93/61	0.1	0.4
				1	0.73	11.08	94	79	110/73	0.1	0.5
				1	0.78	11.08	98	80	110/73	0.1	0.6
24		104/75	72	1	0.73	11.08	107	95	117/77	0.1	0.6
				1	0.76	11.08	111	90	126/82	0.1	0.4
				1	0.83	11.08	110	89	98/80	0.1	0.6
25		105/74	68	1	0.7	11.11	112	95	122/71	0.1	0.5
				1	0.65	11.08	100	89	130/70	0	0.3
				1	0.66	11.08	94	87	129/82	0	0.2
26		86/64	67	1	0.77	11.11	105	94	112/66	0.1	0.7
				1	0.74	11.08	105	95	106/74	0.1	0.7
				1	0.74	11.1	108	96	120/70	0.1	0.5
27		115/106	74	1	0.72	11.11	99	91	107/63	0.1	0.5
				1	0.67	11.08	96	86	113/74	0.1	0.5
				1	0.6	11.08	93	87	115/66	0.1	0.4
28		74/56	66	1	0.73	11.1			106/69	0.1	0.6
				1	0.68	11.08	99	92	105/73	0.1	0.4
				1	0.75	11.08	94	88	119/73	0.1	0.4
29		81/58	61	1	0.67	11.1	95	85	107/64	0.1	0.4
				1	0.69	11.08	94	82	76/60	0.1	0.5
				1	0.68	11.09	92	84	102/68	0.1	0.6
30		87/66	60	1	0.71	11.12	98	87	117/64	0.1	0.4
				1	0.73	11.1	98	83	105/63	0.1	0.5
				1	0.71	11.07	98	83	106/66	0.1	0.4
31		93/62	56	1	0.67	11.1	96	84	97/59	0.1	0.4
				1	0.68	11.08	94	82	93/58	0.1	0.5
				1	0.71	11.08	84	77	99/66	0.1	0.4