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The effects of dietary creatine monohydrate supplementation and resistance training in older men

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THE EFFECTS OF DIETARY CREATINE MONOHYDRATE SUPPLEMENTATION AND RESISTANCE TRAINING IN OLDER MEN

by

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Abstract

In order to ascertain the effects of creatine monohydrate (CrH_2O) supplementation on muscle mass and strength in older males, seventeen volunteers aged between sixty and eighty years were allocated to a creatine or a placebo group. Both groups took part in a training programme of the knee flexors and extensors of one leg only, consisting of knee flexion in a standing position and knee extension in a seated position. An adjustable, weighted cuff was used to provide resistance and subjects increased their weight reps and sets at their own discretion. The creatine group supplemented their training with CrH_2O starting with a loading phase of 15 g CrH_2O per day for 14 days and 3 g per day for the following 10 weeks. The placebo group took an equivalent amount of dextrose. The study was performed in a double-blind fashion.

Strength changes were assessed using isokinetic dynamometry. Both isokinetic and isometric strength were tested. Isokinetic tests were done at 60°, 180° and 240° per second and isometric tests at 45°, 60° and 75°. Endurance was measured at the end of each testing session by means of five sets of 15 repetitions concentric knee extension and flexion at a speed of 180°/sec with 30 s rest between sets. Dual-energy X-ray absorptiometry (DEXA) scans were used to quantify total body lean mass and fat mass as well as limb segment mass changes, these were taken before and after the protocol. Serum creatinine was tested in order to quantify creatine uptake.

There were no significant changes in the amount of serum creatinine for either group, nor were there any significant changes in body composition. Significant differences were found

to occur in isometric and isokinetic strength, for both groups as a result of training over time. Isometric strength showed a significant increase over time overall ($p \leq 0.05$), but there was no statistical significance shown for any of the groups in respect to the baseline values. Subjects supplemented with CrH_2O showed significant increases in isokinetic strength at the two slower velocities compared to baseline values. Subjects' endurance improved with training and the Cr group improved more than the Pl group despite a slightly lower training volume.

The major findings of this study were that CrH_2O supplementation improved muscle function when combined with resistance training, particularly for repeated bout maximal activity in older males. The implications of this study are that this type of supplementation/training programme is well tolerated and would prove suitable for the more frail elderly population as well as individuals suffering from muscular degenerative disorders.

DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

(i) incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education.

(ii) contain any material previously published or written by another person except where due reference is made in the text; or

(iii) contain any defamatory material.

Signature:

Date: 16th February 2004

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Finally thankyou to my parents and sisters who, through their own sacrifices helped me in so many ways. Your support, both financially and emotionally, is very much appreciated. I love you all.

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LIST OF ABREVIATIONS

ANOVA	analysis of variance
ADP	adenosine diphosphate
ATP	adenosine triphosphate
BL	Baseline
CrH_2O	Creatine Monohydrate
Crn	Creatinine
CrT	Creatine Trained Group
CrU	Creatine Untrained Group
DEXA	dual energy x-ray absorptiometry
FFM	fat free mass
PCr	Phosphocreatine
Pl	Placebo
PlT	Placebo Trained Group
PlU	Placebo Untrained Group
SD	Standard Deviation
SEM	Standard Error of the Mean
TCr	Total Creatine

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CHAPTER ONE

Introduction

As people age they experience a decrease in muscle mass, strength and exercise performance. Wasting of muscle can lead to reduced mobility and increased risk of injury due to falls (Rawson et al., 1999). Although loss of muscle mass can be ameliorated with regular physical activity (Fiatrone and Evans, 1993), older individuals are less likely to adopt and maintain a regular exercise programme (Shephard, 1998). Thus any additional means by which the reduction in muscle mass with ageing and inactivity can be slowed or reversed would have great potential for improving the health and well being of the elderly. A number of researchers have reported that, in young subjects, creatine (Cr) supplementation has a positive effect on muscle mass (Balsom, et al., 1993; Earnest et al., 1995; Greenhaff et al., 1994), strength (Earnest et al., 1995; Vandenberge et al., 1997) and performance of high-intensity exercise (Casey et al 1996; Earnest et al, 1995; Jacobs et al., 1997). Few studies have looked at the benefits of Cr supplementation alone or combined with weight training in older adults (Bermon et al., 1998; Rawson et al., 1998; Rawson et al, 2001; Chrusch et al., 2001). These studies have yielded less consistent findings than those using younger subjects.

1.1 Background and Significance

Ergogenic aids, (from the Greek phrase meaning 'work production' (Pepping, 1999)) such as Cr monohydrate, are readily available for use in the sporting community (Becque et al., 2000). Cr monohydrate (CrH_2O) is used by the athletic population because of its perceived ability to increase muscle mass and thereby improve performance in events where strength and power play a major contribution (Nelson et

al., 2001). Creatine (from the word 'kreas', being Greek for 'flesh' (Wyss & Kaddurah - Daouk, 2000)) was first discovered in 1835, by the French scientist Chevreul who found and extracted it from meat products (Waldron et al., 2002). Nearly one hundred years later Eggleton et al., (1927) characterised the intramuscular compound phosphocreatine (PCr). The importance of PCr was realised with the discovery of the creatine phosphokinase (CK) reaction by Lundsgaard in 1934 (Wyss & Schulze, 2002).

One of the main reasons why athletes supplement their diets with Cr is to increase PCr stores (Prevost et al., 1997). The functional basis for this practice is that it leads to an increased intracellular buffering of hydrogen ions (H^+) and an enhanced ability to regenerate adenosine triphosphate (ATP) during high intensity exercise (Harris et al., 1992). Possible alternative mechanisms for the ergogenic effects of CrH_2O supplementation include greater mitochondrial CK activity and enhanced skeletal muscle protein synthesis. These mechanisms positively affect the rate of ATP resynthesis improving recovery resulting in an improvement in muscular performance (Schilling et al., 2001).

Theoretically the individuals who would potentially gain the most benefit from Cr supplementation are those who have reduced muscle mass, or decreased intramuscular PCr levels. Two of these potential groups include the elderly (Rawson et al., 1999) and subjects with neuromuscular diseases (Walter et al., 1999). Any intervention which leads to an improvement in muscle mass and/or muscle PCr content in such individuals would be likely to have the effect of increasing their physical capacity for work. Unlike athletes, Cr supplementation for these populations is not aimed at improving athletic performance, but the ability to carry out everyday tasks which most people take for granted, such as climbing a flight of stairs or moving a piece of furniture without help.

This may in turn facilitate an increase in their level of physical activity and further improve muscle strength, with additional cardiovascular health benefits.

There is evidence to suggest that, in older individuals, levels of muscle PCr, serum Cr and muscle Cr are reduced, although considerable variation exists between individuals (Moller et al., 1980). Older adults lose muscle mass as a consequence of a reduction in both muscle fibre number and size, resulting in a loss of muscle strength (Aniansson et al., 1986). Chrusch et al., (2001) showed that adults over the age of fifty years improved their muscular performance with a combination of Cr supplementation and training, the effects of which could be attributed to improved PCr resynthesis. Therefore, the present study aimed to determine whether supplementation with CrH_2O would lead to increased muscle mass and strength of knee extensors and flexors in males aged 60-80 years, undergoing a home-based resistance training program, compared to a placebo group. Given the potential beneficial effects of Cr supplementation on intramuscular phosphagens, the author also anticipated that those subjects ingesting Cr would show greater improvements in training volume over time, compared to a placebo control group. The study was carried out using males aged between 60 and 80 years. The subjects were tested at baseline for knee extensor and flexor strength and endurance, serum creatinine levels, limb segmental mass of each thigh and whole body mass. The participants were randomly allocated to either a CrH_2O or a placebo group. All subjects were given the same home based light training regimen for the extensors and flexors of one leg only. This created four subgroups, CrH_2O and training (CrT), CrH_2O and no training (CrU), placebo and training (PlT) and placebo and no training (PlU). The training intervention period was 12 weeks. Strength and endurance retests were carried out at weeks 2, 7 and 12. Body composition analysis and plasma creatinine (Crn) tests were performed pre and post intervention.

1.2 Research Questions

1. Will there be an increase in total muscle mass of elderly males as a result of taking creatine monohydrate?
2. Will supplementation with creatine monohydrate support extra training in elderly males compared to a training and placebo condition?
3. Will there be a difference in isometric and isokinetic force production and endurance as a result of supplementation with creatine monohydrate in elderly males?
4. Will there be a difference in trained versus non-trained limbs with creatine monohydrate supplementation?

1.3 Research Hypotheses

1. Muscle mass will increase significantly in the creatine group but not the placebo group.
2. Muscle strength will increase significantly more in the creatine group than the placebo group.
3. Muscular endurance will increase significantly more in the creatine group than the placebo group.
4. Muscle mass will increase more in the trained leg than the untrained limb following training in the placebo group.
5. Muscular strength will increase significantly more in the trained leg than the untrained limb following training in the placebo group.
6. Muscular endurance will increase more in the trained leg than the untrained limb following training in the placebo group.

7. Muscle mass will increase significantly more in the trained leg than the untrained limb following training in the creatine group.
8. Muscular strength will increase significantly more in the trained leg than the untrained limb following training in the creatine group.
9. Muscular endurance will increase more in the trained leg than the untrained limb following training in the creatine group.

CHAPTER TWO

Literature Review

2.1 Sarcopoenia

Sarcopoenia is described by Hurley & Roth (2000) as a loss of strength with advanced age and is associated with a deterioration of health status. Muscle mass and cross-sectional area reaches a peak at approximately 30 years of age and then a steady decline occurs during the fortieth decade, accelerating to around 12 to 14% per decade after the age of 50 years (Roth et al., 2000). Between the ages of 30 and 80 years overall muscle strength and mass may decline by 30-50% (Frischknecht, 1998; Roth et al., 2000). After 70 years of age a further increase in the rate of strength and mass loss is evident, as much as 30% of strength may be lost between the ages of 70 and 80 years (Frischknecht, 1998). Losses in muscle mass and strength with ageing are similar to those resulting from inactivity (Hurley & Roth, 2000). The decrease in muscle strength is closely correlated with changes in muscle cross-sectional area, suggesting that much of the strength loss in ageing is explained by loss of muscle mass rather than neurological factors (Frischknecht, 1998). Studies which have examined muscle biopsy samples from older subjects have described a greater decrease in cross-sectional area of whole skeletal muscles than that of individual muscle fibres (eg. Grimby & Saltin, 1983). This has led to the conclusion that the reduction in muscle fibre size cannot fully explain the loss in muscle mass, but that a reduction in fibre number must also occur. Furthermore, there appears to be a difference in the rate of atrophy between muscle fibre types. The available evidence for changes in muscle fibre type with age is conflicting, with some studies showing that Type I fibres area is unchanged up to the age of about 80 years, but Type II fibres show significant atrophy, with a reduction of

around 26% for quadriceps femoris by the age of 80 years (Larsson et al., 1978). Other investigations have found an increased proportion of Type I fibres in 65 year olds compared with 25 year old subjects (Lexell, 1993). According to Roos et al., (1996) there is no conflict regarding the evidence for a reduction in cross-sectional areas of individual muscle fibres with advancing age. At the age of approximately forty years Type II fibres are around 20% larger than Type I fibres, but Type II fibres measure about 50% for cross-sectional of Type I fibres by the age of 85 years (Roos et al., 1996). In a 12 years longitudinal study, Frontera et al., (2000) recorded a 20-30% loss in isokinetic strength of elbow and knee flexors and extensors for individuals who were about 65 years of age at the first test session. Cross sectional area of the thigh muscles were reduced by approximately 15% after 12 years. They also reported a rate of strength loss of 2.5% per year for knee flexors and 2.0% per year for knee extensors. The authors showed a loss of muscular strength with age in their subjects at both fast and slow angular velocities for knee extensors and flexors as well as elbow. The same study reported showed a significant decrease in cross sectional area of muscles and a decrease in Type I to Type II fibre ratio, leading the authors to conclude that a quantitative loss in muscle mass is directly linked to the associated loss of strength in elderly males. They went on to recommend that increased physical activity in sedentary, healthy older males may reduce the effects of disability due to this gradual loss of strength.

Kent-Braun & Ng (2000) studied the effects of ageing on the oxidative capacity of skeletal muscles in young and older males and females. They found that skeletal locomotor muscles of healthy older males and females showed no deficit in oxidative capacity compared to the muscles of younger men and women of similar physical activity levels. This suggests that loss in oxidative capacity is not a direct consequence of ageing. This investigation also found that PCr recovery was not different between the

groups and that there was a wide range in PCr recovery values between the older and younger participants (Kent-Braun & Ng, 2000). They concluded that most of the variation in oxidative capacity between individuals could be accounted for by differences in physical activity levels, and was not related to the effects of ageing per se.

2.2 Strength Training and the Elderly

Strength training increases muscular strength and cross-sectional area in young adults (Frischknecht, 1998). Mass increases are due to greater cross-sectional area of both Type I and Type II fibres and possibly a greater number of individual fibres. There is some controversy regarding the possibility of increasing fibre number (hyperplasia) in response to training (Frischknecht, 1998). However, even in those subjects described as very old (more than 80 years of age) studies have shown that skeletal muscle strength and mass can be improved with resistance training. For example, Fiatarone et al., (1990) looked at male and female nursing home residents who were instructed on how to perform a series of exercises designed to strengthen their knee extensor muscles. These included 3 sets of 8 eccentric and concentric repetitions performed 3 times weekly for 8 weeks at a training load of 80% of their one repetition maximum (RM). The resistance was increased progressively every two weeks. Over the course of training, quadriceps muscle strength increased by an average of 174% and cross-sectional area was 11% greater. These changes were accompanied by a mean improvement in walking speed of 48%. Interestingly, despite these dramatic gains in muscle area and function, all indices had declined to pre-investigation levels 4 weeks after participants returned to their normal routine.

2.3 Creatine

Creatine is a nonessential dietary element, found in meat and fish (Terjung et al., 2000). Produced endogenously in the body it is an energy-producing substance that is synthesized in the liver, pancreas and kidney from amino acids (Harris et al., 1992). Creatine is also ingested from animal products (Kreider; 1998). Creatine synthesis is a two step reaction, firstly guanidinoacetate is formed from arginine and glycine in a reaction catalyzed by arginine:glycine amidinotransferase. In the second step s-adenosylmethionine, a methyl group is transferred to guanidinoacetate forming creatine (Terjung et al., 2000). Some of the creatine is phosphorylated to form creatine phosphate, also called phosphocreatine (PCr). PCr has four main functions in skeletal muscle metabolism. It allows for the rapid rephosphorylation of ADP during periods of transition between rest and exercise as well as during short periods of high intensity exercise. Secondly, it enhances the capacity for high energy phosphate diffusion from mitochondria to myofibrils. PCr also serves as a buffer against the development of intracellular acidosis during exercise. Lastly, Cr and inorganic phosphate, the products of PCr hydrolysis, are important for activation of glycogenolysis and other catabolic pathways (Terjung et al., 2000). There are many occasions during exercise when mitochondrial ATP production via oxidative phosphorylation is insufficient to support the energy metabolism required for the maintenance of work output. These include situations of high intensity exercise, the rapid transition from one exercise level to a higher intensity, and occasions where oxygen availability is reduced. In such situations energy is provided via PCr phosphorylation and glycogenolysis/glycolysis (Terjung et al., 2000).

Ninety five percent of creatine is found in muscle tissue, its concentration normally being in the range of 100 to 140 mmol/kg dry mass (DM) (Mathews & Van Holde, 1996, p266). Creatine is broken down to creatinine (Crn) in skeletal muscle after which it diffuses into the bloodstream before being excreted in the urine (Volek, 1999a; Benzi, 2000). For this reason, one way of measuring creatine intake and metabolism is the use of urinary Crn collections (made over a 24 hour period). In the absence of Cr supplementation, muscle Cr stores are metabolised at a constant rate of approximately 2 grams per day (Volek, 1999a). Muscle creatine stores must be replenished from dietary sources or by endogenous synthesis to maintain sufficient intramuscular Cr and PCr levels for optimum physiological function (Feldman, 1999). If dietary Cr exceeds that required to maintain muscle stores, it is converted to Crn and readily excreted by the kidneys, there being no renal threshold for the urinary excretion of Crn (Feldman, 1999).

Studies which have investigated Cr uptake in subjects ingesting supplementary CrH_2O using urinary Crn as a measure have found that the greatest muscle Cr uptake usually occurs within the first 2 days of supplementation (Odland et al., 1997). This method, however, is a very imprecise measurement, as endogenous Crn excretion varies among individuals due to physical activity, maturity, metabolic state and gender (Lukaski, 1997).

Energy for muscle contraction is obtained when adenosine triphosphate (ATP) is stripped of a phosphate to form adenosine diphosphate (ADP), with the released chemical free energy converted into mechanical work. For short-term anaerobic exercise, the high-energy phosphate is donated by PCr to replenish ATP stores. Skeletal muscle contains approximately 80 to 100 grams of ATP, which is only enough to support performance of high intensity exercise for several seconds (McArdle, Katch &

Katch, 1996, p102). Creatine has a high phosphate transfer potential and so this compound is capable of phosphorylating ADP very efficiently as shown in figure 1. (Mathews & Van Holde, 1996, p266).

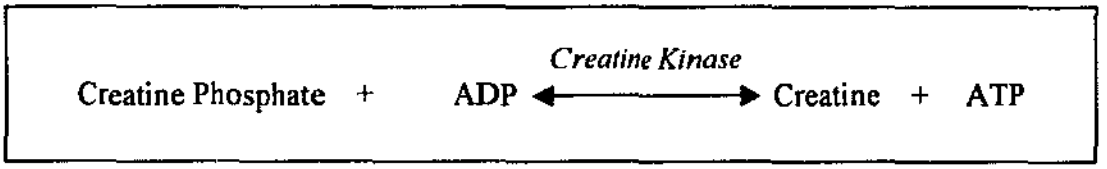

Figure 1. The energy source in muscle is creatine phosphate, which regenerates ATP continually as it is depleted by muscle contraction.

As the equilibrium constant lies to the right of this reaction, almost all muscle adenylate is maintained in the form of ATP while creatine phosphate is available. Creatine phosphate always tends to transfer its phosphate to adenosine diphosphate in order to replenish the ATP (Mathews & van Holde, 1996 p266). This reaction can generate enough power for 4 seconds of muscle contraction (Feldman, 1999). During recovery after strenuous exercise, the CK reaction is reversed to produce PCr and ADP.

2.3.1 Creatine Kinase (CK)

Creatine kinase is an enzyme that catalyses biochemical reactions that occur intramuscularly. CK's primary role is to convert a phosphate group to Cr, resulting in a high-energy molecule PCr. Plasma CK levels are also used in many research and clinical studies as it is an indicator of skeletal muscle damage (Schwane et al., 2000). When the muscle is damaged due to injury or exercise, muscle cells break down and, as CK is normally found in muscle, a rise in the levels of plasma CK indicates that muscle damage has occurred (Schwane et al, 2000).

2.4 Creatine Supplementation in Athletes

PCr depletion is a limiting factor when performing exercise (Rossiter et al., 1996). The first study into the use of Cr supplementation in humans for the purpose of improving performance was conducted by Harris et al., (1992). They used a diverse group of subjects (five females and 12 males between 20 and 62 years) who varied greatly in their fitness levels. There was no training protocol in place for most of the subjects, but five of the subjects conducted a one leg bicycle ergometry training regimen for one hour each day during the experimental period which lasted not more than seven days. On average there was a significant increase in the total creatine pool, although no increase in muscle ATP content occurred. This study showed that exercise can increase the amount of Cr taken up with supplementation in individual muscle groups. The training leg of the subjects, who took part in the single leg training programme, had an increase in total Cr in the trained muscle of 27.2% compared to 20.5% in the untrained leg using muscle biopsy samples. The authors suggested that supplementation with Cr could have a benefit in athletic performance because Cr uptake is enhanced when taken in conjunction with regular exercise. This could be best explained by an increase of blood flow to the working muscles, although it is also possible that a change in the transport kinetics of Cr across the fibre membranes may have contributed to the observed findings (Harris et al., 1992).

Many studies have since been carried out to determine the effect of Cr supplementation on skeletal muscle strength and mass in young healthy recreational athletes (Balsom et al., 1993; Earnest et al., 1995; Casey et al., 1996; Prevost et al., 1997; Volek et al., 1999; Becque et al., 2000; Edwards et al., 2000). In the study by Volek et al., (1999) CrH_2O supplementation proved to be beneficial for high volumes of heavy resistance

training in ten, already well trained individuals. The creatine group saw much faster improvements in strength than the placebo group. These findings were explained on the basis that the increased intracellular PCr resulting from supplementation allowed for ATP replenishment to take place at a faster rate, which, in turn, allowed athletes to train at a higher intensity during individual sessions.

During maximal exercise PCr acts as a buffer maintaining the ATP/ADP ratio within the muscle by donating its phosphate as the ATP is depleted (Rossiter et al., 1995). Volek et al., (1999) concluded that the increases in fat free mass observed following CrH_2O supplementation are a consequence of skeletal muscle fibre hypertrophy because the subjects were able to maintain a higher training volume than the placebo group for the reasons explained previously. Other researchers have reported similar findings. Rossiter et al., (1995) found a non-significant increase in rowing performance of trained rowers who took CrH_2O for five days. These participants improved their maximal rowing time by 2.3 seconds over the five days compared to a placebo group who experienced no change in performance. A number of studies have shown that during intermittent exercise bouts CrH_2O supplementation can support extra work. In a study using ten bouts of 6 seconds maximal effort cycling with rest periods of 30 seconds it has been shown that the group supplemented with CrH_2O had a smaller decline in work output from baseline to the final bout (Balsom et al., 1993). Prevost et al., (1997) showed an increase in time to exhaustion and total work time with CrH_2O supplementation in physically active physical education students compared to a placebo group in repeated bouts of maximal voluntary cycling. The four types of bouts were continuous cycling to exhaustion, thirty seconds of cycling with sixty seconds rest, twenty seconds of cycling with rest periods of forty seconds and ten seconds of cycling separated by twenty seconds rest. This study found CrH_2O supplementation

significantly increased time to exhaustion and total work time in every one of the four protocols tested (Prevost et al., 1997).

The increase in body mass and fat free mass (FFM) associated with CrH_2O supplementation is well documented (Balsom et al., 1993; Earnest et al., 1995; Casey et al., 1996; Prevost et al., 1997; Volek et al., 1999; Becque et al., 2000; Edwards, et al., 2000; Chrusch et al., 2000). The effects have been attributed to increases in total body water (TBW), increased muscle fibre size and enhanced protein synthesis. Haussinger and colleagues (1993) posit that, since Cr is an osmotically active substance, increasing intracellular Cr levels will lead to greater intracellular hydration, leading to myofibre swelling. This belief is further supported by reports of lowered urinary output and an increase in body mass during CrH_2O supplementation as a result of water retention (Hultman et al., 1996). In addition, Preen and colleagues (2001) found evidence to suggest that CrH_2O supplementation was associated with increased protein synthesis, which may also contribute to the elevations in body mass observed with Cr use. Other authors reported that the increased body mass associated with CrH_2O supplementation was associated with increased muscle DM in the absence of any changes in body fluid levels, thus arguing against a role of fluid retention in the changes in body mass observed (Francaux et al., 2000).

Francaux and Poortmans (1999) using bio-impedance spectroscopy to measure body water content, showed that 55% of the body mass increase after nine weeks CrH_2O supplementation occurred due to an increase in intramuscular water content. Importantly, Cr ingestion for longer than several weeks in healthy subjects results in a much greater improvement in both strength and lean muscle mass than shorter term studies (Volek et al., 1997; Prevost et al., 1997; Francaux & Poortmans, 1999; Volek et

al, 1999a). Most of the studies investigating the effects of CrH_2O supplementation have used high intensity resistance training programs. In contrast, Kamber et al., (1999) used cycle ergometry exercise as a training intervention in conjunction with CrH_2O supplementation and high intensity sprint repetitions as a test of functional performance. They found that the CrH_2O supplemented group had a significant improvement in performance over the last three sprints, and lower levels of blood lactate in a series of ten sprint repetitions. The authors concluded that Cr supplementation not only improved the capacity for heavy resistance training, but also high intensity ergometer based exercise.

2.5 Creatine Supplementation in Non-athletes.

Although a decrease in muscle mass is associated with aging (Welle et al., 1996), it is likely that other factors contribute, including a lack of physical activity, degenerative disorders, and poor nutrition (Fiatarone et al., 1990). Resistance training is considered a viable intervention for reversing the reduction in muscle function and degradation of structure in the elderly. Hurley and Roth (2000) suggested that resistance training in the elderly should focus upon an improvement of life quality by preventing disability and progression of disease through modification of risk factors as well as improving cardiovascular and metabolic function. These can help to improve muscle mass, strength, power, flexibility and bone mineral density (BMD) (Hurley and Roth, 2000). While there have been many studies into the use of creatine supplementation in athletes, research into the possible benefits for non-athletes is less common. Some research has been undertaken in the areas of supplementation for young sedentary people (Harris, Soderlund & Hultman, 1992), older populations (Bermon et al., 1998; Rawson et al., 1998; Chrusch et al., 2001) and in various pathological groups (Walter et al., 1999).

Walter et al., (1999) used Cr supplementation in patients with various forms of muscular dystrophy. This study employed a double blind, placebo-controlled, crossover design with a 3-week washout period. The subjects were evaluated for strength using manual assessment (MRC scale) and the patients own assessment of any changes. The researchers found a significant improvement in all evaluations and the patients' own assessment in the CrH_2O compared to the placebo group. There were no side effects reported during this study. Some studies have reported anecdotal evidence of nausea, vomiting and diarrhoea as well as an increased incidence of muscle cramps and strains. There have also been reports of hypertension in athletes supplementing with Cr (Terjung et al., 2000). A recent study by Stout and colleagues (2001), has demonstrated that CrH_2O supplementation during resistance training in a patient with myasthenia gravis resulted in increases in FFM, muscular strength and training volume. In contrast, patients receiving a placebo substance showed significantly smaller improvements when given the same training regimen.

It has been suggested that a low muscle PCr concentration may contribute to fatigue in activities of daily living where high-energy demands are placed on the muscles and that intramuscular PCr may be increased by CrH_2O supplementation (Tarnopolsky and Praise, 1999). There is evidence that short term CrH_2O supplementation can increase intramuscular PCr and total creatine concentrations by as much as 15 to 20 percent in normal subjects (Harris et al., 1992; Vandenberghe et al., 1997) and also in patients with cardiomyopathies (Gordon et al., 1995). Interestingly, individuals with the lowest concentrations of muscle PCr showed the greatest increase in response to supplementation (Gordon et al., 1995).

Tarnopolsky and Praise (1999) measured high-energy phosphate compounds in patients with neuromuscular disease and found PCr concentrations were significantly lower in patients with inflammatory myopathies and muscular dystrophy in comparison to normal controls. On differentiating patients by disorder groups as mitochondrial cytopathy, neuropathy, inflammatory myopathy, dystrophy/congenital myopathy or miscellaneous, they found that the PCr levels for patients with inflammatory myopathies and muscular dystrophy were significantly lower than the normal subjects and suggested that they may stand to benefit from creatine supplementation. A follow up study was conducted in subjects with the same neuromuscular disorders, which looked at body weight and strength measures including hand grip strength, ankle dorsiflexion strength and dorsiflexion fatigue. The authors found a significant improvement in all tests following CrH_2O supplementation of 10g for five days and 5g for five days (Tarnopolsky & Martin, 1999). A further study into creatine transporter and mitochondrial creatine kinase protein content in myopathies concluded that creatine transporter protein is lower in some neuromuscular disorders, which also have lower phosphocreatine concentrations and total creatine. The authors suggest supplementation with CrH_2O may help reduce the rate of muscle degradation in these patients. They further recommend long term, randomised, double-blind studies of CrH_2O and intracellular high-energy phosphates and how these may impact on strength reduction in these groups (Tarnopolsky et al., 2001).

In what is probably the most comprehensive study of the effects of CrH_2O supplementation and training in a non-athletic population to date, Bermon et al., (1998) placed a group of elderly, sedentary people into four test groups; creatine and training, creatine only, placebo and training and placebo only. The control groups did not participate in any resistance training. The exercise intervention consisted of chest press,

leg press and leg extension. They found that both of the training groups had significant increases in one repetition maximum scores as follows: control group, chest press (+7.8%) and leg extension (+5.7%), training group, chest press (14.7%), leg press (+14.0%) and leg extension (+18.1%). The changes in 12 repetition maximums for the control group were chest press (+6.7%) and leg extension (+6.0%). The training group increased their pre-test scores for leg press, chest press and leg extension by 17.5%, 16.2% and 17.1% respectively. Comparing training in combination with CrH_2O supplementation, the control placebo group showed no significant increases for one repetition maximum. The training placebo group showed an increase in leg press (+10.3%), chest press (+11.7%) and leg extension (+17.0%) and the training creatine group showed significant increases for leg press (+17.3), chest press (+17.4%) and leg extension (+18.9). A five day urine analysis was conducted six months after the experimental period in which the subjects ingested 20 grams of CrH_2O daily for five days. This showed that creatine loading was probably not fully achieved as the coefficients of variation for creatine and creatinine were 1 and 2.5% respectively (Bermon et al., 1998). The authors concluded that CrH_2O supplementation did not improve strength and muscle mass but that exercise was the major contributing factor. They speculated that elderly subjects may need a longer period of loading to bring the muscle Cr concentration to a level that can sufficiently support extra training and this is why there was no significant difference between the Cr and placebo groups.

Chrusch et al., (2001) used a double-blind, placebo controlled design with 12 weeks CrH_2O supplementation in which the dosages used were similar to that recommended for athletes (0.3 g/kg body weight for the loading phase and 0.07 g/kg body weight for the maintenance phase). The elderly male subjects were separated into creatine (mean age = 70.4 years) and placebo groups (mean age = 71.1 years) and strength was assessed

by one repetition maximum lifts for leg press, knee extension and bench press. The same exercises were employed to test muscular endurance, but in this case the maximum number of repetitions for three sets at an intensity equivalent to 70%-80% baseline one repetition maximum for bench press, knee extension and leg press. The training protocol consisted of an individualised, supervised gym-based, whole body, programme. The authors found that the creatine group were able to train harder than the placebo group, and completed a training volume which was 30% greater over the course of the programme. Creatine ingestion and training resulted in an increase in lean body mass of 5.7% (average = 3.3 kg) compared to 2.5% (average = 1.3 kg) for the PLA group. They also experienced a greater increase in muscular strength for all lower body exercises. The researchers concluded that creatine had a positive effect on muscular performance, especially for the lower limbs, in older males who were inexperienced in resistance training. The apparent contradiction between the findings of the Bermon et al., (1998) study and the Chrusch et al., (2001) investigation may be related to the dosages of supplementation used. Bermon et al., (1998) used a loading dose of 20 g per day for five days and 3 g per day for the remaining 42 days and Chrusch et al (2001) used a grams of CrH_2O/kilograms body weight dosing protocol giving the average loading dose of 26.4 g per day for five days and a maintenance dose of 6.2 g daily, thus using a maintenance dose over twice that of the earlier study. Whereas, Bermon et al., (1998) found no significant change in body mass in any of the four groups during the study, Chrusch et al., (2001) showed an increase of 5.7% lean body mass for the creatine group compared with a 2.5% increase for the placebo group.

Short-term (5 – 7 days) Cr supplementation studies have been shown to increase both lean body mass and intramuscular PCr stores (Balsom et al., 1993; Kreider, 1998a). Kreider (1998a) reported a 0.6 – 1.1 kg increase in body mass, but as described

previously, most of the increases in body mass resulting from CrH_2O supplementation have been attributed to increased total body water content rather than an increase in myofibrillar protein synthesis.

Long-term (> 4weeks) Cr supplementation studies on healthy individuals, show greater gains in strength and lean body mass (Kreider, 1998b) than studies involving supplementation over several weeks only (Volek et al., 1997). Long-term supplementation of Cr (a typical supplementation regimen consisting of 25 g daily for 5 – 7 days and 2 - 5 g daily for up to 12 weeks) promotes significant gains in strength, body mass and FFM in conjunction with a training program in comparison to placebo controls (Kreider, 1998a). Pepping (1999) suggests that these improvements are mainly due to the uptake of amino acids into contractile muscle proteins thus stimulating protein synthesis. However, not all studies have found improvements in performance to be an outcome of CrH_2O supplementation (eg. Stevenson & Dudley, 2001).

One of the problems encountered when attempting to compare the results of different studies which have used CrH_2O supplementation is the wide range of dosages used. This is due, at least in part, to the lack of consensus as to optimal dosage and duration, as well as issues relating to the efficacy and safety of different supplementation protocols. Although a loading phase of 20 g daily has been used in many research studies as it seems to be optimal for producing the most rapid increases in muscle Cr concentrations (Schilling et al., 2001), the same muscle PCr concentrations can be achieved with lower doses of Cr (3 g daily) but extending the loading period (Terjung et al., 2000). It has been suggested that the lower supplement dose can reduce the potential of developing side effects (Schilling et al., 2001). Volek and colleagues (1999b) have shown that as little as 2 g of Cr ingested daily can improve intramuscular Cr levels in

men who are not exercising vigorously, whilst Harris and associates (1992) found that four to six doses of 5 g of Cr for 2 days produced a significant increase in TCr stores in the quadriceps femoris muscle of 17 subjects. It is interesting to note that Harris et al., (1992) found that the greatest improvements in muscle Cr concentration were seen in subjects with an initially low Cr content.

The washout period for intramuscular Cr (ie. the time taken for muscle Cr to return to pre-supplementation values) can be quite variable. Following Cr supplementation, muscle Cr concentration can remain elevated for weeks or even months depending on the initial dosage ingested (Maughan, 1995). Feldman (1999) and Wyss & Kaddurah - Daouk (2000) reported that muscle Cr and PCr concentrations returned to baseline levels approximately 30 days after cessation of short term CrH_2O supplementation. Vandenberghe and coworkers (1997) found that muscle PCr and urinary Cr and Cm excretion returned to normal values after four weeks of long-term Cr supplementation was stopped.

There are conflicting reports as to the effectiveness of CrH_2O supplementation in improving performance (Stevenson and Dudley, 2001; Yquel et al., 2002). Cr supplementation has been reported to have a reduced ergogenic effect when the supplementation regimens are short term and involve less than 20 grams per day or with regimens that do not have an initial loading phase (Kreider, 1998a). Stevenson and Dudley (2001), in a double-blinded placebo experiment on a group of resistance trained subjects, found that Cr supplementation did not increase the level of PCr usage or rates of recovery during maximal voluntary or electrically stimulated muscle strength and endurance tests. They concluded that Cr loading did not provide an ergogenic effect for knee extensions exercises and suggested that CrH_2O supplementation may even slow

PCr replenishment. These negative findings may be due to the supplementation protocol used, with a CrH_2O loading phase of only one week and the absence of a maintenance phase of supplementation.

The failure to find a consistent positive effect of CrH_2O supplementation on performance may be due to a variety of factors, including sub-optimal dietary absorption of, or intracellular uptake of, Cr by subjects (Volek, 1999a). Other factors which have been cited in contributing to the apparent conflict in the findings of studies in this area include general methodological issues such as familiarisation of the subject with the equipment prior to testing, time of the day when testing occurs, number of subjects involved, drug and nutrient intake, length of supplementation and the type of activity programme (Kreider, 1998a; Tarnopolsky & MacLennan, 2000).

2.6 Possible Side Effects

There have been some reports that prolonged or excessive Cr ingestion can result in deleterious effects such as muscle cramping, nausea, gastrointestinal discomfort and skin rash (Rawson, Wenhert & Clarkson, 1999; Volek, 1999). However, most studies have found that subjects are able to tolerate standard supplementation with few problems. (Walter et al., 1999; Tarnopolsky & Praise, 1999). It is possible that the reports of side effects associated with CrH_2O supplementation may be related to excessive doses over long periods. eg. Koshy, Griswald and Schneeberger (1999) reported a case study of a previously healthy 20-year-old male who presented with nausea, vomiting and bilateral flank pain. This man took 5 g of CrH_2O four times daily for four weeks. This caused problems with his renal function and he returned to normal after ceasing supplementation. Chrusch et al., (2001) reported side effects significantly

more frequently in the Cr than the placebo group. Problems reported included loose stools during the loading phase and increased muscle cramping and muscle strain after 3 and 5 weeks of supplementation.

2.7 Summary

Since the original investigations of Harris et al., (1992) many researchers have since conducted studies of the effects of CrH_2O supplementation, although the results have not always been consistent. The majority of investigations have used young, healthy, and often athletically trained, participants (Balsom et al., 1993; Earnest et al., 1995; Casey et al., 1996; Prevost et al., 1997; Volek et al., 1999), others elderly (Bermon et al., 1998; Clarkson & Melanson, 1999; Chrusch et al., 2001). A few studies have involved elderly subjects and individuals with neuromuscular disorders (Walter et al., 1999; Tarnopolsky & Praise, 1999; Tarnopolsky & Martin, 1999; Tarnopolsky et al., 2000). The rationale for the present study is that an improvement in muscle function with CrH_2O supplementation and/or home-based low-intensity resistance training in older subjects would have the potential for use in improving the quality of life and reducing morbidity in this population.

CHAPTER THREE

Materials and Methods

3.1 Subjects

Ethical approval was granted through the Edith Cowan University Ethics Committee for the conduct of this project prior to the study. Subjects participating in this study provided written informed consent (Appendix A), completed a health check questionnaire (Appendix B) and were evaluated by a medical practitioner in order to screen for any contra-indications for participation in the study.

Participants consisted of healthy, relatively sedentary males aged between 61 and 75 years. Volunteers were recruited via advertisement in the local Community Newspaper and notice boards at the local campus of the University. Twenty-five men volunteered for this study. Volunteers passed as being medically suitable for participation were given further information regarding the study methodology and arranged for laboratory visit for orientation.

Seventeen participants started the study, of these, eleven completed the entire protocol.

Table 1. Physical characteristics of subjects prior to commencement of the supplementation and training programme

Group	Number	Age (Mean±SD)	Height (cm)	Weight (kg)
Creatine	8	68.25 ± 3.31	171.2	82.5
Placebo	9	64.33 ± 3.40	173.9	80.0

Subject attrition occurred for a number of reasons, none of which were related to the study itself. These included illness, personal problems, relocation and work commitments, any of which were reasons given by for withdrawal from the study.

As discussed in the previous chapter it has been suggested that previous researchers have not allowed sufficient time for Cr loading to occur in older subjects (Rawson et al, 1999). In normal, young, active adults, 5-10 days at 20-25 g of CrH_2O per day is regarded as sufficient to increase total intramuscular PCr levels to a point where positive ergogenic effects are seen. Since, in older individuals, the conversion of the extra Cr to Crn seems to occur more readily than in younger people, it was decided to use a loading phase of 14 days at 15 g of CrH_2O daily.

3.2 Design

3.2.1 Equipment

Powdered creatine monohydrate (6kg) (Aussie Bodies)

Powdered dextrose (6kg) (Aussie Bodies)

Electronic chemical balance (to weigh out creatine and dextrose) (Mettler PM 4600 Deltarange)

Rubber gloves

Gelatin capsules (each holds 1gram Cr or dextrose) (Surgi Pack size "000")

Cybex 6000 isokinetic dynamometer (Ronkonkoma, NY, USA)

DEXA scanner (Hologic QDR 4500) (Bedford, MA, USA)

Reflotron Spectrophotometer (Boehringer-Mannheim – Pode, Czech Republic)

Creatinine assay strips (Boehringer-Mannheim – Pode, Czech Republic)

Capillary tubes and pipette (Boehringer-Mannheim – Pode, Czech Republic)

Ankle Cuffs (16x5kg; 4x10kg) (Australian Barbell Company)

Weight poles (40x500g & 4x250g) (Australian Barbell Company)

Electronic scales (0-120kg) (for body weights) (Mettler ID1 Multirange)

Stationary cycle ergometer (for subjects to use as warm up for Cybex tests) (Repco)

Training diaries (see Appendix C)

3.2.2 Supplementation

The supplementation occurred in a double-blind fashion. In order to ensure that neither the subjects nor the experimenter knew to which group each subject belonged, the creatine and dextrose were placed in capsules containing 1 g of each agent. The capsules were filled manually on a clean bench top and bench cover. Rubber gloves and dust masks were used at all times to ensure the working area remained uncontaminated. An independent party allocated the subjects to either the creatine (8) or placebo (9) group. The creatine group took 15 g of CrH_2O in 3 x 3 g doses per day during the loading phase (14 days) and 3 g per day in the maintenance phase (10 weeks). The placebo group consumed an equivalent amount of dextrose, in identical capsule forms. The capsules were used to prevent the possibility that subjects might identify CrH_2O from its characteristic taste.

3.2.3 Training Protocol

All subjects followed the same training protocol. Training was carried out on the knee extensors and flexors with an adjustable ankle cuff and weights were set and reviewed at each test session. The subjects were instructed to increase the number of sets to 3 per

session when the training felt too easy and then begin increasing the weight for a further training stimulus. Only one randomly selected leg was trained. The training regimen consisted of leg flexion in a standing position and leg extension in a seated position as shown in figures 2 and 3. The first training weight was 3 kg (or approx 30% of isometric maximum voluntary contraction torque) and each subject adjusted the weight to suit. Training started with one set of 12 repetitions of each exercise daily and the weight and sets were increased according to the instructions above, as the training became easier an increment of 250 or 500 g was made. Each training session lasted no more than five minutes. In case, during the first weeks, the subjects experienced some muscle soreness they were instructed to take a day off training if they considered this too severe, however supplementation was to remain constant. Each subject was given a simple training diary to fill in (Appendix C), which was used to quantify the volume of training as a product of reps and weight. Subjects were asked to bring their training diaries to the testing sessions to ensure they were continuing the program as instructed and their training progress was discussed in case they had any problems or questions. Subjects were contacted on a weekly basis to monitor progress or deal with any questions or issues they may have had.

a)

b)

Figure 2a & b. Leg flexor training.

a)

b)

Figure 3a & b. Leg extensor training.

3.2.4 Testing

Testing sessions were carried out at times most convenient to the volunteers and was subject to the availability of the testing equipment. Although all tests were conducted in the same laboratory, there was no standardization of room temperature or any other environmental condition or time of day.

3.2.4.1 Body Composition

Dual-energy X-ray absorptiometry (DEXA) was used to quantify bone and soft tissue mass and composition. The technique differentiates body tissue into three compartments based on tissue density, lean soft tissue, fat soft tissue and bone. DEXA has proven to be a reliable method of quantifying body composition for regional as well as whole body parameters (Pollock et al., 1995). Body composition scans were carried out at the Bone Density Unit at Sir Charles Gairdner with data obtained for total body mass and differentiated whole body fat and lean body mass. Scans were also taken of the left and right upper legs to quantify the mass of the limb segment. Limb segments were manually cursored from the scans based on anatomical landmarks of knee joint and greater trochanter. DEXA scans were performed on each subject prior to supplementation and after the 12 weeks training/supplementation programme. An example of the DEXA scan data is included in Appendix D.

3.2.4.2 Isometric and Isokinetic Strength and Endurance

Muscle function assessment was carried out using a Cybex 6000 Isokinetic Dynamometer (Ronkonkoma, NY, USA). Subjects warmed up at a self-selected pace

on a Repco stationary cycle for 5 minutes before being securely restrained in an upright seated position on the dynamometer (Figure 4). Hip alignment was adjusted so that the line from the hip to the knee was perpendicular to the rotating arm of the dynamometer, and the axis of rotation of the arm was level with the lateral epicondyle of the tibia. The dynamometer arm was adjusted so that the pad could be attached as low on the shin as possible without touching the foot. An additional strap was used to prevent the knee from lifting off the seat during each extension. The test sessions lasted not more than one hour and included isometric strength of knee flexors and extensors at three different angles (45, 60 and 75 degrees) and each angle was tested three times before moving to the next one. The subject had 20 s to produce a peak force contraction of the extensors and the flexors and as this was more than enough time there was no programmed rest period. Isokinetic tests at three different speeds (60, 180 and 240 degrees per second) were carried out next. The subject was asked to extend and flex the leg at the knee through a preset range of motion (approx 80°) as quickly as he could for 4 repetitions and given 30 seconds rest between each set. The testing session for each leg concluded with an endurance task consisting of 5 sets of 15 repetitions at 180 degrees per second with 30 s interval between sets. After this was completed the subject was released from the dynamometer and given the opportunity to walk around the laboratory, stretch and drink some water while the investigator adjusted the dynamometer for the other leg. The test protocol was then repeated for the contralateral limb, with the order of testing randomised between left and right limbs. All tests required maximal effort. In order to minimise the likelihood of subjects performing submaximally during the testing, they were given strong and consistent verbal encouragement throughout. Subjects were also provided with visual feedback of their torque output for each contraction in order to give them a target torque to reach each time (Fig 4). Testing took place prior to

beginning the training and supplementation and repeat testing occurred at the end of weeks 2, 7 and 12 of the study.

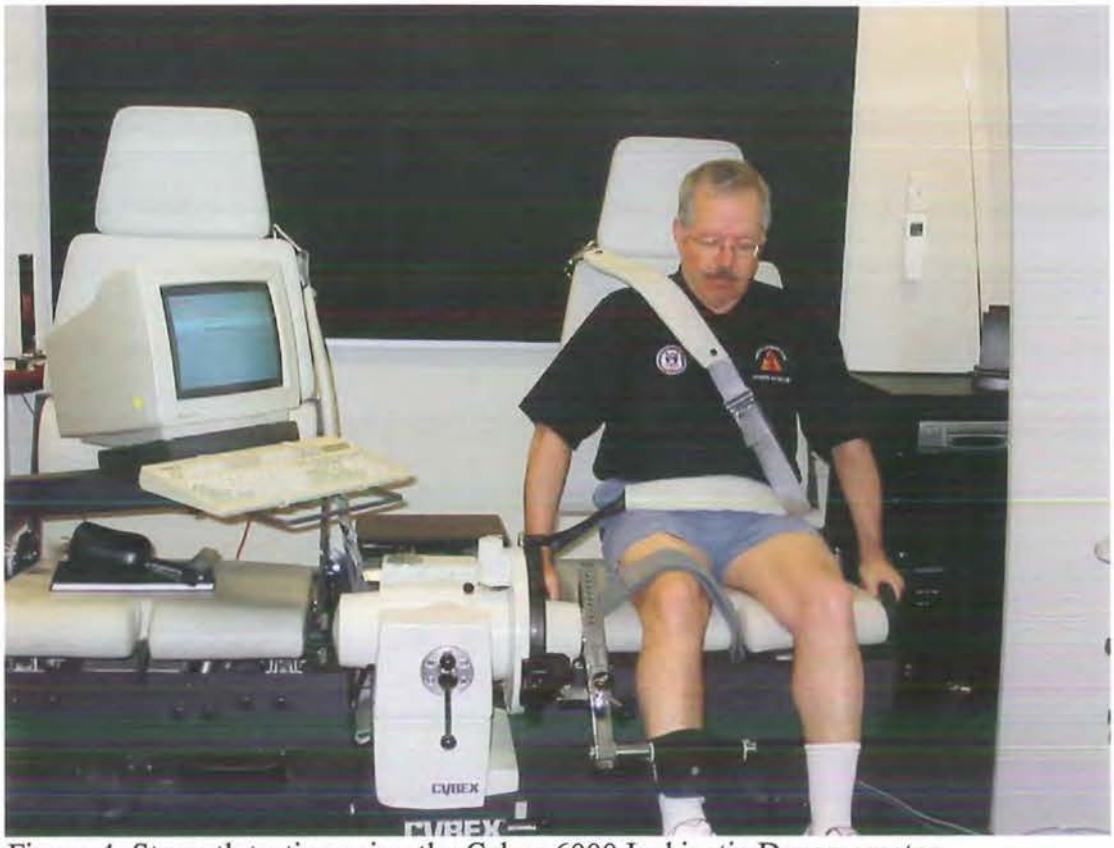

Figure 4. Strength testing using the Cybex 6000 Isokinetic Dynamometer

3.2.4.3 Plasma Creatinine (Crn) Measurement

In order to provide an indication of whether Cr had been absorbed by subjects undergoing CrH_2O supplementation plasma Crn was tested from a 30 μL fingerprick blood sample. A Reflotron Photochemical Analyser was used to measure blood creatinine levels from spectrophotometry before supplementation and again just before the final strength test. The rationale for the use of plasma Crn for this purpose has been described by Willoughby and Rosene (2001).

3.3 Statistical Analysis

All statistical analyses were carried out using SPSS for windows release 10.0 and the accepted level of significance was set at $p \leq 0.05$. Column graphs were prepared using Microsoft Excel 97. DEXA scans were analysed using a t-test for whole body data. It was decided that a t-test was appropriate as there were only two sets of means in each mass test, those being the test done before the implementation of the supplementation and training programme, and those tests taken after the 12 week protocol and only change scores were examined. Limb segment data was analysed using a one way analysis of variance to test the null hypothesis.

As in the total body mass data, only fat free mass and fat mass were used for the present study. However because each limb segment was treated as a separate group there were more mean scores and so the t-test used for the whole body data was discarded in favour of a one-way ANOVA for the limb segment data.

Isometric and Isokinetic tests were analysed using a 2-way ANOVA with repeated measures on one factor (time) (Newton metres). There were four groups creatine and training (CrT), creatine and not training (CrU), placebo and training (PlT) and placebo and not training (PlU) and four test sessions baseline (BL) and weeks 2, 7 and 12. Similarly, the endurance test data consisting of total work done in the five endurance sets were analysed using a Repeated Measures ANOVA.

CHAPTER FOUR

Results

4.1 Training

Figure 5 shows the average training volume for the two groups derived from the training records kept by the subjects. Total training volume was determined by multiplying the number of repetitions by the number of sets by the weight used on each occasion to obtain a work done for each training session. Data for each session was summed to obtain a total work done, or training volume. All subjects started at the same training volume, which was set at 12 repetitions (1 set) with a cuff weight of 3 kg (this was verified as an appropriate weight at the baseline test). Subjects were instructed to increase the repetitions, sets and weight on a weekly basis as the exercises became easier. The total training volumes of the creatine and placebo groups were similar over the 12 week programme (Figure 5). The creatine group performed an estimated mean total work of 8,369 J (± 3089 (sem)) compared to the placebo group value of 8,799.5 J (± 9492), the difference between the groups being approximately 5%. Mean increases in weekly training load from week 1 to week 12 were also similar for the creatine and placebo groups (+ 45 %). From analysis of the training diaries, and assuming that they represent an accurate record of training activities of the individuals concerned, subject adherence to the programme was good. Thus, the creatine group missed a total of 19 sessions (out of 180) or about 10%, compared to the placebo group value of 26 missed sessions out of 216 (approximately 12%).

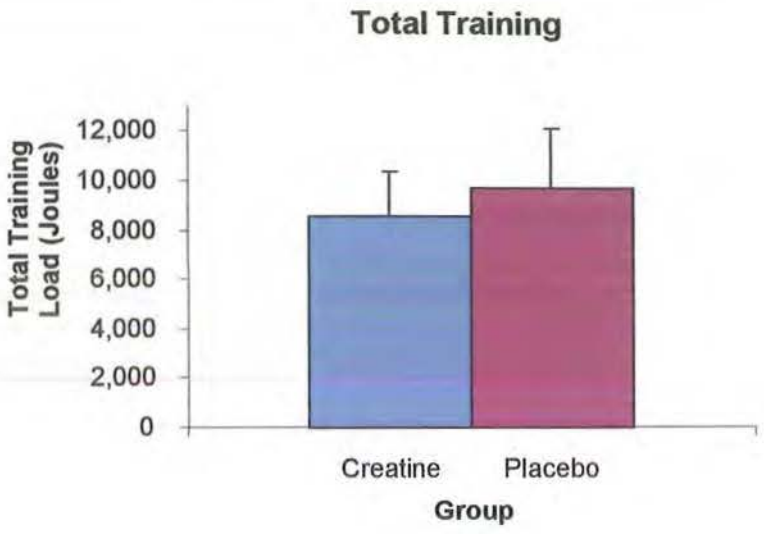

Figure 5. Total training load over 12 weeks for the Cr (n = 5) and Pl (n = 6) groups (mean ± sem). Load was calculated as a product of repetitions x sets x weight for each individual.

4.2 Plasma Creatinine

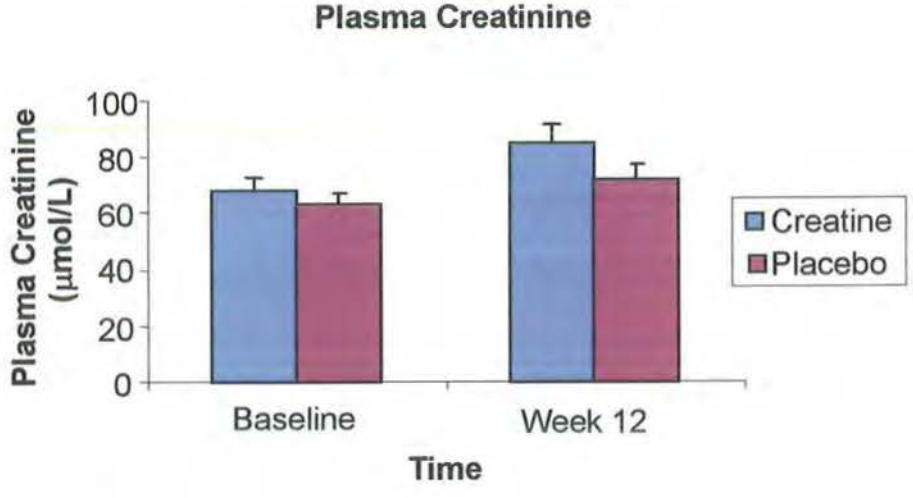

Figure 6 Mean Plasma Creatinine. Plasma creatinine concentration pre and post supplementation/training for Cr (n = 5) and Pl (n = 6). Results are mean ± sem.

Figure 6 illustrates the average plasma creatinine for the two groups at baseline and week 12. The normal range for blood creatinine for males is 53 – 97 μmol/L. Both groups had similar levels at baseline, although the creatine group showed an increase following supplementation (20.2%), as did to the placebo group (11.2%). Neither the extent of the increases over time nor the differences in creatinine concentrations between groups were statistically significant.

4.3 Body Composition

Table 2 shows the Baseline (BL) and Week 12 (Wk 12) DEXA scan results for body weight, total lean body mass and percentage body fat mass for both the groups. The means for the two groups were similar at baseline, although the creatine group was slightly heavier on average and had a slightly higher body fat content. There were no significant alterations in total body mass measures over the twelve weeks of the study for either group. Similarly the lean body mass remained unchanged for both groups. Fat mass measures were not significantly different from BL to Wk 12 for either group.

Table 2. Whole body DEXA results showing total body weight and lean tissue mass in kilograms and percentage of fat mass before and after the programme

Grp *n*	Body Weight (kg)		Lean Body Mass (kg)		Fat Mass (%)	
	BL	Wk12	BL	Wk 12	BL	Wk 12
	Mean (sem)	Mean (sem)	Mean (sem)	Mean (sem)	Mean (sem)	Mean (sem)
Cr *5*	83.62 (4.41)	83.80 (4.53)	72.55 (2.46)	72.22 (2.50)	24.12 (1.86)	24.52 (1.53)
Pl *6*	79.96 (3.88)	80.33 (4.28)	73.58 (4.56)	73.63 (3.75)	22.83 (4.50)	22.80 (3.72)

4.4 Limb Segment Mass

The total lean mass for each upper limb volume cursored from individual DEXA scans is reported as segmental lean mass. Segmental fat mass is expressed as a percentage of total mass for the limb volume of interest. The mean results for each sub-group of limbs are summarised in Table 3 (an example of a DEXA scan is included in Appendix D). Again the two groups were non-significantly different at the beginning of the investigation. As seen in the total body composition data, there were no notable changes in limb composition associated with either ingestion of CrH_2O or training.

Table 3 Limb segment DEXA results showing segmental body weight and lean tissue mass in kilograms and percentage of fat mass before and after the programme.

Group	Limb Segmental Lean Mass (kg)				% Fat Mass			
	BL		12		BL		12	
	Mean	(sem)	Mean	(sem)	Mean	(sem)	Mean	(sem)
Creatine Trained	6.38	(0.38)	6.67	(0.23)	24.34	(2.84)	24.72	(3.28)
Untrained	6.40	(0.37)	6.59	(0.31)	24.84	(3.34)	25.42	(3.26)
Placebo Trained	6.28	(0.31)	6.50	(0.37)	23.38	(3.62)	23.43	(3.27)
Untrained	6.37	(0.37)	6.53	(0.39)	22.95	(4.05)	23.07	(4.09)

4.5 Baseline Strength

On analysis of the data, it was found that the tendency for change for the knee flexors was similar to those of the knee extensors. Therefore, in order to minimise the amount of extraneous data presented, it was decided to display only the knee extensor results for the muscle function assessments. Individual and group findings for all muscle function parameters are included in Appendices E and F.

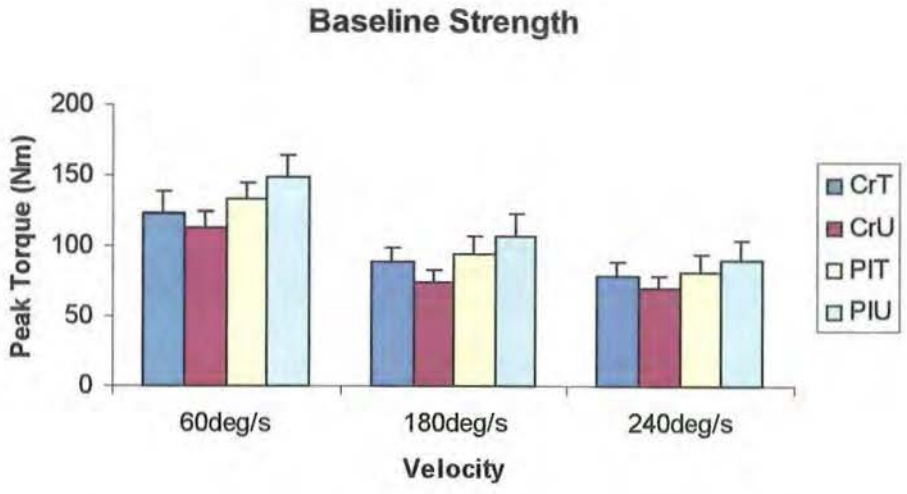

Figure 7. Baseline data for isometric and isokinetic strength at 60°/sec, 180°/sec and 240°/sec for CrT (n = 7), CrU (n = 7), PlT (n = 7), PlU (n = 7). Results are mean ± sem.

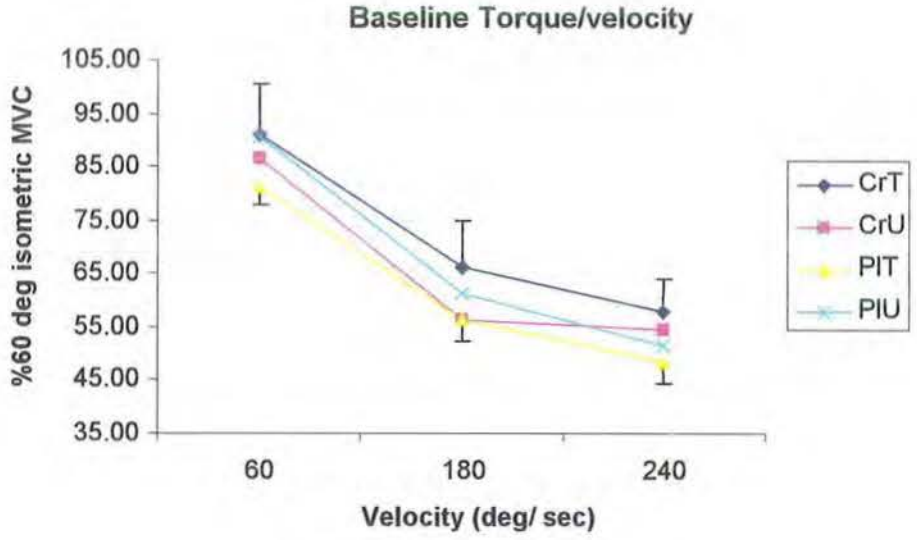

Figure 8. Isokinetic peak torques at 60, 180 and 240°/sec expressed as a percentage of isometric 60 degrees at baseline for CrT (n = 7), CrU (n = 7), PlT (n = 7) and PlU (n = 7). Results are mean ± sem.

Isometric maximal voluntary knee extensions were performed at three angles of knee flexion (45, 60 and 75 degrees). Responses over time were similar for each angle, with the greatest strengths produced at the mid-range value. Only data at 60 degrees of knee extension will be presented in this section (all data are shown in Appendices E and F). Baseline values (mean ± sem) for isometric strength were similar between the trained and untrained limbs for each group (CrT = 140.9 Nm (± 14.6) vs CrU = 133.7 Nm (± 10.9)). Isometric strength at baseline was also non-significantly different between groups, although the Pl group was slightly stronger than the Cr group (PlT = 162.1 Nm (± 11.4) vs PlU = 166.6 NM (± 15.7)). On average the placebo group was approximately 16% stronger than the creatine group. Similar trends between groups and sub-groups were also seen for isokinetic peak torque values (Figure 7). Baseline isokinetic strength results were similar between groups, although the placebo group were, on average, slightly stronger than the creatine group at each of the three velocities tested (approximately 16% at 60°/sec, 19% at 180°/sec and 13% at 240°/sec). When the voluntary torque data at each velocity are expressed as a percentage of isometric torque (Figure 8) it can be seen that the creatine group were able to generate a slightly higher proportion of their isometric torque at each of the testing velocities compared to the placebo group. The observed differences averaged 3-10%, but were not significant for any of the limb groups tested.

4.6 Strength Changes Over Time

4.6.1 Isometric Strength

Responses over time were similar for each angle therefore values for 60 degrees only are presented in this section (all normalised and raw data for extensors are given in Appendix E and flexors in Appendix F).

Overall, there was a significant effect for time ($p \leq 0.01$) on isometric strength and post hoc analysis showed the difference was due to week 7 vs baseline ($p \leq 0.01$) and week 12 vs baseline ($p \leq 0.01$). Figure 9 illustrates that the CrT group improved their isometric strength at this angle by 19% at week 7 and 15% at week 12. The PlT group also experienced some improvement (10% and 11% at weeks 7 and 12 respectively).

4.6.2 Isokinetic strength

At a velocity of 60°/sec the interaction for training and group produced a non-significant p value of 0.059. There was a significant main effect for time ($p = \leq 0.01$), and post hoc analysis showed the differences to be due to week 7 vs baseline ($p \leq 0.01$). Thus, the CrT group had a greater improvement in strength at this velocity than all the other groups at week 7, equating to a 20% strength gain at week 7 (Figure 10). The PlT group saw an improvement of 14% at this time point, whilst the CrU group improved by some 10%.

Figure 11 illustrates the changes in peak torque at 180°/sec over the course of the exercise programme. There was a significant time effect in this case, with post hoc

analysis showing the differences to be week 2 vs baseline ($p < 0.05$), week 7 vs baseline ($p < 0.05$) and week 12 vs baseline ($p < 0.05$). A between groups analysis showed no significant differences. Both the creatine (CrT and CrU) and the placebo trained (PlT) groups saw some improvement in the amount of torque they were able to generate compared to the PlU group during the course of the study. The CrT group improved by only 8% at week 2 while the CrU group improved by 21% and the PlT group improved by 14%. The largest changes were seen at week 7. The CrT group improved 23% at week 7 compared to 32% for the CrU (both increases were significant compared to baseline values) and 19% for the PlT. At week 12 the CrT group were 11% higher than their baseline value, the CrU group scored 21% higher than their baseline and the PlT group improved by week 7 to 22% above baseline.

For the fastest testing velocity (240°/sec) the normalised data is represented in figure 12. The interaction for training and group produced a non-significant p value of 0.07. There was however a significant main effect for time ($p \leq 0.05$). Post hoc analysis showed the effect for time was due to week 2 vs baseline ($p \leq .0.05$), week 7 vs baseline ($p \leq 0.05$) and week 12 vs baseline ($p \leq 0.05$). This shows that the training was the main cause of the improvement as both training groups experienced a similar improvement across time. The largest changes seen for this speed were at week 7 with the CrT group Improving by 23%, the CrU group by 23% and the PlT group by 23% compared to their baseline strength.

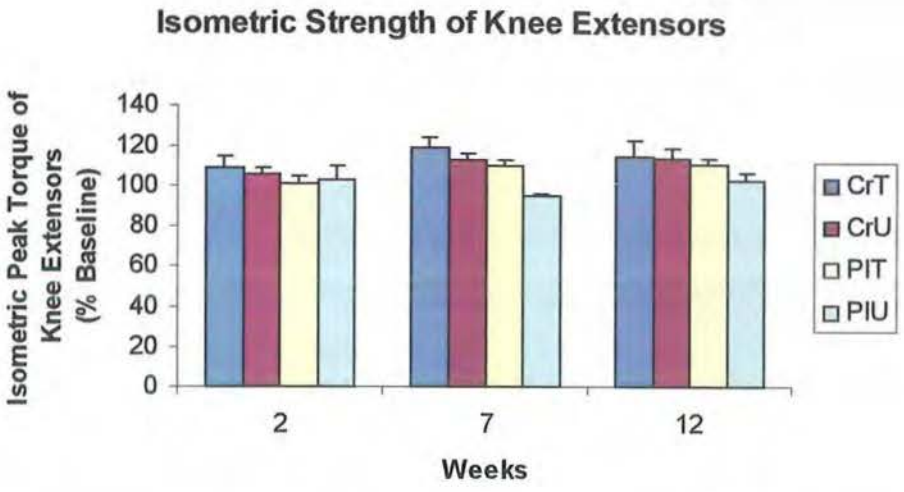

Figure 9. Isometric strength changes over time expressed as a percentage of baseline values for the four limb groups (mean ± sem).

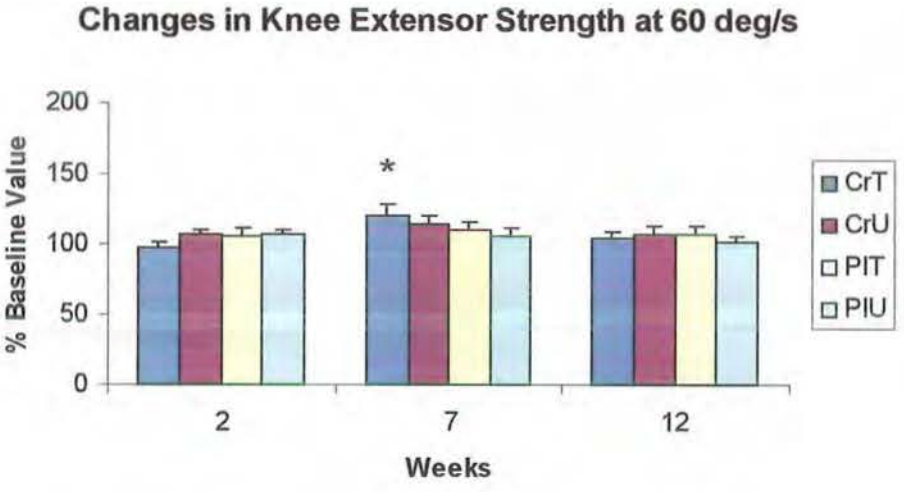

Figure 10. Isokinetic strength (60°/s) changes over time expressed as a percentage of baseline peak torque scores for the four limb groups (mean ± sem). * = $p < 0.05$ compared to baseline.

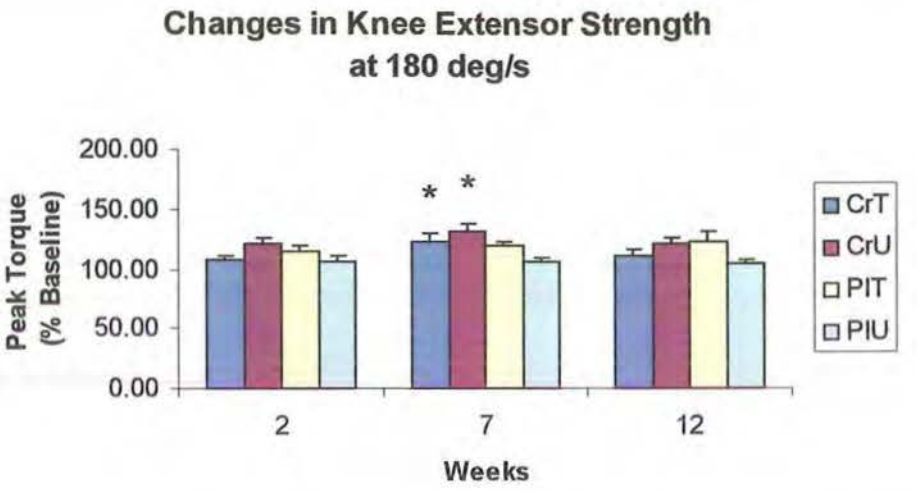

Figure 11. Isokinetic Strength (180°/s) changes expressed as a percentage of baseline peak torque values for the four limb groups (mean ± sem). * = $p < 0.05$ compared to baseline.

Figure 12. Isokinetic strength (240°/s) changes expressed as a percentage of peak torque scores for the four limb groups (mean ± sem). .

4.7 Endurance

The average total work done for each of the limb group over five sets of fifteen maximal voluntary contractions (MVCs) at 180°/sec of the endurance task is shown in figure 13. The group means for this test were similar for the CrT, CrU and the PlT groups at baseline, however, the PlU group was able to generate 13% more work volume than the other three groups at baseline (although this difference did not prove statistically significant). When the endurance tasks were repeated, the CrT group showed the greatest improvement in total work and this is most noticeable at week 7 compared to baseline. The CrT group improved by 14% over baseline at week 2 and performed 21% more work at week 7 compared to the initial test. These improvements in total work were not maintained in this group, and by week 12, the work generated by the CrT group during the endurance task had declined somewhat (although it remained significantly improved (14%) compared to the baseline value). The effect of training in the absence of creatine ingestion (PlT group) resulted in improvements of 9% and 11% at week 2 and week 7 respectively, and this increased to 14% more work than baseline at week 12. The interaction for training and group produced a non-significant p value of 0.057. There was a significant main effect for time ($p \leq 0.05$), and post hoc analysis showed the effect for time was due to a difference in week 2 vs baseline ($p \leq 0.05$), week 7 vs baseline ($p \leq 0.05$) and week 12 vs baseline ($p \leq 0.05$). There was a significant interaction for training and time ($p \leq 0.05$) and post hoc analysis showed the difference was due to week 7 vs baseline ($p \leq 0.05$).

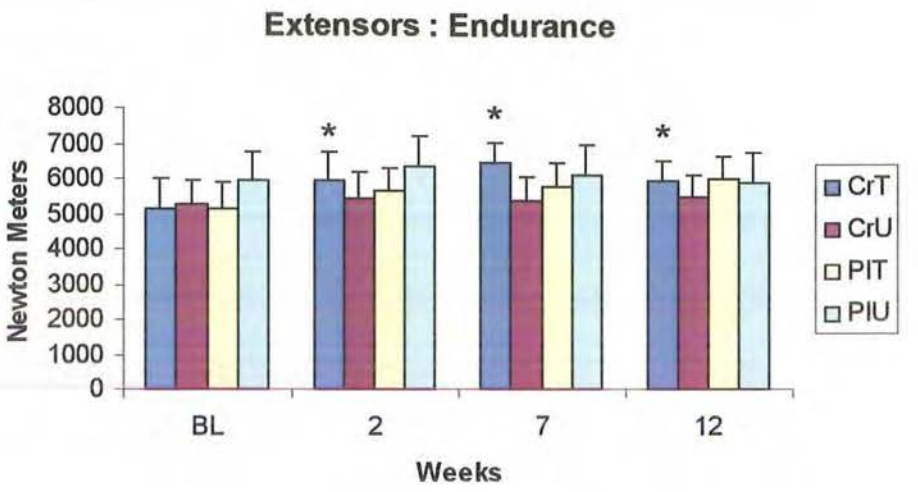

Figure 13 Total Work for extensors over the endurance task for the four limb groups (mean $\pm$ sem). * = $p \leq 0.05$ compared to baseline.

CHAPTER FIVE

Discussion

5.1 Effects of creatine supplementation

Although it is clear that negative changes in muscle oxidative capacity and strength occur in older individuals, the extent to which these changes are related to the effects of reduced activity compared to ageing per se are under debate (Kent-Braun et al., 2000; Frontera et al., 2000). Since it is has been documented that, with advancing age, muscle creatine and phosphocreatine levels become reduced, the use of creatine supplementation to enhance the levels of these agents seems a logical proposition (Chrusch et al., 2001; Rawson et al., 1999). Indeed, in healthy people aged more than fifty years, creatine supplementation has been found to increase resting intramuscular phosphocreatine levels and to speed up phosphocreatine resynthesis post-exercise (Smith et al., 1998). In the present double-blind study the creatine group showed an increase in plasma creatinine levels suggesting that creatine had been absorbed from the gut and metabolised (Harris et al., 1992; Kamber et al., 1999; Willoughby and Rosene, 2001). However it is not possible to say whether the creatine had been incorporated into the muscle fibres. In order to show whether myofibre creatine absorption took place would require multiple muscle biopsy samples. Previous studies of this type have yielded generally positive, results for myofibre uptake of creatine with supplementation, although with subjects exhibiting large individual variation (Willoughby & Rosene, 2001; Tarnopolsky et al., 2000; Volek et al., 1999; Greenhaff et al., 1994; Harris et al., 1992; Annianson et al., 1986). In the present study, subject compliance for ingestion of the supplements was very good, with only one subject returning a container with a dose

still remaining and no subject reported any adverse side effects during the supplementation and training period. Subjects also reported that taking the supplements at the appropriate times quickly became part of their daily routine. From the anecdotal evidence presented by the subjects in this study, routine supplementation with CrH_2O is well tolerated without any adverse effects. Previous studies have shown increases of muscle total creatine concentration of around 25 to 30% in young subjects following ingestion of 20 grams of CrH_2O per day (Greenhaff et al., 1994; Rossiter et al., 1995; Casey et al., 1996). Most studies of younger subjects have used dosages of 20-30 g/day for loading and approximately 5-7 g/day for the maintenance period (Casey et al., 1996; Francaux et al., 2000). Studies of CrH_2O supplementation and training in elderly populations have used reduced loading dosages of 15 g/day (Wiroth et al., 2001) and lower maintenance dosages of 4 g/day (Rawson et al., 1999) with a loading period of five to ten days (Wiroth et al., 2001; Rawson et al., 1999). The rationale for this methodology is that older subjects would be expected to have lower levels of muscle creatine than athletes. Rawson et al., (1999) recommended using a longer loading period (10 days) for older (greater than 60 years) subjects because they found that although the CrH_2O may have been absorbed into the blood it did not effect muscle mass or strength. Taking this into account, it was decided to use a loading period of 14 days for the present study. Since the body's creatine requirement is related to muscle mass, and older sedentary males generally have a lower muscle mass than younger men (Frischknecht, 1998; Fiatarone-Singh, 1998; Young and Skelton, 1994), they would theoretically require less CrH_2O to achieve optimal loading.

5.2 Effects of training

All subjects were given clear instructions on how to perform the training task and asked to record the repetitions, sets and weight used as well as number of sets per week in their training diary. From these records the amount of work done for each subject was calculated and meaned by groups. The training regimen was carefully designed so as to be practical for subjects to complete without supervision. It was a home-based training regimen and took less than five minutes per day to complete. This was important since such an intervention needed to be appropriate for use among an elderly population and for patients with muscular degenerative disorders since these individuals may find it too difficult or expensive to attend a gym or a clinic on a regular basis. All subjects increased their training volume throughout the course of the study by increasing their repetitions, sets and cuff weights. Mean increases in weekly training load from week 1 to week 12 were similar for creatine and placebo groups (approximately 45%) and the question of whether training alone had a benefit for muscle function can be addressed by examining the findings for the placebo training limbs. In this case, there was a trend for both isometric and isokinetic strength to increase over the 12 week programme (range 10-15%) as well as endurance (~ 15%) compared to much smaller changes in the untrained limb. These changes in muscle function over time did not achieve significant levels, nor did any of the measures increase significantly compared to the untrained limb in the placebo group.

A number of reasons could account for the lack of significant changes with training as hypothesised. Firstly, the subject dropout in the early stages meant that only 6 subjects completed the study in the placebo group. Also, it may be that the training volume and intensity were insufficient to show significant improvements in strength and muscle

mass for this group. Although subjects were contacted weekly to determine their progress, it was found that individuals were more inclined to increase the number of sets rather than the weight lifted. A more regimented protocol for increasing the training intensity may have been more appropriate. However, it should be emphasised that an important aspect of this study was to provide a training programme that would be suitable for sedentary, older subjects. A more aggressive programme might have resulted in even greater subject attrition. Perhaps the current protocol would be suited to older, frailer individuals or patients with a degenerative muscular disease and future research should be directed at these populations using the current experimental model. It would also be advisable for future studies to maintain greater control over the training regimen in order keep the training load optimal by imposing greater increases in workload through increased weight, sets and reps and/or training frequency. In the study by Chrusch et al., (2001) subjects were supervised in a gym and encouraged directly to increase their workload. These subjects experienced increases in lean tissue mass as well as improved strength and endurance of the lower limbs. Other studies to show significant increases in mass and strength have also implemented more rigorous training protocols and often used younger subjects compared with the current investigation (Volek et al., 1999; Kamber et al., 1999; Prevost et al., 1997; Volek et al., 1997; Balsom et al., 1993).

5.3 Effects of supplementation and training

Subjects in both groups were given the same training regimen and allowed to progress at their own pace. The placebo group had a slightly greater training workload for the entire 12 weeks than the creatine group. Thus, there was no evidence to support my hypothesis that CrH_2O supplementation would enhance the training capabilities of the

subjects. None of the subjects who completed the protocol reported illness or injury and training diaries show they were training throughout the 12 weeks although some subjects missed training sessions. Several studies have been conducted to investigate the combination of training and supplementation for reducing the effects of muscle degradation and strength loss in elderly people (Chrusch et al., 2001; Rawson et al., 1999; Bermon et al., 1998; Evans, 1992). There have also been review articles which cover this topic (Fiatarone-Singh, 1998; Fielding, 1995) all of which cite the loss of skeletal muscle with advancing age as a major problem among the elderly, and that the phenomenon may be reduced with exercise and/or dietary intervention. Apart from CrH_2O (Chrusch et al., 2001; Rawson et al., 1999; Bermon et al., 1998), other supplements which have been used in conjunction with physical activity programmes include calcium and vitamin D (Fiatarone-Singh, 1998).

A number of studies have shown that supplementation with CrH_2O in conjunction with a resistance training programme may promote gains in muscle strength and FFM in patients with muscular degenerative diseases (Stout et al., 2001; Tarnopolsky et al., 2000; Walter et al., 1999; Tarnopolsky & Martin, 1999). The present study was conducted in an effort to add to the body of knowledge regarding possible health improvement interventions for the elderly. It has shown that perhaps supplementation with CrH_2O may have some ergogenic benefit for older populations and can be more effective when used in conjunction with a resistance training programme.

5.4 Muscle mass

The present study found no changes in muscle mass for the untrained limbs of the creatine and the placebo groups as tested by DEXA, which does not support the first

hypothesis. X-ray absorptiometry has been shown to be a highly reliable (r = 0.99) and precise (coefficient of variation of 0.5 – 1.0%) method for the evaluation of individual body composition segments, so it is likely that even small increases in muscle mass could have been detected (Kreider et al., 1998). Although the creatine group did increase their blood creatinine level more than the placebo group, it is possible that the supplementation did not increase muscle creatine stores sufficiently to effect a change in muscle mass. CrH_2O supplementation has been reported to result in an increase in total body weight (Earnest et al., 1993; Greenhaff et al., 1994; Volek et al., 1999; Francaux & Poortmans, 1999; Becque et al., 2000; Chrusch et al., 2001). When creatine is ingested and taken up by muscle an increase in muscle PCr concentration results (Harris et al., 1992). This increased concentration of PCr should alter the osmolarity of the cell causing water to be drawn into the intracellular space thereby increasing the volume of the cell and therefore the total muscle mass (Francaux & Poortmans, 1999). The lack of any discernible increase in body weight or total lean mass is however consistent with previous studies using subjects of similar age (Wiroth et al., 2001; Rawson et al., 1999). In young subjects the added creatine seems to have the osmotic described, but this uptake does not seem to occur as readily in older people. Why older subjects fail to experience the same improvements as young subjects with creatine supplementation is not yet clear, however the differences may be related to a reduced ability to absorb creatine from the gut or for it to be less readily transported into muscle (Rawson et al., 2002). Creatine and its associated phosphotransferase, phosphocreatine kinase, aid in supporting high ATP/ADP ratios at equilibrium and the maintenance of cellular ATP homeostasis (Harris et al., 1992). Chrush et al., (2001) gave elderly subjects a loading dose of 26.4g/day and a maintenance dose of 6.2g/day, considerably higher than the present study. This high dosage was chosen as it had been used successfully in previous studies to increase muscle PCr levels (Harris et al., 1992;

Hultman et al., 1996). They found significant changes in body composition with an increase in lean mass of 5.7% compared to 2.5% in the placebo group, although in this study subjects underwent a 12 week supervised whole body training programme. This is the only study to date that has shown a significant change in muscle mass as a result of CrH_2O in the elderly. Clearly, more work needs to be carried out into determining the optimal dosing strategies for older populations, and how this should be incorporated into a training programme to optimize responses.

The fourth hypothesis stated that training alone would cause an increase in muscle mass, but this was not the case. It is likely that the training stimulus used for this study was insufficient to cause an increase in muscle mass. For the reasons already described, a light resistance programme was purposely designed for this study and it is likely that a heavier programme would have yielded changes in muscle mass as well as greater increases in muscle strength in these subjects, but would also have been more stressful and may have caused muscle soreness. The subjects were given a training load approximately 30% of their 1 rep maximum and some subjects quickly found that weight to be easily lifted and increased their workload (repetitions, sets and/or weight) in the first two weeks of the programme. The increases noticed in the leg strength of trained subjects in this study are unlikely related to any change in muscle mass since there was no increase in mass shown by segmental DEXA scanning. Furthermore, the increases in strength and power output in the first few weeks of a resistance training regimen can be largely attributed to adaptations which occur at the neural level (Hurley & Roth, 2000). In the study by Chrusch et al., (2001) subjects participated in a supervised whole body training programme conducted three times per week producing a much higher workload than the present study. This heavy training elicited no body mass changes in the placebo group, the current investigation showed similar findings.

Another study using a similar training protocol to the present study found the elderly subjects did increase their mid thigh circumference by 9% after eight weeks of training with weights of 50-80% 1RM (Fiatrone et al., 1990). This supports the suggestion that in order to achieve appreciable gains in muscle mass subjects require a larger training volume than that used in the present study. Also, Fiatarone et al., (1990) used subjects who were considerably older (mean age = 90 years) than those studied by Chrusch et al., (2001) (71 years) and in the present study (66 years). Perhaps their lack of physical conditioning prior to the study made them more likely to realise a response to the training protocol. Although the majority of the subjects in the present study were sedentary, two participated in sport (lawn bowls) on a weekly basis and several subjects regularly walked on a recreational basis. The subjects in the Fiatarone et al., (1990) experiment were not involved in any regular exercise prior to the study and the subjects in the Chrusch et al., (2001) study were described as participating in some strenuous, moderate and mild physical activity. The training protocol for the current study was very easy and simple, and designed to be of practical use as a home based programme whereas the protocols used for the Fiatarone et al., (1996) and Chrusch et al., (2001) investigations were conducted under supervision by the research teams. This investigation was designed to test the efficacy and practicality of a home-based training protocol, which could be done safely without the need for expensive equipment or a training supervisor.

Hypothesis seven stated there would be a greater increase in muscle mass in the creatine group compared to the placebo group with training and this was found not to be the case. Previous studies have shown that supplementation with CrH_2O in combination with a strength training programme caused an increase in lean muscle mass compared to a similarly trained placebo group (Chrush et al., 2001; Becque et al., 2000; Francaux &

Poortmans, 1999; Earnest et al., 1995; Volek,et al., 1997). Apart from the current study the Chrusch et al., (2001) investigation was the only one to use DEXA scanning to quantify muscle mass. Other methods employed to quantify body composition include skinfold tests and a medical scale (Schilling et al., 2000), magnetic resonance imaging (MRI) (Welle et al., 1996), hydrostatic weighing (Rawson et al., 1999). Bermon et al., (1998) used the Jones & Pearson method to estimate lower limb muscular volume. The training protocols used for these studies were gym based and whole body training programmes and all except Chrusch et al., (2001) and Bermon et al., (1998) used young subjects. Other studies have reported no change in body composition while using creatine monohydrate in combination with training (Bermon et al., 1998). The subjects for the Bermon et al., (1998) study were a similar age group to the current investigation. As mentioned previously some investigations have shown that creatine loading is more difficult to achieve in elderly subjects (Bermon et al., 1998). The present study showed there was no statistically significant change in serum creatinine in the group supplemented with creatine monohydrate, both groups were well within normal range values for pre and post supplementation. For the present study there was very little change in lean muscle mass for both CrT and PlT groups, this is in line with previous studies using similar age groups (Bermon et al., 1998; Rawson et al., 1999).

5.5 Muscle strength

Hypothesis two predicted that the muscle strength of the Cr group would be greater than that of the Pl group and this was confirmed when Cr was combined with training. The findings are consistent with previous studies (Rawson et al., 1999). The isokinetic strength of the untrained limbs of the Cr group showed an increase over time at weeks 2 (21%), 7 (32%) and 12 (21%) at 180°/sec. The PlU group had no significant strength

changes throughout the twelve weeks. Possibly, sufficient uptake of creatine was achieved to increase strength in the absence of any observable increase in muscle mass. It is likely that the effect was related to creatine since the PlU group showed no significant improvement in strength (and the study was double-blinded). It is possible that the findings relate to improved recovery between contractions during testing since 87 contractions were made for each test session (including the endurance task). Although appropriate rest was allowed (60-120 seconds) for recovery of high energy phosphates, it may still have been insufficient for complete recovery. The present study also confirmed the findings of Rawson et al., (1999), who did not observe any effect on isokinetic strength from CrH_2O supplementation alone.

Interestingly for the strength tests all groups, excluding the PlU group, experienced some improvement in strength at all velocities during the course of the investigation. This improvement may be due partially to the "learning effect" in which a motor pattern is developed in the nervous system and produces a correct sequence of muscle contractions. During this early training phase there is little or no increase in muscle size or strength (Jones et al., 1989). So, even though the training stimulus was small compared to other experiments (Fiatarone et al., 1990; Chrusch et al., 2001) some benefit appears to have been derived. In the study by Chrusch et al., (2001) the placebo group increased their strength during the course of the study possibly because they used a gym based, supervised, whole body training protocol, which was enough to elicit a muscular adaptation response in the lower limbs. Their training load was many times that of the subjects in the present study. The low training stimulus made it more difficult to notice the change in strength for these subjects but certainly some improvements were made as can be seen in the isokinetic tests (eg, week 7, at 180°/sec, CrT improved by 23 and PlT by 19%). In another study (Fiatarone et al., 1990) subjects

improved their strength by approximately 177% after 8 weeks using simple knee extension exercises. However the subjects were older (average age = 90 years) than those involved in the current investigation and were described as "frail, elderly patients" (Fiatarone et al., 1990). Possibly this older age group could best benefit from the type of light training protocol used for the present study. In his review article of 1995, Fielding states that studies which used heavier weights and a reduced number of repetitions were more effective for evoking muscle strength adaptations than high repetitions and lower weights. He further concluded that, in experiments using young subjects, weights less than 40% 1RM were ineffective for bringing about any increase in muscle strength. Anianson et al., (1981) conducted 12 weeks of lower extremity exercise in healthy older males using the subjects' own body weight to provide resistance and noticed a 9 - 22% increase in isometric and isokinetic peak torques of knee extensors. Another investigation involving older males (mean age 70 years) employed an 8 weeks training protocol of the elbow flexors at 66% 1RM and noted a 23% isometric strength increase (Moritani and De Vries, 1980). More recently Frontera et al., (1988) used a knee flexion and extension protocol at 80% of 1 RM and found a 107% increase in extensor strength and a 226% increase for flexors.

Hypothesis eight stated that the strength gain of the creatine group would be greater than that of the placebo group with supplementation and training. The CrT group did improve during this study, particularly at week 7 (approximately 25% for all velocities), although this was not significantly greater than the improvement of the PlT group (approximately 19%). At week 12 the PlT group continued to improve in strength whilst the CrT group had declined slightly. The reasons for the decrease in strength between weeks 7 and 12 are not clear. It may be due to a lack of motivation, as this was a long training protocol with little supervision, or possibly reduced effectiveness of

supplementation over time. Perhaps the strength measurements were not a true reflection of their strength capabilities as their training in the final few weeks was consistent according to their diaries. In the study by Chrusch., et al (2001) the creatine group improved their strength more than a placebo group for the lower limbs. Casey et al., (1996) showed that with repeated bouts of maximal isokinetic cycling improved ATP resynthesis increased PCr levels causing an enhanced performance. No such effect was observed in the present study. It is possible that Cr may not have been completely taken up by the muscles in the creatine supplemented group and although they improved their strength slightly more than the placebo group at weeks 2 and 7 the differences were insignificant. Perhaps greater numbers of participants would have shown a difference.

5.6 Muscular endurance

The third hypothesis stated that there would be a positive change in the endurance of the untrained limb of the creatine group compared with that of the untrained placebo group. This was not the case since both untrained (creatine and placebo) groups had similar endurance capacities throughout the study. It was expected that the creatine group would show some improvement in endurance, particularly in the final sets. The rationale for this comes from previous work on the effects of creatine supplementation on endurance performance. Prevost et al., (1997) who used a maximal cycling protocol, showed that creatine supplementation significantly improved the capacity to maintain high intensity intermittent exercise. Also, Kamber et al., (1999), using repeated 30 s Wingate testing found that young subjects improved over the final few bouts compared to a placebo condition. Chrusch et al., (2001) found an improvement in quadriceps endurance for a creatine group compared with a placebo group undergoing similar

training protocols. It is interesting to note that this study also had subjects perform a bench press training and testing protocol and found no difference between the groups in endurance for the upper body exercise task. Rawson et al., (1999) showed an 8% increase in muscular endurance of quadriceps using five sets of 30 MVC repetitions following 10 days of supplementation with CrH_2O in elderly males. A Cybex 6000 isokinetic dynamometer was used for the present study to test muscular endurance, and the testing protocol was 15 MVC repetitions x 5 sets, with 30 seconds recovery between sets. This protocol was preferred to a cycle ergometer test because it allowed the testing of each leg separately, enabling comparison of trained and untrained limbs for each subject. In the final sets, as the subjects fatigued it was hoped the extra stored PCr in the supplemented group would enhance the capacity of muscles to resynthesise ATP and thereby maintain greater power output. Although Rawson et al., (1999) used twice the repetitions of the present study for this test the quadriceps muscles were not subjected to a strength test prior to the endurance test so for the present investigation it is possible that the subjects were partially fatigued at the start of the endurance test. Since subjects were given appropriate rest between strength tests and prior to the endurance test it is thought that this is unlikely. In the final sets, as the muscles fatigued it was hoped the extra stored phosphocreatine would give more support allowing the muscles to generate a greater force. This was not the case for the present investigation. Perhaps the dosage for this group was too low. It was thought that because elderly males generally have lower muscle mass than athletes for whom high doses are recommended, the lower dose combined with an extended loading period would increase PCr stores in the muscle enough to support extra work at the end of the endurance test. For future studies a higher loading dose combined with an extended loading period may be required to increase muscle PCr stores for the elderly. The

present study found no negative side effects, so an increased dose for a longer time frame should not create major problems in this respect.

The sixth hypothesis stated that there would be an increase in total work during an endurance task with training alone. This was not shown in this study. The placebo and training group improved their endurance only slightly at week 2 and were close to baseline at weeks 7 and 12. Again it is possible that the training was not sufficient to stress the muscles enough to improve muscular endurance for this group. The tests were 5 sets of 15 repetitions at maximal effort and the training was approximately 12 to 15 repetitions, 1 to 3 sets at 30% maximal effort. The subjects were told to take no rest between sets for the present study, ie do one set of extensors, then immediately do flexors then extensors again and so on. Effectively this gives the muscle approximately 30 seconds to rest while the opposite muscles are being worked. The instructions given to the subjects were such that their training would be carried out at approximately 180°/second, (the speed used for the endurance test) and all subjects reported that the endurance test was much harder than the training. They were told to count during the training in order to keep the appropriate cadence, although this may have varied between subjects and training sessions. Perhaps a training regimen, which was more specific to the endurance test would have shown a larger improvement in performance. In the Chrusch et al., (2001) study the subjects in the placebo group conducted a whole body, training regimen, which was more rigorous than the present investigation. Although the training volume was not as high and the improvement was not as significant as the creatine group, the subjects did notice a significant improvement in endurance during the course of the investigation for leg extension and leg press but not for bench press. The difference between the current investigation and the Chrusch et al., (2001) study is the subjects' training volume. In the study by Bermon et al., (1998) the participants were older adults who were tested using leg extension, leg press and chest

press. Although the testing protocol for this investigation did not have a repeated bouts endurance component, it did look at a 12 RM test for the above exercises. Bermon et al., (1998) found a significant improvement for the three test protocols for the trained placebo group. This improvement was similar to that of the training group supplemented with CrH_2O. This investigation also used a greater training volume than that of the present study, which, as already discussed, may have been an important factor in explaining my findings. Studies, which have used training loads of approximately 80% 1RM, have noticed more significant changes in strength and endurance than the current investigation (Chrusch et al., 2001; Bermon et al., 1998; Fielding, 1995; Fiatarone, et al., 1990). Wiroth et al., (2001) found that fatigue was delayed significantly in 10 seconds of repeated bouts cycling and this could have implications for lower intensity, longer duration activity such as non-stop cycling or walking. Having said this, the rationale behind this training protocol should be re-emphasised, that it should be a home-based training programme that does not require a supervisor or expensive training equipment. For this reason the subjects were all started at a given weight and allowed to progress at their own pace.

Hypothesis nine stated that endurance in the creatine group would be greater than the placebo group with training. The CrT group improved their endurance significantly at weeks 2 (14%), 7 (21%) and 12 (14%). The PlT group also improved their endurance scores although not as much as the CrT group at weeks 2 (9%) and 7 (11%) despite a greater training volume. The two groups were however, the same at week 12 due to the drop in endurance scores by the CrT group at the final testing session. From this it is possible to conclude that supplementation with creatine supported extra work in the endurance tests. During short-term maximal-intensity exercise ATP is depleted and then regenerated by hydrolysis of PCr stored in the muscle. Previous studies have

shown that oral supplementation with creatine monohydrate can increase PCr stores in the muscles, which can then add further support to the production of ATP (Casey et al., 1996; Volek et al., 1999; Greenhaff et al., 1994; Harris et al., 1992). This added PCr availability works to enhance the endurance capability of the muscles at high intensity repeated bouts. Prevost et al., (1997) suggested that, in activities where intermittent bursts of maximal or near maximal effort are required, creatine supplementation may be of benefit by allowing individuals to perform at a higher intensity or to recover more quickly following activity. It is this idea that also forms the basis of the rationale for the present study. If supplementation with CrH_2O can support extra effort in the elderly, or people with a degenerative muscular disease in the same way as for athletes, then daily tasks may be able to be carried out more quickly and efficiently and with a reduced risk of injury due to falling. Elderly people may be at or near a "functionally-important strength-related threshold" and changes in the ability of the cardiovascular and muscular systems to support performance of daily tasks can reduce an individuals' quality of life (Young & Skelton, 1994; Fielding, 1995). Results from the present study support the concept of increased endurance in repeated bouts, although many of the previous studies used cycle ergometry to test for endurance in repeated bouts of maximal exercise (Balsom et al., 1993; Wiroth et al., 2001).

5.7 Conclusions and Recommendations for future research

The present study has shown that, despite a limited subject population, a moderate home-based resistance training protocol combined with CrH_2O supplementation can have a positive effect on muscular endurance. Although there were minimal improvements in isometric or isokinetic maximal strength or total body and limb segment mass compared to the other groups, the tendency suggest some beneficial

effects of combined training/supplementation with CrH_2O. Th the results of this investigation support one of the nine hypotheses put forward and report the major finding of the study to be that oral supplementation of CrH_2O combined with a light home based training programme can improve endurance in repeated bouts of maximal voluntary exercise. Perhaps a larger subject pool could have elicited clearer information. The low number of individuals who completed the protocol made it difficult to show a statistically significant difference between the groups. Further research is required however, as to the potential use of CrH_2O in the very old, people with degenerative muscular diseases and women. Some studies have already been carried out with positive findings for supplementation with CrH_2O in the elderly (Chrusch et al., 2001; Rawson et al., 1999; Bermon et al., 1998), pathological groups (Stout et al., 2001; Tarnopolsky et al., 2000, Tarnopolsky et al., 1999;) and women (Hamilton et al., 2000).

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APPENDIX A

APPENDIX A

INFORMED CONCENT FORM

The effects of creatine monohydrate supplementation and training on skeletal muscle mass, strength and endurance in older males.

I am doing research on muscle strength training, could you please take a couple of minutes to read this.

The purpose of this study is to investigate the responses of muscle to strength training while taking a dietary supplement.

You will be asked to perform a series of strength tests. Both, strength at certain angles, pushing against an immovable object and strength in moving the lower leg will be tested. Other tests include a type of x-ray and a finger prick blood sample. X-rays will be taken of each thigh and will take approximately half an hour in total. These will be carried out before supplementation and training begins, and again at week 12. Training will consist of lifting the foot with an ankle cuff to provide weighted resistance. As an increase in the ease of training is noticed, the weight will be increased slightly. Training will be conducted three times per week for twelve weeks.

During the tests you will be lifting and lowering your foot as fast as you can four times. Each test will last only a matter of a few seconds with the exception of one test, which takes approximately 135 seconds. The entire procedure will take not more than one hour. For any reason you wish to stop the test session, we will stop. Testing will be done before the start of training and supplementation and re-tests will occur at weeks 2, 7, and 12 Tests will be carried out at Edith Cowan University, Joondalup.

It is hoped that this research will help reduce the incidences and effects of falls in the elderly, and will also go a long way to improving the lifestyle of this population by making them more able to enjoy physical pursuits.

For the purposes of this study you will receive free health checks, strength assessments and professional fitness and nutritional advice.

.....

I understand that I am free to withdraw from this study at any time.

I acknowledge that I have read the above statement, which explains the nature of the investigation and the statement has been explained to me to my satisfaction. Before signing this document I have been given the opportunity to ask any questions relating to the study and I have received satisfactory answers. I agree that research data gathered from the result of the study may be published provided my name is not used.

I,....., aged.....yrs, agree to participate as a subject in the study described above.

Signed..... Date.....

For further information please contact Andrew Lavender on 93626024 or Dr Paul Sacco on 94005642.

APPENDIX B

APPENDIX B

Health Screening Questionnaire

The Effect of Creatine Monohydrate Supplementation and Training on Skeletal Muscle Mass and Strength in Older Males.

Investigator Andrew Lavender BSc

For this study you will be asked to attend a health screening with our campus Doctor. To assist with this check up we would like you to answer the following questions.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check yes or no.

	YES	NO	
1.	.....	.....	Has your doctor ever said you have a heart condition and that you should only do physical activity recommended by a doctor?
2.	.....	.....	Do you feel pain in your chest when you do physical activity?
3.	.....	.....	In the past month have you had chest pain when you were not doing any physical activity?
4.	.....	.....	Do you lose balance because of dizziness or do you ever lose conciousness?
5.	.....	.....	Do you have a bone or joint problem which may limit your physical activity?
6.	.....	.....	Is your doctor currently prescribing drugs for your blood pressure or heart condition?
7.	.....	.....	Are you a vegetarian?
8.	.....	.....	Do you drink coffee or tea? How much? ..... cups/day.
9.	.....	.....	Do you drink alcohol? How much? ..... drinks/day.
10.	.....	.....	Do you know of any other reason why you should not do physical activity?

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

Name..... Witness.....

Signature..... Date.....

APPENDIX C

APPENDIX C

Participants Training Diary

Name of Participant:

Week	Mon			Tue			Wed			Thu			Fri			Sat			Sun		
	Date	Rep / Set	Wt	Date	Rep / Set	Wt	Date	Rep / Set	Wt	Date	Rep / Set	Wt	Date	Rep / Set	Wt	Date	Rep / Set	Wt	Date	Rep / Set	Wt
1																					
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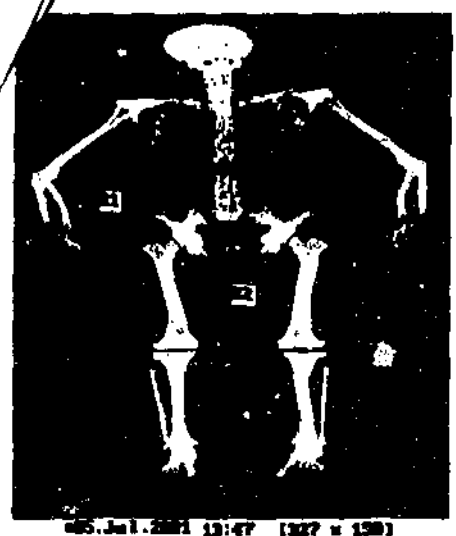
APPENDIX D

APPENDIX D

DUAL ENERGY X-RAY ABSORPTIOMETRY SCANS



A07840188 Wed 04.Jul.2001 13:09
Name: [redacted]
Comment:
I.D.: WIEN H Sex: M
S.S.#: 288-18-784 Ethnic: C
ZIPCode: CHRAT Height: 178.00 cm
Operator: MH Weight: 79.90 kg
BirthDate: 25.Aug.39 Age: 61
Physician: P SACCO
Image not for diagnostic use

Region	C.F.	1.020 Area (cm2)	1.010 BMC (grams)	1.000 BMD (gm/cm2)
R1		176.27	258.51	1.467
R2		186.20	269.35	1.447
METHAC		362.47	527.87	1.456

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Hologic QDR-4500A (S/N 45081)
Whole Body V8.26a:3

HOLOGIC

Hologic QDR-4500A (S/N 45081)
Whole Body V8.26a:3
e05.Jul.2001 13:47

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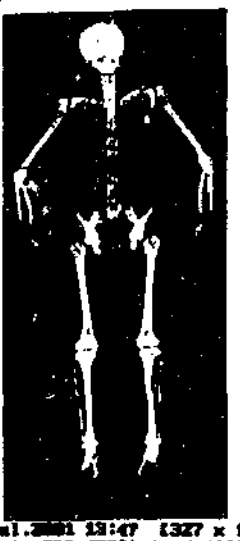
F.S. 60.00x 8(10.00)x

A07840188 Wed 04.Jul.2001 13:09
Name: WIEN, HANS
Comment:
I.D.: WIEN H Sex: M
S.S.#: 288-18-784 Ethnic: C
ZIPCode: CHRAT Height: 178.00 cm
Operator: MH Weight: 79.90 kg
BirthDate: 25.Aug.39 Age: 61
Physician: P SACCO

Region	BMC (grams)	Fat (grams)	Lean (grams)	Lean+BMC (grams)	Total (grams)	% Fat (%)
R1	258.5	1930.6	6292.3	6550.8	8539.4	23.3
R2	269.4	1851.4	6969.2	7238.6	8698.8	21.3
METHAC	527.9	3848.1	12861.5	13389.4	17229.5	22.3

LBM 73.2% water

HOLOGIC



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Whole Body V8.26a:3

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Name: [redacted]
Comment:
I.D.: UIBH H Sex: M
S.S.#: 288-18-784 Ethnic: C
ZIPCode: CRBAT Height: 170.00 cm
Operator: MH Weight: 79.50 kg
BirthDate: 25.Aug.39 Age: 61
Physician: P BACCO
Image not for diagnostic use

TOTAL BMC and BMD CV is < 1.0%
C.F. 1.020 1.010 1.000

Region	Area (cm2)	BMC (grams)	BMD (gm/cm2)
L Arm	236.62	193.94	0.820
R Arm	253.69	232.32	0.916
L Rib	128.63	91.48	0.711
R Rib	119.98	86.87	0.718
T Spine	154.44	149.61	0.969
L Spine	62.73	59.01	0.941
Pelvis	211.61	298.87	1.409
L Leg	396.62	518.38	1.287
R Leg	389.87	522.95	1.344
SubTot	1553.31	2143.75	1.097
Head	221.14	439.80	1.986
TOTAL	2174.45	2582.83	1.188

HOLOGIC

Hologic QDR-4500A (S/N 45001)
Whole Body V8.26a:3
04.Jul.2001 13:47

TBA0882
F.S. 60.00x 0(10.00)%

AB7D4818X Wed 04.Jul.2001 13:09
Name: UIBC, HANS
Comment:
I.D.: UIBH H Sex: M
S.S.#: 288-18-784 Ethnic: C
ZIPCode: CRBAT Height: 170.00 cm
Operator: MH Weight: 79.50 kg
BirthDate: 25.Aug.39 Age: 61
Physician: P BACCO

Region	BMC (grams)	Fat (grams)	Lean (grams)	Lean+BMC (grams)	Total (grams)	% Fat (%)
L Arm	193.9	1178.6	3281.9	3475.8	4654.4	25.3
R Arm	232.3	1286.8	3835.8	4068.1	5374.1	23.9
Trunk	694.2	18674.3	26395.8	27088.1	37754.4	28.3
L Leg	518.3	2238.7	9879.7	9598.0	11828.7	18.9
R Leg	522.9	2582.3	9847.8	9578.8	12373.1	20.7
SubTot	2143.8	17879.9	51661.8	53804.7	71684.7	24.9
Head	439.1	912.4	3182.7	3621.8	4534.2	20.1
TOTAL	2582.8	18792.3	54843.7	57426.5	76218.9	24.7

Assumes 17.0% brain fat
LBM 73.2% water

HOLOGIC

APPENDIX E

(Knee Extensor Muscle Function Data)

CREATINE **Isometric 75, 60, 45deg**

Isometric trained (75deg)

	BL	2	7	12
1	140	142	167	171
2	243	236	218	216
3	102	107	148	146
4	159	197	203	161
5	159	159	175	145
6	*108*	141		
7	*188*	202	199	
mean	**157.00**	**169.14**	**185**	**167.8**
sd	**48.44**	**44.38**	**26.08**	**29.05**
sem	**18.31**	**16.78**	**10.65**	**12.99**

Isometric untrained (75deg)

	BL	2	7	12
1	122	148	157	114
2	206	167	220	164
3	119	138	148	149
4	121	145	122	125
5	138	152	136	146
6	*121*	126		
7	*194*	174	195	
mean	**145.86**	**150.00**	**163.00**	**140.00**
sd	**37.69**	**16.42**	**37.27**	**20.14**
sem	**14.25**	**6.21**	**15.21**	**9.01**

Isometric trained (75deg)

	BL	2	7	12
1	100	101	119	122
2	100	97	90	89
3	100	105	145	143
4	100	124	128	101
5	100	100	110	91
6	100	131		
7	100	107	106	
mean	**100**	**109.34**	**116.28**	**109.32**
sd	**0**	**12.81**	**19.09**	**23.02**
sem	**0**	**4.84**	**7.79**	**10.29**

Isometric untrained (75deg)

	BL	2	7	12
1	100	121	129	93
2	100	81	107	80
3	100	116	124	125
4	100	120	101	103
5	100	110	99	107
6	100	104		
7	100	90	101	
mean	**100**	**106.02**	**109.96**	**101.76**
sd	**0**	**15.46**	**13.20**	**16.90**
sem	**0**	**5.84**	**5.39**	**7.56**

PLACEBO

Isometric trained (75deg)

	BL	2	7	12
8	191	220	232	214
9	133	144	122	130
10	151	184	174	122
11	122	127	137	138
12	213	207	175	168
13	188	159	179	218
14	*175*	213		
mean	**167.57**	**179.14**	**169.83**	**165**
sd	**33.25**	**36.46**	**38.36**	**42.5**
sem	**12.57**	**13.78**	**15.66**	**17.34**

Isometric untrained (75deg)

	BL	2	7	12
8	250	278	266	114
9	99	126	117	164
10	160	183	157	149
11	160	168	193	125
12	216	187	212	148
13	179	160	172	
14	*179*	207		
mean	**177.57**	**187**	**186.17**	**140**
sd	**47.47**	**47.45**	**50.84**	**20.1**
sem	**17.94**	**17.93**	**20.75**	**9.01**

Isometric trained (75deg)

	BL	2	7	12
8	100	115	121	112
9	100	108	92	98
10	100	122	115	81
11	100	104	112	113
12	100	97	82	79
13	100	85	95	116
14	100	122		
mean	**100.00**	**107.55**	**103.02**	**99.75**
sd	**0.00**	**13.61**	**15.49**	**16.68**
sem	**0**	**5.14**	**6.32**	**6.81**

Isometric trained (75deg)

	BL	2	7	12
8	100	111	106	46
9	100	50	47	66
10	100	73	63	60
11	100	67	77	50
12	100	75	85	59
13	100	64	69	
14	100	83		
mean	**100.00**	**74.80**	**74.47**	**56.00**
sd	**0.00**	**18.98**	**20.34**	**8.05**
sem	**0.00**	**7.17**	**8.30**	**3.60**

CREATINE

Isometric trained (60deg)

	BL	2	7	12
1	126	140	160	157
2	191	210	214	187
3	83	100	115	119
4	148	170	182	167
5	148	136	157	145
6	*108*	140		
7	*182*	161	193	
mean	**140.86**	**151.00**	**170.17**	**155.00**
sd	**38.64**	**34.18**	**34.36**	**25.34**
sem	**14.60**	**12.92**	**14.03**	**11.33**

Isometric untrained (60deg)

	BL	2	7	12
1	125	151	146	161
2	170	168	203	163
3	107	118	126	134
4	121	129	122	130
5	136	129	148	155
6	*100*	113		
7	*174*	165	198	
mean	**133.29**	**139.00**	**157.17**	**148.60**
sd	**28.96**	**22.28**	**35.17**	**16.50**
sem	**10.95**	**8.42**	**14.36**	**6.93**

Isometric trained (60deg)

	BL	2	7	12
1	100	111	127	125
2	100	110	112	98
3	100	120	139	143
4	100	115	123	113
5	100	92	106	98
6	100	130		
7	100	88	106	
mean	**100**	**109.48**	**118.78**	**115.34**
sd	**0**	**14.78**	**13.00**	**19.26**
sem		**5.22**	**4.91**	**7.86**

Isometric untrained (60deg)

	BL	2	7	12
1	100	121	117	129
2	100	99	119	96
3	100	110	118	125
4	100	107	101	107
5	100	95	109	114
6	100	113		
7	100	95	114	
mean	**100**	**105.60**	**112.90**	**114.26**
sd	**0**	**9.88**	**6.99**	**13.38**
sem		**3.74**	**2.64**	**5.06**

PLACEBO

Isometric trained (60deg)

	BL	2	7	12
8	209	216	255	209
9	115	142	136	132
10	160	164	176	178
11	140	121	145	155
12	172	161	175	187
13	171	157	178	209
14	*168*	176		
mean	**162.14**	**162.43**	**177.50**	**178.33**
sd	**29.22**	**29.50**	**41.94**	**30.49**
sem	**11.04**	**11.15**	**17.12**	**12.45**

Isometric untrained (60deg)

	BL	2	7	12
8	236	251	226	258
9	118	115	107	110
10	163	180	160	164
11	190	155	180	175
12	171	156	170	206
13	174	160	157	174
14	*114*	161		
mean	**166.57**	**168.29**	**166.67**	**182.60**
sd	**41.99**	**41.37**	**38.49**	**54.56**
sem	**15.87**	**15.64**	**15.71**	**22.27**

Isometric trained (60deg)

	BL	2	7	12
8	100	103	122	100
9	100	123	118	115
10	100	103	110	111
11	100	86	104	111
12	100	94	102	109
13	100	92	104	122
14	100	105		
mean	**100.00**	**100.85**	**109.95**	**111.28**
sd	**0.00**	**12.10**	**8.45**	**7.30**
sem	**0**	**4.57**	**3.45**	**2.98**

Isometric untrained (60deg)

	BL	2	7	12
8	100	106	96	109
9	100	97	91	93
10	100	110	98	101
11	100	82	95	92
12	100	91	99	120
13	100	92	90	100
14	100	141		
mean	**100.00**	**102.89**	**94.83**	**102.62**
sd	**0.00**	**19.48**	**3.78**	**10.71**
sem	**0.00**	**7.36**	**1.54**	**4.37**

CREATINE

Isometric trained (45deg)

	BL	2	7	12
1	114	114	142	130
2	168	165	197	157
3	65	80	92	96
4	100	145	134	136
5	117	100	123	126
6	*102*	114		
7	*134*	122	172	
mean	**114.29**	**120.00**	**143.33**	**129.00**
sd	**31.79**	**28.07**	**36.98**	**21.98**
sem	**12.02**	**10.61**	**15.10**	**9.83**

Isometric untrained (45deg)

	BL	2	7	12
1	107	119	126	148
2	130	129	164	136
3	83	107	111	108
4	102	103	103	119
5	122	115	122	130
6	*84*	103		
7	*148*	133	163	
mean	**110.86**	**115.57**	**131.50**	**128.20**
sd	**24.02**	**12.15**	**26.08**	**15.40**
sem	**9.08**	**4.59**	**10.65**	**6.89**

Isometric trained (45deg)

	BL	2	7	12
1	100	100	125	114
2	100	98	117	93
3	100	123	142	148
4	100	145	134	136
5	100	85	105	108
6	100	112		
7	100	91	128	
mean	**100**	**107.80**	**125.14**	**119.77**
sd	**0**	**20.68**	**12.81**	**21.88**
sem	**0**	**7.81**	**5.23**	**9.78**

Isometric untrained (45deg)

	BL	2	7	12
1	100	111	118	138
2	100	99	126	105
3	100	129	134	130
4	100	101	101	117
5	100	94	100	107
6	100	123		
7	100	90	110	
mean	**100**	**106.73**	**114.79**	**119.26**
sd	**0**	**14.69**	**13.62**	**14.69**
sem	**0.00**	**5.55**	**5.56**	**6.57**

PLACEBO

Isometric trained (45deg)

	BL	2	7	12
8	199	217	231	214
9	80	122	111	110
10	125	129	141	151
11	121	115	129	138
12	146	108	133	148
13	136	137	144	171
14	*129*	138		
mean	**133.71**	**138.00**	**148.17**	**155.33**
sd	**35.50**	**36.53**	**42.21**	**35.0**
sem	**13.42**	**13.81**	**17.23**	**14.28**

Isometric untrained (45deg)

	BL	2	7	12
8	188	207	187	216
9	95	88	89	103
10	133	138	125	129
11	182	132	152	153
12	149	138	159	183
13	141	136	132	148
14	*88*	130		
mean	**139.43**	**138.43**	**140.67**	**156.8**
sd	**38.57**	**35.03**	**33.47**	**44.4**
sem	**14.58**	**13.24**	**13.66**	**18.11**

Isometric trained (45deg)

	BL	2	7	12
8	100	109	116	108
9	100	153	139	138
10	100	103	113	121
11	100	95	107	114
12	100	74	91	101
13	100	101	106	126
14	100	107		
mean	**100.00**	**92.93**	**96.89**	**102.71**
sd	**0.00**	**42.77**	**42.16**	**41.73**
sem	**0**	**16.17**	**17.21**	**17.04**

Isometric untrained (45deg)

	BL	2	7	12
8	100	110	99	115
9	100	93	94	108
10	100	104	94	97
11	100	73	84	84
12	100	93	107	123
13	100	96	94	105
14	100	148		
mean	**100.00**	**102.26**	**95.16**	**105.36**
sd	**0.00**	**23.22**	**7.66**	**13.63**
sem	**0.00**	**8.78**	**3.13**	**5.56**

Isokinetic 60deg/sec

Peak Torque

CREATINE

Isokinetic trained

	BL	2	7	12
1	111	113	134	123
2	178	176	184	161
3	118	108	111	127
4	107	125	133	119
5	102	102	126	106
6	*99*	80	153	
7	*149*	134		
mean	**123.43**	**119.71**	**140.17**	**127.20**
sd	**29.27**	**30.20**	**25.40**	**20.5**
sem	**11.06**	**11.42**	**10.37**	**9.16**

Isokinetic untrained

	BL	2	7	12
1	91	102	113	111
2	156	160	168	155
3	117	136	156	133
4	88	92	91	98
5	98	114	96	92
6	*117*	113	137	
7	*122*	129		
mean	**112.71**	**120.86**	**126.83**	**117.40**
sd	**23.44**	**22.82**	**31.86**	**26.5**
sem	**8.86**	**8.63**	**13.01**	**11.83**

Isokinetic trained

	BL	2	7	12
1	100	101.80	120.72	110.81
2	100	98.88	103.37	90.45
3	100	91.53	94.07	107.63
4	100	116.82	124.30	111.21
5	100	100.00	123.53	103.92
6	100	80.81	154.55	
7	100	89.93		
mean	**100.00**	**97.11**	**120.09**	**104.80**
sd	**0.00**	**11.33**	**20.85**	**8.5**
sem	**0**	**4.28**	**8.51**	**3.82**

Isokinetic untrained

	BL	2	7	12
1	100	112.09	124.18	121.98
2	100	102.56	107.69	99.36
3	100	116.24	133.33	113.68
4	100	104.55	103.41	109.09
5	100	116.33	97.96	93.88
6	100	96.58	117.09	
7	100	105.74		
mean	**100.00**	**107.73**	**113.94**	**107.60**
sd	**0.00**	**7.42**	**13.39**	**11.2**
sem	**0.00**	**2.80**	**5.47**	**5.01**

PLACEBO

Isokinetic trained

	BL	2	7	12
8	201	195	233	193
9	92	117	119	103
10	122	121	118	111
11	94	91	95	103
12	146	161	167	175
13	145	136	152	171
14	*132*	155		
mean	**133.14**	**139.43**	**147.33**	**142.67**
sd	**37.11**	**34.15**	**49.29**	**41.31**
sem	**14.02**	**12.91**	**20.12**	**16.86**

Isokinetic untrained

	BL	2	7	12
8	218	209	221	218
9	113	118	107	102
10	94	114	129	104
11	126	130	127	129
12	187	186	195	213
13	161	165	153	146
14	*138*	167		
mean	**148.14**	**155.57**	**155.33**	**152.00**
sd	**43.43**	**36.04**	**44.10**	**51.86**
sem	**16.41**	**13.62**	**18.00**	**21.17**

Isokinetic trained

	BL	2	7	12
8	100	97.01	115.92	96.02
9	100	127.17	129.35	111.96
10	100	99.18	96.72	90.98
11	100	96.81	101.06	109.57
12	100	110.27	114.38	119.86
13	100	93.79	104.83	117.93
14	100	117.42		
mean	**100**	**105.95**	**110.38**	**107.72**
sd	**0**	**12.63**	**11.92**	**11.75**
sem	**0**	**4.78**	**4.87**	**4.80**

Isokinetic trained

	BL	2	7	12
8	100	95.87	101.38	100.00
9	100	104.42	94.69	90.27
10	100	121.28	137.23	110.64
11	100	103.17	100.79	102.38
12	100	99.47	104.28	113.90
13	100	102.48	95.03	90.68
14	100	121.01		
mean	**100**	**106.82**	**105.57**	**101.31**
sd	**0**	**10.18**	**15.96**	**9.83**
sem	**0.00**	**3.85**	**6.52**	**4.01**

Isokinetic 180deg/sec — **Peak Torque**

CREATINE

Isokinetic trained

	BL	2	7	12
1	72	72	98	79
2	140	140	149	133
3	91	102	96	99
4	69	79	88	80
5	80	85	108	100
6	*84*	91	107	
7	*81*	94		
mean	**88.14**	**94.71**	**107.67**	**98.20**
sd	**24.01**	**22.27**	**21.57**	**21.9**
sem	**9.07**	**8.42**	**8.80**	**9.78**

Isokinetic untrained

	BL	2	7	12
1	58	76	88	77
2	115	119	132	118
3	76	98	104	100
4	60	72	77	76
5	77	84	87	84
6	*66*	79	96	
7	*68*	92		
mean	**74.29**	**88.57**	**97.33**	**91.00**
sd	**19.35**	**16.18**	**19.26**	**17.9**
sem	**7.31**	**6.12**	**7.86**	**8**

Isokinetic trained

	BL	2	7	12
1	100	100.00	136.11	109.72
2	100	100.00	106.43	95.00
3	100	112.09	105.49	108.79
4	100	114.49	127.54	115.94
5	100	106.25	135.00	125.00
6	100	108.33	127.38	
7	100	116.05		
mean	**100.00**	**108.17**	**122.99**	**110.89**
sd	**0.00**	**6.51**	**13.69**	**11.0**
sem	**0**	**2.46**	**5.59**	**4.91**

Isokinetic untrained

	BL	2	7	12
1	100	131.03	151.72	132.76
2	100	103.48	114.78	102.61
3	100	128.95	136.84	131.58
4	100	120.00	128.33	126.67
5	100	109.09	112.99	109.09
6	100	119.70	145.45	
7	100	135.29		
mean	**100.00**	**121.08**	**131.69**	**120.54**
sd	**0.00**	**11.69**	**15.90**	**13.8**
sem	**0.00**	**4.42**	**6.49**	**6.17**

PLACEBO

Isokinetic trained

	BL	2	7	12
8	160	149	175	145
9	57	77	76	80
10	80	81	83	81
11	60	72	72	76
12	91	111	117	132
13	102	123	121	132
14	*106*	111		
mean	**93.71**	**103.43**	**107.33**	**107.67**
sd	**34.87**	**28.18**	**39.20**	**31.80**
sem	**13.18**	**10.65**	**16.00**	**12.98**

Isokinetic untrained

	BL	2	7	12
8	156	164	176	174
9	84	81	79	72
10	65	81	76	71
11	88	91	89	85
12	127	123	127	141
13	121	132	132	133
14		106		
mean	**106.83**	**111.14**	**113.17**	**112.67**
sd	**33.62**	**30.60**	**39.06**	**42.74**
sem	**13.72**	**11.57**	**15.94**	**17.45**

Isokinetic trained

	BL	2	7	12
8	100	93.13	109.38	90.63
9	100	135.09	133.33	140.35
10	100	101.25	103.75	101.25
11	100	120.00	120.00	126.67
12	100	121.98	128.57	145.05
13	100	120.59	118.63	129.41
14	100	104.72		
mean	**100**	**113.82**	**118.94**	**122.23**
sd	**0**	**14.56**	**11.17**	**21.72**
sem	**0**	**5.50**	**4.56**	**8.87**

Isokinetic trained

	BL	2	7	12
8	100	105.13	112.82	111.54
9	100	96.43	94.05	85.71
10	100	124.62	116.92	109.23
11	100	103.41	101.14	96.59
12	100	96.85	100.00	111.02
13	100	109.09	109.09	109.92
14				
mean	**100**	**105.92**	**105.67**	**104.00**
sd	**0**	**10.38**	**8.69**	**10.56**
sem	**0.00**	**4.24**	**3.55**	**4.31**

Isokinetic 240deg/sec **Peak Torque**

CREATINE

Isokinetic trained

	BL	2	7	12
1	60	57	80	72
2	126	122	132	122
3	71	79	80	80
4	62	66	76	69
5	76	83	104	94
6	72	77	91	
7	87	106		
mean	**79.14**	**84.29**	**93.83**	**87.40**
sd	**22.53**	**22.57**	**21.30**	**21.63**
sem	**8.51**	**8.53**	**8.70**	**9.67**

Isokinetic untrained

	BL	2	7	12
1	52	65	81	73
2	108	103	114	103
3	68	79	88	83
4	60	64	76	76
5	71	79	71	73
6	77	66	92	
7	58	98		
mean	**70.57**	**79.14**	**87.00**	**81.60**
sd	**18.55**	**15.95**	**15.28**	**12.64**
sem	**7.01**	**6.03**	**6.24**	**5.65**

Isokinetic trained

	BL	2	7	12
1	100	95	133.33	120
2	100	96.83	104.76	96.83
3	100	111.27	112.68	112.68
4	100	106.45	122.58	111.29
5	100	109.21	136.84	123.68
6	100	106.94	126.39	
7	100	121.84		
mean	**100**	**106.79**	**122.76**	**112.90**
sd	**0**	**9.04**	**12.24**	**10.34**
sem	**0**	**3.42**	**5.00**	**4.62**

Isokinetic untrained

	BL	2	7	12
1	100	125	155.77	140.38
2	100	95.37	105.56	95.37
3	100	116.18	129.41	122.06
4	100	106.67	126.67	126.67
5	100	111.27	100	102.82
6	100	85.71	119.48	
7	100	168.97		
mean	**100**	**116**	**123**	**117**
sd	**0**	**27**	**20**	**18**
sem	**0.00**	**10.16**	**8.11**	**8.17**

PLACEBO

Isokinetic trained

	BL	2	7	12
8	145	138	151	130
9	47	69	83	64
10	64	77	71	72
11	58	57	60	64
12	92	99	102	111
13	81	103	108	114
14	79	92		
mean	**80.86**	**90.71**	**95.83**	**92.50**
sd	**32.13**	**26.63**	**32.54**	**29.17**
sem	**12.14**	**10.06**	**13.29**	**11.91**

Isokinetic untrained

	BL	2	7	12
8	123	133	145	136
9	66	66	76	60
10	60	81	72	69
11	77	77	69	71
12	111	113	110	119
13	104	119	113	111
14		81		
mean	**90.17**	**95.71**	**97.50**	**94.33**
sd	**25.96**	**25.49**	**30.26**	**31.58**
sem	**10.60**	**9.63**	**12.35**	**12.89**

Isokinetic trained

	BL	2	7	12
8	100	95.17	104.14	89.66
9	100	146.81	176.60	136.17
10	100	120.31	110.94	112.50
11	100	98.28	103.45	110.34
12	100	107.61	110.87	120.65
13	100	127.16	133.33	140.74
14	100	116.46		
mean	**100**	**115.97**	**123.22**	**118.34**
sd	**0**	**17.85**	**28.32**	**18.69**
sem	**0**	**6.745**	**11.561**	**7.629**

Isokinetic untrained

	BL	2	7	12
8	100	108.13	117.89	110.57
9	100	100.00	115.15	90.91
10	100	135.00	120.00	115.00
11	100	100.00	89.61	92.21
12	100	101.80	99.10	107.21
13	100	114.42	108.65	106.73
14	#DIV/0!	#DIV/0!		
mean	**100**	**109.89**	**108.40**	**103.77**
sd	**0**	**13.53**	**11.91**	**9.92**
sem	**0.000**	**5.523**	**4.864**	**4.050**

Total Work Set One

CREATINE

Endurance Trained

	BL	2	7	12
1	1029	888	1428	1022
2	2132	2275	2224	2100
3	1187	1222	1428	1359
4	679	1309	1330	1031
5	948	1243	1391	1497
6	1322	1455		
7	1261	1447	807	
mean	**1222.57**	**1405.57**	**1434.67**	**1401.80**
sd	**456.07**	**427.67**	**453.86**	**441.62**
sem	**172.38**	**161.643**	**185.29**	**197.5**

PLACEBO

Endurance Trained

8	2029	1847	2123	2119
9	860	1285	1177	1170
10	942	1039	1020	1189
11	857	900	1036	1130
12	1431	1584	1818	1771
13	1302	1824	1764	1901
14	1135	1428		
mean	**1222.29**	**1415.29**	**1489.67**	**1546.67**
sd	**418.64**	**366.55**	**470.81**	**435.17**
sem	**158.23**	**138.54**	**192.21**	**177.66**

CREATINE

Endurance Trained

	BL	2	7	12
1	100	86.30	138.78	99.32
2	100	106.71	104.32	98.50
3	100	102.95	120.30	114.49
4	100	192.78	195.88	151.84
5	100	131.12	146.73	157.91
6	100	110.06		
7	100	114.75	64.00	
mean	**100.00**	**120.67**	**128.33**	**124.41**
sd	**0.00**	**34.51**	**44.25**	**28.61**
sem	**0**	**13.05**	**18.06**	**12.79**

PLACEBO

Endurance Trained

8	100	91.03	104.63	104.44
9	100	149.42	136.86	136.05
10	100	110.30	108.28	126.22
11	100	105.02	120.89	131.86
12	100	110.69	127.04	123.76
13	100	140.09	135.48	146.01
14	100	125.81		
mean	**100.00**	**118.91**	**122.20**	**128.05**
sd	**0.00**	**20.57**	**13.56**	**14.00**
sem	**0**	**7.78**	**5.53**	**5.72**

CREATINE

Endurance Untrained

	BL	2	7	12
1	1002	1066	1168	1077
2	1805	1945	1996	1949
3	1077	1475	1467	1467
4	848	869	986	1105
5	1345	1272	1199	1188
6	1391	1136		
7	1298	1249	689	
mean	**1252.29**	**1287.43**	**1250.83**	**1357.20**
sd	**314.17**	**345.53**	**446.62**	**365.04**
sem	**118.75**	**130.60**	**182.33**	**133.25**

PLACEBO

Endurance Untrained

8	1639	2194	2433	2297
9	1222	1243	1062	965
10	774	1079	1064	991
11	1079	1224	1146	1245
12	1832	1936	2073	1889
13	1639	1695	1601	1593
14	713	1588		
mean	**1271.14**	**1565.57**	**1563.17**	**1496.67**
sd	**444.07**	**409.65**	**581.78**	**530.18**
sem	**167.84**	**154.83**	**237.51**	**216.44**

CREATINE

Endurance Untrained

	BL	2	7	12
1	100	106.39	116.57	107.49
2	100	107.76	110.58	107.98
3	100	136.95	136.21	136.21
4	100	102.48	116.27	130.31
5	100	94.57	89.14	88.33
6	100	81.67		
7	100	96.22	53.08	
mean	**100.00**	**103.72**	**103.64**	**114.06**
sd	**0.00**	**17.11**	**28.99**	**19.35**
sem	**0.00**	**6.47**	**11.84**	**8.65**

PLACEBO

Endurance Untrained

8	100	133.86	148.44	140.15
9	100	101.72	86.91	78.97
10	100	139.41	137.47	128.04
11	100	113.44	106.21	115.38
12	100	105.68	113.16	103.11
13	100	103.42	97.68	97.19
14	100	222.72		
mean	**100.00**	**131.46**	**114.98**	**110.47**
sd	**0.00**	**42.93**	**23.64**	**22.07**
sem	**0.00**	**16.23**	**9.65**	**9.01**

Total Work Set Two

CREATINE

Endurance Trained

	BL	2	7	12
1	957	843	1325	1070
2	1931	1976	1965	1817
3	1063	1273	1256	1149
4	713	1120	1245	1031
5	869	1276	1341	1455
6	1158	1254		
7	1189	1154	1249	
mean	**1125.71**	**1270.86**	**1125.71**	**1270.86**
sd	**392.04**	**345.69**	**392.04**	**345.69**
sem	**148.18**	**130.66**	**160.05**	**154.60**

PLACEBO

Endurance Trained

8	1648	1536	1597	1615
9	700	1017	932	903
10	866	906	1035	1106
11	727	740	876	945
12	1540	1519	1620	1563
13	1287	1736	1520	1645
14	1026	1176		
mean	**1113.43**	**1232.86**	**1263.33**	**1298.17**
sd	**384.48**	**371.15**	**351.10**	**348.88**
sem	**145.32**	**140.28**	**143.34**	**142.43**

CREATINE

Endurance Trained

	BL	2	7	12
1	100	88.09	138.45	111.81
2	100	102.33	101.76	94.10
3	100	119.76	118.16	108.09
4	100	157.08	174.61	144.60
5	100	146.84	154.32	167.43
6	100	108.29		
7	100	97.06	105.05	
mean	**100.00**	**117.06**	**132.06**	**125.21**
sd	**0.00**	**25.91**	**28.94**	**30.00**
sem	**0**	**9.79**	**11.82**	**13.42**

PLACEBO

Endurance Trained

8	100	93.20	96.91	99.50
9	100	145.29	133.14	129.00
10	100	104.62	119.52	127.71
11	100	101.79	120.50	129.99
12	100	98.64	105.19	101.49
13	100	134.89	118.10	127.82
14	100	114.62		
mean	**100.00**	**113.29**	**115.56**	**119.00**
sd	**0.00**	**19.65**	**12.74**	**14.98**
sem	**0**	**7.43**	**5.20**	**6.12**

CREATINE

Endurance Untrained

	BL	2	7	12
1	1235	1036	1144	1063
2	1612	1779	1734	1745
3	938	1245	1226	1197
4	751	765	805	875
5	1239	1211	1101	1166
6	1258	1024		
7	1097	1187	1106	
mean	**1161.43**	**1178.14**	**1161.43**	**1178.14**
sd	**272.73**	**311.26**	**272.73**	**311.26**
sem	**103.08**	**117.65**	**111.34**	**139.20**

PLACEBO

Endurance Untrained

8	1733	2008	1926	1898
9	934	822	803	701
10	799	1026	989	959
11	945	1102	983	1005
12	1691	1889	1980	1649
13	1456	1501	1431	1459
14	679	1279		
mean	**1176.71**	**1375.29**	**1352.00**	**1278.50**
sd	**438.74**	**445.74**	**509.79**	**461.31**
sem	**165.83**	**168.47**	**208.12**	**188.33**

CREATINE

Endurance Untrained

	BL	2	7	12
1	100	83.89	92.63	86.07
2	100	110.36	107.57	108.25
3	100	132.73	130.70	127.61
4	100	101.86	107.19	116.51
5	100	97.74	88.86	94.11
6	100	81.40		
7	100	108.20	100.82	
mean	**100.00**	**102.31**	**104.63**	**106.51**
sd	**0.00**	**17.43**	**14.85**	**16.73**
sem	**0.00**	**6.59**	**6.06**	**7.48**

PLACEBO

Endurance Untrained

8	100	115.87	111.14	109.52
9	100	88.01	85.97	75.05
10	100	128.41	123.78	120.03
11	100	116.61	104.02	106.35
12	100	111.71	117.09	97.52
13	100	103.09	98.28	100.21
14	100	188.37		
mean	**100.00**	**121.72**	**106.71**	**101.45**
sd	**0.00**	**31.96**	**13.62**	**15.15**
sem	**0.00**	**12.08**	**5.56**	**6.19**

Total Work Set Three

CREATINE

Endurance Trained

	BL	2	7	12
1	887	839	1210	934
2	1530	1643	1713	1412
3	910	1113	1131	955
4	763	1024	1104	759
5	763	1192	1237	1299
6	980	1074		
7	1073	1059	993	
mean	**986.57**	**1134.86**	**1231.33**	**1071.80**
sd	**264.13**	**248.74**	**251.23**	**272.87**
sem	**99.83**	**94.015**	**102.56**	**122.03**

Endurance Untrained

	BL	2	7	12
1	1172	989	1059	994
2	1376	1515	1420	1455
3	797	991	980	930
4	574	607	538	709
5	1088	1083	980	1097
6	1127	835		
7	903	991	873	
mean	**1005.29**	**1001.57**	**975.00**	**1037.00**
sd	**266.69**	**275.09**	**285.13**	**273.50**
sem	**100.798**	**103.975**	**116.41**	**122.31**

PLACEBO

Endurance Trained

8	1344	1149	1323	1340
9	541	899	739	704
10	921	827	1017	1022
11	666	633	747	805
12	1463	1345	1239	1451
13	1182	1397	1280	1328
14	1048	961		
mean	**1023.57**	**1030.14**	**1057.50**	**1108.33**
sd	**339.78**	**279.53**	**265.49**	**310.58**
sem	**128.43**	**105.65**	**108.39**	**126.79**

Endurance Untrained

8	1829	1555	1435	1714
9	724	687	595	552
10	873	1003	906	934
11	777	930	812	934
12	1526	1814	1687	1489
13	1322	1285	1365	1233
14	720	1079		
mean	**1110.14**	**1193.29**	**1133.33**	**1142.67**
sd	**447.79**	**387.18**	**423.31**	**422.02**
sem	**169.25**	**146.34**	**172.82**	**172.29**

CREATINE

Endurance Trained

	BL	2	7	12
1	100	94.59	136.41	105.30
2	100	107.39	111.96	92.29
3	100	122.31	124.29	104.95
4	100	134.21	144.69	99.48
5	100	156.23	162.12	170.25
6	100	109.59		
7	100	98.70	92.54	
mean	**100.00**	**117.57**	**128.67**	**114.45**
sd	**0.00**	**21.78**	**24.65**	**31.33**
sem	**0**	**8.23**	**10.07**	**14.15**

Endurance Untrained

	BL	2	7	12
1	100	84.39	90.36	84.81
2	100	110.10	103.20	105.74
3	100	124.34	122.96	116.69
4	100	105.75	93.73	123.52
5	100	99.54	90.07	100.83
6	100	74.09		
7	100	109.75	96.68	
mean	**100.00**	**101.14**	**99.50**	**106.32**
sd	**0.00**	**16.97**	**12.47**	**14.97**
sem	**0.00**	**6.42**	**5.09**	**6.69**

PLACEBO

Endurance Trained

8	100	85.49	98.44	99.70
9	100	166.17	136.60	130.13
10	100	89.79	110.42	110.97
11	100	95.05	112.16	120.87
12	100	91.93	84.69	99.18
13	100	118.19	108.29	112.35
14	100	91.70		
mean	**100.00**	**105.48**	**108.43**	**112.20**
sd	**0.00**	**28.79**	**17.17**	**12.03**
sem	**0**	**10.88**	**7.01**	**4.91**

Endurance Untrained

8	100	85.02	78.46	93.71
9	100	94.89	82.18	76.24
10	100	114.89	103.78	106.99
11	100	119.69	104.50	120.21
12	100	118.87	110.55	97.58
13	100	97.20	103.25	93.27
14	100	149.86		
mean	**100.00**	**111.49**	**97.12**	**98.00**
sd	**0.00**	**21.55**	**13.33**	**14.75**
sem	**0.00**	**8.14**	**5.44**	**6.02**

Total Work Set Four

CREATINE

Endurance Trained

	BL	2	7	12
1	862	747	1205	810
2	1520	1532	1451	1315
3	839	965	1035	868
4	700	1009	1017	675
5	805	1226	1125	1234
6	883	956		
7	987	875	823	
mean	**942.29**	**1044.29**	**1109.33**	**980.40**
sd	**268.93**	**259.24**	**210.79**	**278.93**
sem	**101.64**	**97.99**	**86.06**	**124.74**

PLACEBO

Endurance Trained

8	1231	1082	1219	1257
9	423	801	640	643
10	807	856	913	1001
11	589	622	656	725
12	1401	1246	1456	1380
13	1069	1311	1172	1214
14	1094	907		
mean	**944.86**	**975.00**	**1009.33**	**1036.67**
sd	**352.51**	**248.82**	**328.77**	**300.42**
sem	**133.24**	**94.04**	**134.22**	**122.64**

CREATINE

Endurance Trained

	BL	2	7	12
1	100	86.66	139.79	93.97
2	100	100.79	95.46	86.51
3	100	115.02	123.36	103.46
4	100	144.14	145.29	96.43
5	100	152.30	139.75	153.29
6	100	108.27		
7	100	88.65	83.38	
mean	**100.00**	**113.69**	**121.17**	**108.73**
sd	**0.00**	**25.73**	**25.95**	**26.72**
sem	**0**	**9.73**	**10.59**	**11.95**

PLACEBO

Endurance Trained

8	100	87.90	99.03	102.11
9	100	189.36	151.30	152.01
10	100	106.07	113.14	124.04
11	100	105.60	111.38	123.09
12	100	88.94	103.93	98.50
13	100	122.64	109.64	113.56
14	100	82.91		
mean	**100.00**	**111.92**	**114.73**	**118.89**
sd	**0.00**	**36.82**	**18.66**	**19.32**
sem	**0**	**13.92**	**7.62**	**7.89**

Endurance Untrained

	BL	2	7	12
1	1067	997	944	964
2	1271	1321	1269	1302
3	735	858	826	791
4	503	534	471	631
5	1180	1062	1028	1055
6	1077	761		
7	831	850	757	
mean	**952.00**	**911.86**	**882.50**	**948.60**
sd	**272.62**	**248.14**	**269.30**	**256.01**
sem	**103.04**	**93.79**	**109.94**	**114.49**

PLACEBO

Endurance Untrained

8	1460	1406	1288	1304
9	644	628	480	506
10	951	982	930	913
11	696	826	776	839
12	1653	1610	1527	1368
13	1193	1173	1272	1127
14	681	944		
mean	**1039.71**	**1081.29**	**1045.50**	**1009.50**
sd	**405.70**	**339.79**	**386.71**	**322.79**
sem	**153.34**	**128.43**	**157.87**	**131.78**

CREATINE

Endurance Untrained

	BL	2	7	12
1	100	93.44	88.47	90.35
2	100	103.93	99.84	102.44
3	100	116.73	112.38	107.62
4	100	106.16	93.64	125.45
5	100	90.00	87.12	89.41
6	100	70.66		
7	100	102.29	91.10	
mean	**100.00**	**97.60**	**95.42**	**103.05**
sd	**0.00**	**14.73**	**9.45**	**14.75**
sem	**0.00**	**5.57**	**3.86**	**6.60**

PLACEBO

Endurance Untrained

8	100	96.30	88.22	89.32
9	100	97.52	74.53	78.57
10	100	103.26	97.79	96.00
11	100	118.68	111.49	120.55
12	100	97.40	92.38	82.76
13	100	98.32	106.62	94.47
14	100	138.62		
mean	**100.00**	**107.16**	**95.17**	**93.61**
sd	**0.00**	**15.93**	**13.32**	**14.79**
sem	**0.00**	**6.02**	**5.44**	**6.04**

Total Work Set Five

CREATINE

Endurance Trained

	BL	2	7	12
1	814	671	1115	818
2	1443	1413	1368	1296
3	784	839	942	856
4	603	951	850	636
5	781	1146	1077	1210
6	854	937		
7	904	750	807	
mean	**883.29**	**958.14**	**1026.50**	**963.20**
sd	**264.02**	**252.54**	**206.63**	**278.97**
sem	**99.79**	**95.45**	**84.36**	**124.76**

PLACEBO

Endurance Trained

8	1125	1083	1059	1162
9	458	719	641	598
10	823	854	929	926
11	595	515	606	708
12	1436	1281	1463	1319
13	963	1241	1135	1235
14	1157	820		
mean	**936.71**	**930.43**	**972.17**	**991.33**
sd	**339.81**	**282.24**	**322.67**	**295.00**
sem	**128.44**	**106.68**	**131.73**	**120.43**

Endurance Untrained

	BL	2	7	12
1	1130	970	974	922
2	1229	1258	1197	1296
3	754	805	776	767
4	503	506	479	607
5	1083	1033	1001	1013
6	1018	767		
7	757	797	689	
mean	**924.86**	**876.57**	**852.67**	**921.00**
sd	**259.36**	**237.86**	**255.96**	**260.48**
sem	**98.03**	**89.90**	**104.50**	**116.49**

PLACEBO

Endurance Untrained

8	1439	1361	1197	1279
9	587	633	465	424
10	933	983	928	888
11	700	819	735	800
12	1692	1566	1471	1357
13	1134	1157	1215	1136
14	696	902		
mean	**1025.86**	**1060.14**	**1001.83**	**980.67**
sd	**416.80**	**323.35**	**365.65**	**348.10**
sem	**157.54**	**122.22**	**149.27**	**142.11**

CREATINE

Endurance Trained

	BL	2	7	12
1	100	82.43	136.98	100.49
2	100	97.92	94.80	89.81
3	100	107.02	120.15	109.18
4	100	157.71	140.96	105.47
5	100	146.73	137.90	154.93
6	100	109.72		
7	100	82.96	89.27	
mean	**100.00**	**112.07**	**120.01**	**111.98**
sd	**0.00**	**29.56**	**22.92**	**25.09**
sem	**0**	**11.17**	**9.36**	**11.22**

PLACEBO

Endurance Trained

8	100	96.27	94.13	103.29
9	100	156.99	139.96	130.57
10	100	103.77	112.88	112.52
11	100	86.55	101.85	118.99
12	100	89.21	101.88	91.85
13	100	128.87	117.86	128.25
14	100	70.87		
mean	**100.00**	**104.65**	**111.43**	**114.24**
sd	**0.00**	**29.16**	**16.37**	**14.90**
sem	**0**	**11.02**	**6.68**	**6.08**

Endurance Untrained

	BL	2	7	12
1	100	85.84	86.19	81.59
2	100	102.36	97.40	105.45
3	100	106.76	102.92	101.72
4	100	100.60	95.23	120.68
5	100	95.38	92.43	93.54
6	100	75.34		
7	100	105.28	91.02	
mean	**100.00**	**95.94**	**94.20**	**100.60**
sd	**0.00**	**11.50**	**5.74**	**14.48**
sem	**0.00**	**4.35**	**2.34**	**6.48**

PLACEBO

Endurance Untrained

8	100	94.58	83.18	88.88
9	100	107.84	79.22	72.23
10	100	105.36	99.46	95.18
11	100	117.00	105.00	114.29
12	100	92.55	86.94	80.20
13	100.00	102.03	107.14	100.18
14	100.00	129.60		
mean	**100.00**	**106.99**	**93.49**	**91.83**
sd	**0.00**	**12.92**	**11.90**	**14.92**
sem	**0.00**	**4.88**	**4.86**	**6.09**

Total Work for Five Sets

CREATINE

Trained	BL	2	7	12	Untrained	BL	2	7	12
1	4549	3988	6273	4654		5606	5058	5289	5040
2	8556	8839	8721	7940		7293	7818	7616	7747
3	4783	5412	5592	5187		4301	5374	5275	5152
4	3531	5413	5546	5132		3179	3281	3279	3927
5	4166	6083	6171	6695		5935	5661	5309	5519
mean	**5117**	**5947**	**6460.6**	**5921.6**	**mean**	**5262.8**	**5438.4**	**5353.6**	**5477**
sd	**1979.9**	**1788.2**	**1305.7**	**1364.0**	**sd**	**1577.9**	**1621.4**	**1535.8**	**1401.2**
sem	**885.46**	**799.73**	**583.93**	**610.00**	**sem**	**705.64**	**725.10**	**686.83**	**626.65**

PLACEBO

Trained	BL	2.00	7.00	12.00	Untrained	BL	2.00	7.00	12.00
8	7377.0	6697.0	7321.0	7493.0		8100.00	8524.0	8279.00	8490.0
9	2982.0	4721.0	4129.0	4018.0		4111.00	4013.0	3405.00	3148.0
10	4359.0	4482.0	4914.0	5244.0		4330.00	5073.0	4818.00	4685.0
11	3434.0	3410.0	3921.0	4313.0		4197.00	4901.0	4452.00	4823.0
12	7071.0	6975.0	7596.0	7484.0		8394.00	8815.0	8741.00	7752.0
13	5703.0	7509.0	6871.0	7323.0		6544.00	6811.0	6884.00	6548.0
mean	**5154.3**	**5632.3**	**5792.0**	**5979.1**	**mean**	**5946.00**	**6356.1**	**6096.50**	**5907.6**
sd	**1856.1**	**1646.2**	**1660.9**	**1644.6**	**sd**	**2001.38**	**2010.3**	**2189.06**	**2038.0**
sem	**757.76**	**672.08**	**678.08**	**671.44**	**sem**	**817.06**	**820.70**	**893.68**	**832.01**

CREATINE

Trained	BL	2.00	7.00	12.00	Untrained	BL	2.00	7.00	12.00
1	100.00	87.67	137.90	102.31		100.00	90.22	94.35	89.90
2	100.00	103.31	101.93	92.80		100.00	107.20	104.43	106.23
3	100.00	113.15	116.91	108.45		100.00	124.95	122.65	119.79
4	100.00	153.30	157.07	145.34		100.00	103.21	103.15	123.53
5	100.00	146.02	148.13	160.71		100.00	95.38	89.45	92.99
mean	**100.00**	**120.69**	**132.39**	**121.92**	**mean**	**100.00**	**104.19**	**102.80**	**106.49**
sd	**0.00**	**28.08**	**22.66**	**29.44**	**sd**	**0.00**	**13.36**	**12.71**	**15.20**
sem	**0.00**	**12.56**	**10.13**	**13.17**	**sem**	**0.00**	**5.97**	**5.68**	**6.80**

PLACEBO

Trained	BL	2.00	7.00	12.00	Untrained	BL	2.00	7.00	12.00
8	100.00	90.78	99.24	101.57		100.00	105.23	102.21	104.81
9	100.00	158.32	138.46	134.74		100.00	97.62	82.83	76.58
10	100.00	102.82	112.73	120.30		100.00	117.16	111.27	108.20
11	100.00	99.30	114.18	125.60		100.00	116.77	106.08	114.92
12	100.00	98.64	107.42	105.84		100.00	105.02	104.13	92.35
13	100.00	131.67	120.48	128.41		100.00	104.08	105.20	100.06
mean	**100.00**	**113.59**	**115.42**	**119.41**	**mean**	**100.00**	**107.65**	**101.95**	**99.49**
sd	**0.00**	**26.04**	**13.35**	**13.09**	**sd**	**0.00**	**7.74**	**9.85**	**13.55**
sem	**0.00**	**11.65**	**5.97**	**5.86**	**sem**	**0.00**	**3.46**	**4.40**	**6.06**

APPENDIX F

(Knee Flexor Muscle Function Data)

CREATINE

Isometric trained (75deg)

	BL	2	7	12
1	62	65	83	83
2	75	84	98	102
3	41	62	58	62
4	76	65	102	83
5	71	68	72	72
6	*58*	60		
7	*81*	96	83	
mean	**66.29**	**71.43**	**82.67**	**80.4**
sd	**13.76**	**13.39**	**16.32**	**14.91**
sem	**5.20**	**5.06**	**6.66**	**6.67**

Isometric untrained (75deg)

	BL	2	7	12
1	65	61	89	84
2	87	98	108	111
3	42	49	49	57
4	62	68	81	71
5	57	64	85	79
6	*47*	68		
7	*80*	87	69	
mean	**62.86**	**70.71**	**80.17**	**80.40**
sd	**16.34**	**16.51**	**19.86**	**19.92**
sem	**6.18**	**6.24**	**8.11**	**8.91**

Isometric trained (75deg)

	BL	2	7	12
1	100	105	134	134
2	100	112	131	136
3	100	151	141	151
4	100	86	134	109
5	100	96	101	101
6	100	103		
7	100	119	102	
mean	**100**	**110.19**	**124.01**	**126.34**
sd	**0**	**21.00**	**17.46**	**20.52**
sem	**0**	**7.94**	**7.13**	**9.16**

Isometric untrained (75deg)

	BL	2	7	12
1	100	94	137	129
2	100	113	124	128
3	100	117	117	136
4	100	110	131	115
5	100	112	149	139
6	100	145		
7	100	109	86	
mean	**100**	**114.08**	**123.96**	**129.13**
sd	**0**	**15.31**	**21.55**	**9.34**
sem	**0.00**	**5.79**	**8.80**	**4.18**

PLACEBO

Isometric trained (75deg)

	BL	2	7	12
8	117	118	99	114
9	45	41	41	42
10	47	56	56	50
11	58	81	83	89
12	73	95	77	71
13	77	76	84	85
14	*65*	68		
mean	**68.86**	**76.43**	**73.33**	**75.17**
sd	**24.43**	**25.29**	**21.10**	**26.63**
sem	**9.23**	**9.56**	**8.81**	**10.87**

Isometric untrained (75deg)

	BL	2	7	12
8	89	107	110	77
9	45	61	50	57
10	58	52	60	62
11	64	80	81	80
12	92	73	80	76
13	84	75	75	75
14	*89*	99		
mean	**74.43**	**78.14**	**76.00**	**70.40**
sd	**16.57**	**19.51**	**20.64**	**10.21**
sem	**7.02**	**7.38**	**8.43**	**4.17**

Isometric trained (75deg)

	BL	2	7	12
8	100	101	85	97
9	100	91	91	93
10	100	119	119	106
11	100	140	143	153
12	100	130	105	97
13	100	99	109	110
14	100	105		
mean	**100.00**	**112.03**	**108.76**	**109.71**
sd	**0.00**	**17.97**	**20.94**	**22.35**
sem	**0**	**6.79**	**8.55**	**9.13**

Isometric trained (75deg)

	BL	2	7	12
8	100	120	124	87
9	100	69	56	64
10	100	58	67	70
11	100	90	91	90
12	100	82	90	85
13	100	84	84	
14	100	111		
mean	**100.00**	**87.80**	**85.39**	**79.10**
sd	**0.00**	**21.93**	**23.19**	**11.47**
sem	**0**	**8.29**	**9.47**	**5.13**

CREATINE

Isometric trained (60deg)

	BL	2	7	12
1	71	75	89	100
2	81	91	115	114
3	50	80	66	73
4	81	56	110	94
5	73	75	81	84
6	*56*	89		
7	*96*	115	103	
mean	**72.57**	**83.00**	**94.00**	**93.00**
sd	**15.69**	**18.21**	**18.74**	**15.59**
sem	**5.93**	**6.88**	**7.65**	**6.97**

Isometric untrained (60deg)

	BL	2	7	12
1	66	60	92	98
2	98	114	121	132
3	28	53	53	62
4	58	79	104	77
5	54	65	94	88
6	*42*	64		
7	83	89	91	
	61.29	**74.86**	**92.50**	**91.40**
	23.75	**21.07**	**22.40**	**26.34**
sem	**8.98**	**7.96**	**9.15**	**11.78**

Isometric trained (60deg)

	BL	2	7	12
1	100	106	125	141
2	100	112	142	141
3	100	160	132	146
4	100	69	136	116
5	100	103	111	115
6	100	159		
7	100	120		
mean	**100**	**118.37**	**129.22**	**131.74**
sd	**0**	**32.27**	**11.86**	**14.93**
sem	**0**	**12.20**	**5.30**	**6.68**

Isometric untrained (60deg)

	BL	2	7	12
1	100	91	139	148
2	100	116	123	135
3	100	189	189	221
4	100	136	179	133
5	100	120	174	163
6	100	152		
7	100	107		
mean	**100**	**130.39**	**161.11**	**160.07**
sd	**0**	**32.61**	**28.20**	**36.39**
sem	**0**	**12.32**	**12.61**	**16.27**

PLACEBO

Isometric trained (60deg)

	BL	2	7	12
8	122	145	117	138
9	50	49	53	52
10	66	68	66	65
11	69	88	95	100
12	87	113	94	102
13	95	80	96	95
14	*68*	80		
mea				
n	**79.57**	**89.00**	**86.83**	**92.00**
sd	**23.80**	**31.40**	**23.20**	**30.39**
				12.40
sem	**8.9943**	**11.87**	**9.471**	**7**

Isometric untrained (60deg)

	BL	2	7	12
8	81	133	136	126
9	54	60	54	60
10	73	73	73	73
11	77	85	85	91
12	99	85	76	94
13	89	85	76	89
14	*102*	122		
mea				
n	**82.14**	**91.86**	**83.33**	**88.80**
sd	**16.48**	**26.18**	**27.75**	**24.97**
		9.895		**10.19**
sem	**6.228**	**7**	**11.33**	**6**

Isometric trained (60deg)

	BL	2	7	12
8	100	119	96	113
9	100	98	106	104
10	100	103	100	98
11	100	128	138	145
12	100	130	108	117
13	100	84	101	100
14	100	118		
mea		**111.3**	**108.1**	**112.9**
n	**100.00**	**1**	**1**	**6**
sd	**0.00**	**16.76**	**15.12**	**17.31**
sem	**0**	**6.33**	**6.17**	**7.07**

Isometric untrained (60deg)

	BL	2	7	12
8	100	164	168	156
9	100	111	100	111
10	100	100	100	100
11	100	110	110	118
12	100	86	77	95
13	100	96	85	100
14	100	120		
mea	**100.0**	**112.3**	**106.7**	**113.3**
n	**0**	**8**	**4**	**0**
sd	**0.00**	**25.44**	**32.25**	**22.38**
sem	**0**	**9.62**	**13.16**	**9.14**

CREATINE

Isometric trained (45deg)

	BL	2	7	12
1	87	87	87	106
2	80	84	134	126
3	46	88	64	83
4	76	49	108	99
5	77	76	81	79
6	*50*	92		
7	*103*	118	114	
mean	**74.14**	**84.86**	**98.00**	**98.60**
sd	**20.08**	**20.53**	**25.37**	**18.93**
sem	**7.59**	**7.76**	**10.36**	**8.47**

Isometric untrained (45deg)

	BL	2	7	12
1	57	69	87	95
2	92	107	134	138
3	47	45	73	75
4	58	75	95	89
5	57	45	92	94
6	*39*	84		
7	*85*	94	106	
mean	**62.14**	**74.14**	**97.83**	**98.20**
sd	**19.36**	**23.44**	**20.74**	**23.64**
sem	**7.32**	**8.86**	**8.47**	**10.57**

Isometric trained (45deg)

	BL	2	7	12
1	100	100	100	122
2	100	105	168	158
3	100	191	139	160
4	100	64	142	130
5	100	99	105	103
6	100	184		
7	100	115		
mean	**100**	**122.58**	**130.79**	**138.53**
sd	**0**	**47.13**	**28.06**	**30.63**
sem	**0**	**17.81**	**12.55**	**13.70**

Isometric untrained (45deg)

	BL	2	7	12
1	100	121	153	167
2	100	116	146	150
3	100	96	155	160
4	100	129	164	153
5	100	79	161	165
6	100	215		
7	100	111		
mean	**100**	**123.90**	**155.76**	**158.92**
sd	**0**	**43.69**	**7.22**	**7.17**
sem	**0**	**16.51**	**3.23**	**3.21**

PLACEBO

Isometric trained (45deg)

	BL	2	7	12
8	121	159	134	149
9	52	50	52	53
10	79	81	80	73
11	76	108	98	110
12	100	117	103	110
13	100	98	88	102
14	*66*	79		
mean	**84.86**	**98.86**	**92.50**	**99.50**
sd	**23.50**	**34.47**	**27.13**	**33.3**
sem	**8.88**	**13.03**	**11.07**	**13.59**

Isometric untrained (45deg)

	BL	2	7	12
8	110	145	165	156
9	58	62	57	65
10	85	79	91	95
11	81	91	91	94
12	117	102	85	104
13	110	98	94	98
14	*99*	103		
mean	**94.29**	**97.14**	**97.17**	**102.8**
sd	**20.86**	**25.66**	**35.91**	**33.2**
sem	**7.89**	**9.70**	**14.66**	**13.54**

Isometric trained (45deg)

	BL	2	7	12
8	100	131	111	123
9	100	96	100	102
10	100	103	101	92
11	100	142	129	145
12	100	117	103	110
13	100	98	88	102
14	100	120		
mean	**100.00**	**101.11**	**91.28**	**98.03**
sd	**0.00**	**43.19**	**39.21**	**41.67**
sem	**0**	**16.32**	**16.01**	**17.01**

Isometric untrained (45deg)

	BL	2	7	12
8	100	132	150	142
9	100	107	98	112
10	100	93	107	112
11	100	112	112	116
12	100	87	73	89
13	100	89	85	89
14	100	104		
mean	**100.00**	**103.47**	**104.30**	**109.95**
sd	**0.00**	**15.69**	**26.66**	**19.69**
sem	**0**	**5.93**	**10.88**	**8.04**

Isokinetic 60deg/sec

CREATINE

Isokinetic trained

	BL	2	7	12
1	68	81	79	100
2	76	87	123	111
3	64	75	88	106
4	75	56	83	83
5	60	61	71	60
6	*58*	71		
7	*88*	95	100	
mean	**69.86**	**75.14**	**90.67**	**92.00**
sd	**10.56**	**13.86**	**18.55**	**20.8**
sem	**3.99**	**5.24**	**7.57**	**9.29**

Isokinetic untrained

	BL	2	7	12
1	54	49	83	84
2	92	111	114	117
3	65	83	106	107
4	61	76	85	76
5	62	61	83	73
6	*57*	91		
7	*75*	87	100	
mean	**66.57**	**79.71**	**95.17**	**91.40**
sd	**13.05**	**20.32**	**13.38**	**19.6**
sem	**4.93**	**7.68**	**5.46**	**8.74**

Isokinetic trained

	BL	2	7	12
1	100	119.12	116.18	147.06
2	100	114.47	161.84	146.05
3	100	117.19	137.50	165.63
4	100	74.67	110.67	110.67
5	100	101.67	118.33	100.00
6	100	122.41		
7	100	107.95	113.64	
mean	**100.00**	**108.21**	**126.36**	**133.88**
sd	**0.00**	**16.37**	**19.80**	**27.5**
sem	**0**	**6.19**	**8.08**	**12.28**

Isokinetic untrained

	BL	2	7	12
1	100	90.74	153.70	155.56
2	100	120.65	123.91	127.17
3	100	127.69	163.08	164.62
4	100	124.59	139.34	124.59
5	100	98.39	133.87	117.74
6	100	159.65		
7	100	116.00	133.33	
mean	**100.00**	**119.67**	**141.21**	**137.94**
sd	**0.00**	**22.33**	**14.51**	**20.8**
sem	**0**	**8.44**	**5.92**	**9.28**

PLACEBO

Isokinetic trained

	BL	2	7	12
8	127	151	142	153
9	46	47	47	52
10	94	92	75	79
11	76	100	94	102
12	107	119	118	126
13	100	91	85	98
14	*68*	84		
mean	**88.29**	**97.71**	**93.50**	**101.67**
sd	**26.99**	**31.98**	**33.26**	**35.27**
sem	**10.2**	**12.09**	**13.58**	**14.40**

Isokinetic untrained

	BL	2	7	12
8	122	146	152	167
9	53	62	58	69
10	80	84	91	91
11	84	92	91	89
12	110	95	103	119
13	92	89	84	85
14	*89*	115		
mean	**90.00**	**97.57**	**96.50**	**103.33**
sd	**22.11**	**26.49**	**31.05**	**35.13**
sem	**8.36**	**10.01**	**12.68**	**14.34**

Isokinetic trained

	BL	2	7	12
8	100	118.90	111.81	120.47
9	100	102.17	102.17	113.04
10	100	97.87	79.79	84.04
11	100	131.58	123.68	134.21
12	100	111.21	110.28	117.76
13	100	91.00	85.00	98.00
14	100	123.53		
mean	**100**	**110.90**	**102.12**	**111.25**
sd	**0**	**14.68**	**16.84**	**17.74**
sem	**0**	**5.55**	**6.87**	**7.24**

Isokinetic trained

	BL	2	7	12
8	100	119.67	124.59	136.89
9	100	116.9[illegible]	109.43	130.19
10	100	105.00	113.75	113.75
11	100	109.52	108.33	105.95
12	100	86.36	93.64	108.18
13	100	96.74	91.30	92.39
14	100	129.21		
mean	**100**	**109.07**	**106.84**	**114.56**
sd	**0**	**14.52**	**12.55**	**16.43**
sem	**0**	**5.49**	**5.12**	**6.71**

Isokinetic 180deg/sec

CREATINE

Isokinetic trained

	BL	2	7	12
1	58	68	60	76
2	66	77	88	83
3	65	72	69	79
4	50	50	75	69
5	54	50	53	50
6	*49*	52		
7	*54*	72	69	
mean	**56.57**	**63.00**	**69.00**	**71.40**
sd	**6.78**	**11.85**	**13.55**	**13.0**
sem	**2.56**	**4.48**	**5.53**	**5.82**

Isokinetic untrained

	BL	2	7	12
1	49	68	76	84
2	73	85	87	83
3	58	71	68	72
4	56	72	81	73
5	54	60	66	65
6	*27*	65		
7	*69*	75	77	
mean	**55.14**	**70.86**	**75.60**	**75.40**
sd	**15.00**	**7.95**	**8.79**	**8.0**
sem	**5.67**	**3.00**	**3.59**	**3.59**

Isokinetic trained

	BL	2	7	12
1	100	117.24	103.45	131.03
2	100	116.67	133.33	125.76
3	100	110.77	106.15	121.54
4	100	100.00	150.00	138.00
5	100	92.59	98.15	92.59
6	100	106.12		
7	100	133.33	127.78	
mean	**100.00**	**110.96**	**118.22**	**121.78**
sd	**0.00**	**13.25**	**22.39**	**17.4**
sem	**0.00**	**5.01**	**9.14**	**7.80**

Isokinetic untrained

	BL	2	7	12
1	100	138.78	155.10	171.43
2	100	116.44	119.18	113.70
3	100	122.41	117.24	124.14
4	100	128.57	144.64	130.36
5	100	111.11	122.22	120.37
6	100	240.74		
7	100	108.70	111.59	
mean	**100.00**	**138.11**	**131.68**	**132.00**
sd	**0.00**	**46.43**	**17.11**	**22.9**
sem	**0.00**	**17.55**	**6.98**	**10.22**

PLACEBO

Isokinetic trained

	BL	2	7	12
8	92	108	96	102
9	45	39	39	45
10	57	66	52	53
11	31	68	69	68
12	73	91	85	91
13	77	79	68	68
14	*54*	66		
mean	**61.29**	**73.86**	**68.17**	**71.17**
sd	**20.74**	**21.83**	**20.84**	**21.81**
sem	**7.84**	**8.25**	**8.51**	**8.90**

Isokinetic untrained

	BL	2	7	12
8	98	96	100	111
9	49	49	42	54
10	53	56	62	68
11	61	58	64	64
12	84	76	77	81
13	73	73	69	68
14	*56*	77		
mean	**67.71**	**69.29**	**69.00**	**74.33**
sd	**18.07**	**16.06**	**19.12**	**19.95**
sem	**6.83**	**6.07**	**7.81**	**8.14**

Isokinetic trained

	BL	2	7	12
8	100	117.39	104.35	110.87
9	100	86.67	86.67	100.00
10	100	115.79	91.23	92.98
11	100	219.35	222.58	219.35
12	100	124.66	116.44	124.66
13	100	102.60	88.31	88.31
14	100	122.22		
mean	**100**	**126.95**	**118.26**	**122.70**
sd	**0**	**42.81**	**52.36**	**49.13**
sem	**0.00**	**16.18**	**21.37**	**20.06**

Isokinetic untrained

	BL	2	7	12
8	100	97.96	102.04	113.27
9	100	100.00	85.71	110.20
10	100	105.66	116.98	128.30
11	100	95.08	104.92	104.92
12	100	90.48	91.67	96.43
13	100	100.00	94.52	93.15
14	100	137.50		
mean	**100**	**103.81**	**99.31**	**107.71**
sd	**0**	**15.58**	**11.11**	**12.71**
sem	**0.00**	**5.89**	**4.54**	**5.19**

Isokinetic 240deg/sec

CREATINE

Isokinetic trained

	BL	2	7	12
1	56	68	57	76
2	68	64	89	77
3	60	60	61	68
4	45	49	64	66
5	56	45	50	45
6	*35*	39		
7	*54*	69	61	
mean	**53.43**	**56.29**	**63.67**	**66.40**
sd	**10.64**	**11.91**	**13.32**	**12.90**
sem	**4.02**	**4.50**	**5.44**	**5.77**

Isokinetic untrained

	BL	2	7	12
1	56	65	71	79
2	73	77	75	75
3	53	62	65	57
4	61	69	62	58
5	52	53	58	58
6	*38*	46		
7	*65*	71	79	
mean	**56.86**	**63.29**	**68.33**	**65.40**
sd	**11.10**	**10.72**	**8.04**	**10.69**
sem	**4.19**	**4.05**	**3.28**	**4.78**

Isokinetic trained

	BL	2	7	12
1	100	121.43	101.79	135.71
2	100	94.12	130.88	113.24
3	100	100.00	101.67	113.33
4	100	108.89	142.22	146.67
5	100	80.36	89.29	80.36
6	100	111.43		
7	100	127.78	112.96	
mean	**100**	**106.29**	**113.13**	**117.86**
sd	**0**	**16.25**	**19.95**	**25.48**
sem	**0.00**	**6.14**	**8.14**	**11.40**

Isokinetic untrained

	BL	2	7	12
1	100	116.07	126.79	141.07
2	100	105.48	102.74	102.74
3	100	116.98	122.64	107.55
4	100	113.11	101.64	95.08
5	100	101.92	111.54	111.54
6	100	121.05		
7	100	109.23	121.54	
mean	**100**	**111.98**	**114.48**	**111.60**
sd	**0**	**6.79**	**10.76**	**17.58**
sem	**0.00**	**2.56**	**4.39**	**7.86**

PLACEBO

Isokinetic trained

	BL	2	7	12
8	83	99	87	80
9	43	42	39	37
10	57	60	52	53
11	37	61	57	56
12	69	84	72	79
13	65	56	62	62
14	*47*	66		
mean	**57.29**	**66.86**	**61.50**	**61.17**
sd	**16.22**	**18.91**	**16.60**	**16.44**
sem	**6.13**	**7.15**	**6.78**	**6.71**

Isokinetic untrained

	BL	2	7	12
8	84	75	85	98
9	42	43	47	49
10	52	47	61	64
11	50	54	53	57
12	68	62	71	71
13	69	62	61	64
14	*49*	68		
mean	**59.14**	**58.71**	**63.00**	**67.17**
sd	**14.86**	**11.40**	**13.51**	**16.85**
sem	**5.62**	**4.31**	**5.51**	**6.88**

Isokinetic trained

	BL	2	7	12
8	100	119.28	104.82	96.39
9	100	97.67	90.70	86.05
10	100	105.26	91.23	92.98
11	100	164.86	154.05	151.35
12	100	121.74	104.35	114.49
13	100	86.15	95.38	95.38
14	100	140.43		
mean	**100**	**119.34**	**106.76**	**106.11**
sd	**0**	**26.74**	**23.98**	**24.09**
sem	**0.00**	**10.11**	**9.79**	**9.83**

Isokinetic untrained

	BL	2	7	12
8	100	89.29	101.19	116.67
9	100	102.38	111.90	116.67
10	100	90.38	117.31	123.08
11	100	108.00	106.00	114.00
12	100	91.18	104.41	104.41
13	100	89.86	88.41	92.75
14	100	138.78		
mean	**100**	**101.41**	**104.87**	**111.26**
sd	**0**	**18.02**	**9.90**	**10.91**
sem	**0.00**	**6.81**	**4.04**	**4.45**

Total Work for Set One

CREATINE

Endurance Trained

	BL	2	7	12
1	1043	1128	869	1155
2	946	1074	1055	1108
3	1021	1124	1131	1125
4	660	898	1021	1041
5	636	860	692	786
6	800	827		
7	515	1051	709	
mean	**803.00**	**994.57**	**912.83**	**1042.60**
sd	**206.91**	**128.82**	**185.33**	**149.41**
sem	**78.20**	**48.69**	**75.66**	**66.82**

PLACEBO

Endurance Trained

8	1351	1036	976	1246
9	579	557	536	447
10	763	759	772	677
11	754	1056	1025	945
12	1062	1397	1109	1196
13	923	978	917	909
14	909	869		
mean	**905.86**	**950.29**	**889.17**	**903.33**
sd	**249.38**	**263.54**	**206.66**	**304.73**
sem	**94.26**	**99.61**	**84.37**	**124.41**

CREATINE

Endurance Untrained

	BL	2	7	12
1	766	852	922	1003
2	1197	1328	1193	1333
3	926	1014	913	891
4	838	980	839	720
5	934	845	955	979
6	690	1136		
7	894	773	873	
mean	**892.14**	**989.71**	**949.17**	**985.20**
sd	**161.01**	**192.96**	**126.07**	**223.90**
sem	**60.86**	**72.93**	**51.47**	**100.13**

PLACEBO

Endurance Untrained

8	1374	1226	1482	1323
9	385	747	616	622
10	513	589	662	711
11	777	925	814	883
12	1161	1147	1146	1069
13	1045	974	879	816
14	995	1299		
mean	**892.86**	**986.71**	**933.17**	**904.00**
sd	**354.17**	**258.23**	**327.96**	**256.02**
sem	**133.86**	**97.60**	**133.89**	**104.52**

CREATINE

Endurance Trained

	BL	2	7	12
1	100	108.15	83.32	110.74
2	100	113.53	111.52	116.91
3	100	110.09	110.77	110.19
4	100	136.06	154.70	157.73
5	100	135.22	108.81	123.58
6	100	103.38		
7	100	204.08	137.67	
mean	**100.00**	**130.07**	**117.80**	**123.83**
sd	**0.00**	**35.13**	**24.96**	**19.71**
sem	**0.00**	**13.28**	**10.19**	**8.82**

PLACEBO

Endurance Trained

8	100	76.68	72.24	92.23
9	100	96.20	92.57	77.20
10	100	99.48	101.18	88.73
11	100	140.05	135.94	125.33
12	100	131.54	104.43	112.62
13	100	105.96	99.35	98.48
14	100	95.60		
mean	**100.00**	**106.50**	**100.95**	**99.10**
sd	**0.00**	**22.05**	**20.66**	**17.35**
sem	**0.00**	**8.33**	**8.43**	**7.08**

CREATINE

Endurance Untrained

	BL	2	7	12
1	100	111.23	120.37	130.94
2	100	110.94	99.67	111.36
3	100	109.50	98.60	96.22
4	100	116.95	100.12	85.92
5	100	90.47	102.25	104.82
6	100	164.64		
7	100	86.47	97.65	
mean	**100.00**	**112.88**	**103.11**	**105.85**
sd	**0.00**	**25.54**	**8.60**	**16.96**
sem	**0.00**	**9.65**	**3.51**	**7.59**

PLACEBO

Endurance Untrained

8	100	89.23	107.86	96.29
9	100	194.03	160.00	161.56
10	100	114.81	129.04	138.60
11	100	119.05	104.76	113.64
12	100	98.79	98.71	92.08
13	100	93.21	84.11	78.09
14	100	130.55		
mean	**100.00**	**119.95**	**114.08**	**113.37**
sd	**0.00**	**35.90**	**26.80**	**31.46**
sem	**0.00**	**13.57**	**10.94**	**12.84**

Total Work for Set Two									
CREATINE						CREATINE			
Endurance Trained						Endurance Untrained			
	BL	2	7	12		BL	2	7	12
1	936	1021	823	1031	1	900	773	869	848
2	873	835	876	839	2	1039	1169	846	979
3	875	1044	932	975	3	814	807	758	761
4	711	818	933	1100	4	757	926	839	704
5	605	772	656	725	5	919	868	835	884
6	678	838			6	738	1223		
7	597	862	559		7	730	757	690	
mean	753.57	884.29	753.57	884.29	mean	842.43	931.86	842.43	931.86
sd	139.28	105.09	139.28	105.09	sd	115.09	189.96	115.09	189.96
sem	52.64	39.72	56.86	47.00	sem	43.50	71.80	46.98	84.95
PLACEBO					PLACEBO				
Endurance Trained					Endurance Untrained				
8	1054	906	720	941	8	1128	1215	1242	957
9	656	490	403	391	9	309	607	530	522
10	583	621	607	541	10	449	454	561	599
11	715	926	883	853	11	732	744	705	698
12	941	1106	953	952	12	1037	1096	1022	1003
13	791	818	791	774	13	921	797	749	788
14	801	644			14	928	1149		
mean	791.57	787.29	726.17	742.00	mean	786.29	866.00	801.50	761.17
sd	162.80	213.08	199.46	228.32	sd	306.15	291.91	277.95	192.38
sem	61.53	80.54	81.43	93.21	sem	115.71	110.33	113.47	78.54
CREATINE					CREATINE				
Endurance Trained					Endurance Untrained				
	BL	2	7	12		BL	2	7	12
1	100	109.08	87.93	110.15	1	100	85.89	96.56	94.22
2	100	95.65	100.34	96.11	2	100	112.51	81.42	94.23
3	100	119.31	106.51	111.43	3	100	99.14	93.12	93.49
4	100	115.05	131.22	154.71	4	100	122.32	110.83	93.00
5	100	127.60	108.43	119.83	5	100	94.45	90.86	96.19
6	100	123.60			6	100	165.72		
7	100	144.39	93.63		7	100	103.70	94.52	
mean	100.00	119.24	104.68	118.45	mean	100.00	111.96	94.55	94.23
sd	0.00	15.27	15.12	21.99	sd	0.00	26.51	9.56	1.22
sem	0.00	5.77	6.17	9.83	sem	0.00	10.02	3.90	0.54
PLACEBO					PLACEBO				
Endurance Trained					Endurance Untrained				
8	100	85.96	68.31	89.28	8	100	107.71	110.11	84.84
9	100	74.70	61.43	59.60	9	100	196.44	171.52	168.93
10	100	106.52	104.12	92.80	10	100	101.11	124.94	133.41
11	100	129.51	123.50	119.30	11	100	101.64	96.31	95.36
12	100	117.53	101.28	101.17	12	100	105.69	98.55	96.72
13	100	103.41	100.00	97.85	13	100	86.54	81.32	85.56
14	100	80.40			14	100	123.81		
mean	100.00	99.72	93.11	93.33	mean	100.00	117.56	113.79	110.80
sd	0.00	20.22	23.57	19.55	sd	0.00	36.48	31.82	33.58
sem	0.00	7.64	9.62	7.98	sem	0.00	13.79	12.99	13.71

Total Work for Set Three

CREATINE

Endurance Trained

	BL	2	7	12
1	895	1002	721	993
2	697	761	792	679
3	810	892	784	876
4	770	692	773	1033
5	589	636	570	620
6	583	738		
7	446	773	471	
mean	**684.29**	**784.86**	**685.17**	**840.20**
sd	**154.83**	**124.04**	**133.65**	**184.58**
sem	**58.52**	**46.88**	**54.56**	**82.55**

PLACEBO

Endurance Trained

8	881	725	503	914
9	640	404	301	316
10	567	584	507	422
11	589	860	633	715
12	743	921	640	856
13	724	697	704	670
14	702	534		
mean	**692.29**	**675.00**	**548.00**	**648.83**
sd	**106.76**	**182.27**	**144.73**	**236.77**
sem	**40.35**	**68.89**	**59.09**	**96.66**

CREATINE

Endurance Trained

	BL	2	7	12
1	100	111.96	80.56	110.95
2	100	109.18	113.63	97.42
3	100	110.12	96.79	108.15
4	100	89.87	100.39	134.16
5	100	107.98	96.77	105.26
6	100	126.59		
7	100	173.32	105.61	
mean	**100.00**	**118.43**	**98.96**	**111.19**
sd	**0.00**	**26.46**	**11.04**	**13.80**
sem	**0.00**	**10.00**	**4.51**	**6.17**

PLACEBO

Endurance Trained

8	100	82.29	57.09	103.75
9	100	63.13	47.03	49.38
10	100	103.00	89.42	74.43
11	100	146.01	107.47	121.39
12	100	123.96	86.14	115.21
13	100	96.27	97.24	92.54
14	100	76.07		
mean	**100.00**	**98.67**	**80.73**	**92.78**
sd	**0.00**	**28.72**	**23.61**	**27.07**
sem	**0.00**	**10.85**	**9.64**	**11.05**

Endurance Untrained

	BL	2	7	12
1	876	716	754	736
2	900	923	723	789
3	700	740	633	656
4	785	826	812	622
5	755	734	765	808
6	765	1123		
7	613	655	571	
mean	**770.57**	**816.71**	**709.67**	**722.20**
sd	**98.45**	**160.32**	**90.31**	**81.30**
sem	**37.21**	**60.60**	**36.87**	**36.36**

PLACEBO

Endurance Untrained

8	1287	997	1010	972
9	274	484	393	419
10	450	399	536	548
11	606	682	629	641
12	862	929	894	979
13	804	702	656	613
14	942	1022		
mean	**746.43**	**745.00**	**686.33**	**695.33**
sd	**336.13**	**247.57**	**228.36**	**230.13**
sem	**127.05**	**93.57**	**93.23**	**93.95**

CREATINE

Endurance Untrained

	BL	2	7	12
1	100	81.74	86.07	84.02
2	100	102.56	80.33	87.67
3	100	105.71	90.43	93.71
4	100	105.22	103.44	79.24
5	100	97.22	101.32	107.02
6	100	146.80		
7	100	106.85	93.15	
mean	**100.00**	**106.59**	**92.46**	**90.33**
sd	**0.00**	**19.75**	**8.85**	**10.72**
sem	**0.00**	**7.47**	**3.61**	**4.80**

PLACEBO

Endurance Untrained

8	100	77.47	78.48	75.52
9	100	176.64	143.43	152.92
10	100	88.67	119.11	121.78
11	100	112.54	103.80	105.78
12	100	107.77	103.71	113.57
13	100	87.31	81.59	76.24
14	100	108.49		
mean	**100.00**	**108.41**	**105.02**	**107.64**
sd	**0.00**	**32.83**	**24.21**	**29.35**
sem	**0.00**	**12.41**	**9.88**	**11.98**

Total Work for Set Four

CREATINE

Endurance Trained

	BL	2	7	12
1	923	997	679	888
2	711	708	674	633
3	758	852	742	784
4	709	772	694	951
5	560	605	530	576
6	648	803		
7	395	740	415	
mean	**672.00**	**782.43**	**622.33**	**766.40**
sd	**164.89**	**122.63**	**123.98**	**160.64**
sem	**62.32**	**46.35**	**50.61**	**71.84**

PLACEBO

Endurance Trained

8	942	793	544	808
9	605	354	216	271
10	541	542	522	415
11	572	842	628	618
12	673	875	777	777
13	583	628	602	601
14	659	454		
mean	**653.57**	**641.14**	**548.17**	**581.67**
sd	**135.56**	**202.31**	**185.83**	**207.54**
sem	**51.24**	**76.46**	**75.87**	**84.73**

CREATINE

Endurance Untrained

	BL	2	7	12
1	873	644	702	711
2	841	890	639	651
3	701	693	594	635
4	744	774	765	564
5	724	685	698	704
6	674	1028		
7	613	640	571	
mean	**738.57**	**764.86**	**661.50**	**653.00**
sd	**91.43**	**145.33**	**73.40**	**59.61**
sem	**34.56**	**54.93**	**29.97**	**26.66**

PLACEBO

Endurance Untrained

8	1172	1024	941	856
9	366	437	359	391
10	466	423	477	498
11	502	603	609	605
12	898	845	880	968
13	728	678	598	576
14	869	946		
mean	**714.43**	**708.00**	**644.00**	**649.00**
sd	**287.34**	**238.70**	**226.43**	**219.65**
sem	**108.60**	**90.22**	**92.44**	**89.67**

CREATINE

Endurance Trained

	BL	2	7	12
1	100	108.02	73.56	96.21
2	100	99.58	94.80	89.03
3	100	112.40	97.89	103.43
4	100	108.89	97.88	134.13
5	100	108.04	94.64	102.86
6	100	123.92		
7	100	187.34	105.06	
mean	**100.00**	**121.17**	**93.97**	**105.13**
sd	**0.00**	**30.07**	**10.69**	**17.23**
sem	**0.00**	**11.37**	**4.36**	**7.71**

PLACEBO

Endurance Trained

8	100	84.18	57.75	85.77
9	100	58.51	35.70	44.79
10	100	100.18	96.49	76.71
11	100	147.20	109.79	108.04
12	100	130.01	115.45	115.45
13	100	107.72	103.26	103.09
14	100	68.89		
mean	**100.00**	**99.53**	**86.41**	**88.98**
sd	**0.00**	**31.95**	**32.15**	**25.99**
sem	**0.00**	**12.08**	**13.13**	**10.61**

CREATINE

Endurance Untrained

	BL	2	7	12
1	100	73.77	80.41	81.44
2	100	105.83	75.98	77.41
3	100	98.86	84.74	90.58
4	100	104.03	102.82	75.81
5	100	94.61	96.41	97.24
6	100	152.52		
7	100	104.40	93.15	
mean	**100.00**	**104.86**	**88.92**	**84.50**
sd	**0.00**	**23.74**	**10.24**	**9.14**
sem	**0.00**	**8.97**	**4.18**	**4.09**

PLACEBO

Endurance Untrained

8	100	87.37	80.29	73.04
9	100	119.40	98.09	106.83
10	100	90.77	102.36	106.87
11	100	120.12	121.31	120.52
12	100	94.10	98.00	107.80
13	100	93.13	82.14	79.12
14	100	108.86		
mean	**100.00**	**101.96**	**97.03**	**99.03**
sd	**0.00**	**13.90**	**14.98**	**18.62**
sem	**0.00**	**5.25**	**6.12**	**7.60**

Total Work for Set Five

CREATINE

Endurance Trained

	BL	2	7	12
1	919	989	648	891
2	697	674	597	620
3	717	786	701	789
4	735	796	705	937
5	553	599	480	609
6	690	753		
7	506	792	469	
mean	**688.14**	**769.86**	**600.00**	**769.20**
sd	**134.07**	**121.19**	**104.98**	**151.09**
sem	**50.67**	**45.81**	**42.86**	**67.57**

PLACEBO

Endurance Trained

8	881	728	553	766
9	594	370	176	260
10	518	540	521	376
11	551	743	532	700
12	690	868	816	706
13	603	618	597	601
14	659	453		
mean	**642.29**	**617.14**	**532.50**	**568.17**
sd	**120.55**	**175.61**	**206.00**	**204.20**
sem	**45.56**	**66.37**	**84.10**	**83.36**

CREATINE

Endurance Trained

	BL	2	7	12
1	100	107.62	70.51	96.95
2	100	96.70	85.65	88.95
3	100	109.62	97.77	110.04
4	100	108.30	95.92	127.48
5	100	108.32	86.80	110.13
6	100	109.13		
7	100	156.52	92.69	
mean	**100.00**	**113.74**	**88.22**	**106.71**
sd	**0.00**	**19.39**	**9.93**	**14.70**
sem	**0.00**	**7.33**	**4.05**	**6.58**

PLACEBO

Endurance Trained

8	100	82.63	62.77	86.95
9	100	62.29	29.63	43.77
10	100	104.25	100.58	72.59
11	100	134.85	96.55	127.04
12	100	125.80	118.26	102.32
13	100	102.49	99.00	99.67
14	100	68.74		
mean	**100.00**	**97.29**	**84.47**	**88.72**
sd	**0.00**	**27.55**	**32.36**	**28.49**
sem	**0.00**	**10.41**	**13.21**	**11.63**

Endurance Untrained

	BL	2	7	12
1	922	636	679	626
2	796	823	552	636
3	655	637	551	583
4	704	759	625	526
5	755	677	641	746
6	663	1055		
7	445	584	564	
mean	**705.71**	**738.71**	**602.00**	**623.40**
sd	**147.04**	**161.35**	**53.90**	**81.11**
sem	**55.58**	**60.98**	**22.00**	**36.27**

PLACEBO

Endurance Untrained

8	1045	1043	903	934
9	343	438	359	401
10	468	428	479	491
11	484	652	574	576
12	896	909	873	914
13	709	640	610	618
14	849	898		
mean	**684.86**	**715.43**	**633.00**	**655.67**
sd	**260.14**	**240.62**	**216.01**	**220.88**
sem	**98.32**	**90.95**	**88.19**	**90.17**

CREATINE

Endurance Untrained

	BL	2	7	12
1	100	68.98	73.64	67.90
2	100	103.39	69.35	79.90
3	100	97.25	84.12	89.01
4	100	107.81	88.78	74.72
5	100	89.67	84.90	98.81
6	100	159.13		
7	100	131.24	126.74	
mean	**100.00**	**108.21**	**87.92**	**82.07**
sd	**0.00**	**29.29**	**20.40**	**12.12**
sem	**0.00**	**11.07**	**8.33**	**5.42**

PLACEBO

Endurance Untrained

8	100	99.81	86.41	89.38
9	100	127.70	104.66	116.91
10	100	91.45	102.35	104.91
11	100	134.71	118.60	119.01
12	100	101.45	97.43	102.01
13	100	90.27	86.04	87.17
14	100	105.77		
mean	**100.00**	**107.31**	**99.25**	**103.23**
sd	**0.00**	**17.33**	**12.30**	**13.34**
sem	**0.00**	**6.55**	**5.02**	**5.45**

Total Work for five Sets

CREATINE

Trained	BL	2	7	12	Untrained	BL	2	7	12
1	4716	5137	3740	4958		4337	3621	3826	3924
2	3904	4052	3994	3877		4773	5133	3953	4388
3	4181	4698	4290	4549		3796	3891	3449	3526
4	3585	3976	4126	5062		3828	4265	3880	3136
5	2943	3472	2728	3316		4087	3809	3894	4121
mean	**3865.8**	**4267**	**3775.6**	**4352.4**		**4164.2**	**4143.8**	**3800.4**	**3819**
sd	**662.2**	**653.0**	**619.2**	**743.1**		**404.7**	**600.5**	**201.6**	**494.6**
sem	**296.15**	**292.03**	**276.93**	**332.35**	**sem**	**180.98**	**268.56**	**90.14**	**221.17**

PLACEBO

Trained	BL	2	7	12	Untrained	BL	2	7	12
8	5109	4188	3296	4675		6006	5505	5578	5042
9	3074	2175	1632	1645		1677	2713	2257	2355
10	2972	3046	2929	2431		2366	2313	2715	2847
11	3181	4427	3701	3831		3101	3606	3331	3403
12	4109	5167	4295	4487		4854	4926	4815	4933
13	3624	3739	3611	3555		3207	3791	3492	3411
mean	**3678.2**	**3790.3**	**3244.0**	**3437.3**		**3535.2**	**3809.0**	**3698.0**	**3665.2**
sd	**818.1**	**1060.6**	**910.9**	**1185.5**		**1610.0**	**1233.3**	**1265.1**	**1097.5**
sem	**334.00**	**433.00**	**371.87**	**484.00**	**sem**	**657.27**	**503.48**	**516.46**	**448.05**

CREATINE

Trained	BL	2	7	12	Untrained	BL	2	7	12
1	100	108.93	79.30	105.13		100	83.49	88.22	90.48
2	100	103.79	102.31	99.31		100	107.54	82.82	91.93
3	100	112.37	102.61	108.80		100	102.50	90.86	92.89
4	100	110.91	115.09	141.20		100	111.42	101.36	81.92
5	100	117.97	92.69	112.67		100	93.20	95.28	100.83
mean	**100**	**110.79**	**98.40**	**113.42**		**100**	**99.63**	**91.71**	**91.61**
sd	**0.0**	**5.2**	**13.3**	**16.3**		**0.0**	**11.3**	**7.0**	**6.7**
sem	**0.00**	**2.31**	**5.95**	**7.28**	**sem**	**0.00**	**5.06**	**3.14**	**3.02**

PLACEBO

Trained	BL	2	7	12	Untrained	BL	2	7	12
8	100	81.97	64.51	91.51		100	91.66	92.87	83.95
9	100	70.75	53.09	53.51		100	161.78	134.59	140.43
10	100	102.49	98.55	81.80		100	97.76	114.75	120.33
11	100	139.17	116.35	120.43		100	116.29	107.42	109.74
12	100	125.75	104.53	109.20		100	101.48	99.20	101.63
13	100	103.17	99.64	98.10		100	118.21	108.89	106.36
mean	**100.0**	**103.9**	**89.4**	**92.4**		**100.0**	**114.5**	**109.6**	**110.4**
sd	**0.0**	**25.7**	**24.8**	**23.3**		**0.0**	**25.4**	**14.5**	**18.9**
sem	**0.00**	**10.49**	**10.13**	**9.53**	**sem**	**0.00**	**10.37**	**5.90**	**7.73**