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Effects of Creatine-Electrolyte Supplement on Power and Strength Performance

Erik Hummer
Western Washington University, hummere@students.wwu.edu

Effects of creatine-electrolyte supplement on power and strength performance

By
Erik Hummer

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Kathleen L. Kitto, Dean of the Graduate School

ADVISORY COMMITTEE

Chair, Dr. Jun San Juan

Dr. Dave Suprak

Dr. Lorrie Brilla

MASTER'S THESIS

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Effects of creatine-electrolyte supplement on power and strength performance

A Thesis
Presented to
The Faculty of
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Abstract

The purpose of this study was to investigate the effects of a creatine and electrolyte formulated multi-ingredient performance supplement (MIPS) on strength and power performance. Maximal strength, total concentric work, mean rate of force development (mRFD), mean power, peak power, and peak force was determined at pre-test and post-test separated by six weeks of supplementation. Subject's body density and body water were measured using a BodPod and Quantum X Bioelectrical Impedance unit respectively. Subjects performed three akimbo countermovement jumps (ACMJ) on a force platform. Subjects performed a one-repetition maximum (1RM) for back squat and bench press consisting of a maximal repetition test at a 90% predicted value. Eighty percent of the subjects pre-test 1RM was used for a maximal repetition test to test for performance variables including: total concentric work, mRFD, mean power, peak power, and peak force. Testing was separated by six weeks of supplementation in a double blind fashion with a placebo group for comparison. A two way mixed analysis of variance (ANOVA) was applied with an alpha level of 0.05 for all body composition, body water, akimbo countermovement jump, back squat, and bench press variables. The MIPS showed a significant increased back squat and bench press maximal strength (13.4%, $p = 0.035$ and 5.9%, $p = 0.045$ respectively), as well as total concentric work (26.5%, $p = 0.024$), mRFD (22.4%, $p = 0.050$), and mean power (17.9%, $p = 0.025$) for the maximal repetition bench press test at 80% of their 1RM. The placebo group had a significant decreased mRFD of -26% over the six-week supplementation. Creatine formulated with electrolytes could be beneficial for recreationally trained individuals.

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Table of Contents

List of Tables

List of Figures

List of Appendices

Chapter I

The Problem and Its Scope

Introduction

The human body utilizes various energy systems to generate human movement under different circumstances. These systems can be split into two categories, aerobic and anaerobic energy systems (Bemben, Bemben, Loftiss & Knehans, 2001; Larson-Meyer et al., 2000). Aerobic energy systems are utilized for prolonged exercise that utilizes oxygen to generate a large amount of adenosine triphosphate (ATP) (Bemben et al., 2010). A primary system that generates ATP under very quick and acute circumstances is the creatine phosphagen system. It has been determined that increasing the storage of free creatine and creatine phosphates can help prolong the usage of the creatine phosphagen system. Supplementation of creatine enhances the total storage of creatine and helps increase both power and strength performances (Aedma, Timpmann, Lätt, & Ööpik, 2015; Greenhaff, Bodin, Soderlund, & Hultman, 1994; Wiroth et al., 2001).

Creatine supplementation has become a very popular supplement among athletes and recreationally trained people for decades (Brenner, Rankin, & Sebolt, 2000; Claudino et al., 2014; McGuine, Sullivan, & Bernhardt, 2001). Supplementation of creatine has also become wide spread across varying skill levels of athletes, ranging from recreational to professional levels (Antonio & Ciccone, 2013; Bemben et al., 2010; Vincent & Jenkins, 1998). Creatine is primarily found in the human body to support movement through a fast activation energy system known as the creatine phosphagen system (Aedma et al., 2015; Becque, Lochmann, & Melrose, 2000; Kresta et al., 2014). The creatine phosphagen system is used by the human body for short duration activity using creatine phosphates as a source of fuel to produce

Adenosine Triphosphate (ATP) for bodily movement. Adenosine Diphosphate (ADP) is phosphorylated using phosphocreatine and transformed into ATP which is used for muscular movement. The creatine phosphate system is an acute pathway for metabolic energy only lasting for about ten seconds prior to being depleted (Becque et al., 2000; Hoffman et al., 2006).

Supplementation involving creatine is used by many people to enhance characteristics of their performance in physical activity. Creatine supplementation has been previously used to increase various aspects of both power and strength activities (Earnest, Snell, Rodrigues, Almada, & Mitchell, 1995; Francaux & Poortmans, 1999; Peeters, Lantz, & Mayhew, 1999). Most of the literature on creatine supplementation appears to support the trend that this supplementation is beneficial for a wide variety of people for several reasons. Multiple studies have concluded that creatine supplementation ranging from one week to twelve weeks can be helpful in enhancing one-repetition maximum strength, total work capacity, increasing lean-body mass, and, in some cases, increases in lower limb power output (Claudino et al., 2014; Earnest et al., 1995; Herda et al., 2009).

The most common form of creatine supplementation comes in the form of creatine monohydrate (Francaux et al., 1999; Kreider et al., 1998). Research has varied on the dosages required to elicit benefits from creatine supplementation, ranging from 20g/day for loading phases to 3g/day for maintenance dosages (Barros et al., 2012; Olsen et al., 2006; Robinson, 2000). While some studies have combined the use of creatine supplementation with beta alanine and other solutions, there is very little to no literature on creatine supplementation coupled with electrolytes. Electrolytes such as sodium, potassium, and magnesium are transporters used to aid in the absorption and utilization of creatine by the human body (Allen, 2012). The current study aims to investigate the potential effects of a creatine supplement combined with various electrolytes for body composition, body water analysis, power, and strength outcomes for college-aged individuals.

Purpose of the Study

The purpose of this study was to examine the effects of a multi-ingredient performance supplement comprised of electrolytes and creatine on the performance of individuals who are regularly strength training. The primary purpose of the study was to examine the potential benefits of the multi-ingredient performance supplement (MIPS) supplementation on power and strength performance outcomes during an akimbo countermovement jump, and the back squat, and bench press exercises. The study was aimed at examining the implications for performance enhancement in an active population that would benefit or would potentially use supplementation for enhancement.

Hypothesis

We hypothesized that a six-week supplementation period of the MIPS would increase: lean body mass (LBM), intra-cellular water, peak and mean power for an akimbo countermovement jump (ACMJ), and increase predicted one-repetition maximum (1RM) strength for back squat and bench press. Additionally, there will be an increase the amount of concentric work, mean power, peak power, mean rate of force development, and peak force for back squat and bench press during a maximal repetition test at 80% 1RM load.

Significance of the Study

Creatine is one of the most researched supplements to help enhance performance across many activities (Bemben et al., 2001; Greenhaff et al., 1994; Jagim et al., 2012;

Larson-Meyer et al., 2000; McGuine et al., 2001). Specifically, creatine has been used to enhance performance in various settings for both strength and power activities. Currently, there are very few studies that examine the effects of a specific MIPS such as this one, formulated with electrolytes and creatine. The ideology is that the MIPS will allow for greater absorption and utilization of the creatine dosage due to increased availability of electrolytes used for cell transportation. This study will give insight to possible adaptations to the supplementation procedure using creatine.

Limitations

- This study is unable to account for subject history and experience with specific exercises. Familiarity with either the back squat or bench press could have had an effect on the outcome measures.
- All testing occurred inside of a laboratory setting and may not be applicable to real world settings. The maintenance of internal validity caused a decrease in external validity.
- Subjects were self-reporting their own adherence when taking their assigned supplement.
- Back squat range of motion or depth was not controlled in the one repetition max testing or the maximal repetition test.
- The load used for the maximal repetition test was kept consistent to give an accurate comparison between the pre-test to post-test. Subjects could have either increased or decreased the 1RM strength and the 80% 1RM could have been adjusted for with the post-test 1RM value.

Definition of Terms

Akimbo Countermovement Jump	A maximal effort jump including an unweighting period and loading while keeping hands fixed on their hips. (Claudino et al., 2014)
Body Composition	Measurements used to describe the overall make up of a person's body in terms of body fat and fat free mass. (Jagim et al., 2012)
Center of Mass	The most central point of an object mass at which the mass is even distributed around. (Lukos, Ansuini, & Stantello, 2007)
Creatine Phosphagen System	The acute metabolic energy pathway in which ADP is phosphorylated using creatine phosphate into ATP. This is a very short term energy system only lasting a couple of seconds before needing to be replenished. (Allen, 2012)
Concentric Work	The product of a force applied to an object that also results in displacement or movement of said object. (Work = Force * Displacement * cosine(theta)) (Wiroth et al., 2001)
Dosage	Amount of a certain substance taken prescribed in an amount of grams per day for supplementation (Aedma et al., 2015; Greenhaff et al., 1994; Wiroth et al., 2001)
Electrolytes	A group of minerals that are found in the body. Aids in membrane transportation. (Allen, 2012)
Extra-cellular Water	Physiological measurement of the amount of water that exists outside of an individual's cells. (Francaux et al., 1999)

Force	An interaction that when unopposed can cause a change in direction. (Force = Mass x Acceleration) (Francaux et al., 1999)
Intra-cellular Water	Physiological measurement of the amount of water that exists inside of an individual's cells. (Francaux et al., 1999)
Lean Body Mass (LBM)	The amount of body tissue that is attributed to be free of adipose tissue. Used in a two compartment model with fat mass to describe the overall make up of individuals body. (Francaux et al., 1999)
One-Repetition Maximum (1RM)	The load that someone can only perform for a single time before failure, used a value for maximal strength (Bemben et al., 2010)
Power	The rate at which an amount of work takes place during a specified movement (Power = Force*Velocity) (Claudino et al., 2014)
Rate of Force Development (RFD)	The speed at which and individual reaches their peak force expressed in the units of N/s (Mikrov et al., 2016)
Time in Flight	The amount of time someone is airborne during a jumping task, measured in seconds. (Noonan, Berg, Latin, Wagner, & Reimers, 1998)
Total Body Water	Physiological measurement of the total amount of water stored in an individual's body. A combination of both intra-cellular and extra-cellular waters. (Francaux et al., 1999)

Chapter II

Review of the Literature

Introduction

Creatine has become one of the most researched and well-known products used for supplementation (Aedma et al., 2015; Jagim et al., 2012; Kresta et al., 2014; Olsen et al., 2006). Creatine is widely known for its ability to enhance performance in both strength and power activities. Creatine supplementation aids in boosting and enhancing the performance of ATP generation through the phosphorylation of ADP using the creatine phosphagen system (Hultman, Söderlund, Timmons, Cederblad, & Greenhaff, 1996; Zuniga et al., 2012). Creatine supplementation daily has become a common routine with the dosages ranging from 20g/day to as little as 3g/day (Allen, 2012; Larson-Meyer et al., 2000; Robinson, 2000). Research has concluded that while the dosage range does not play a critical factor, any supplementation of creatine can prove to be beneficial (Allen, 2012; Brenner et al., 2000; Robinson, 2000). Individuals using creatine as supplementation increase overall maximum strength, maximal repetition strength, as well as power output (Cooper et al., 2013; del Favero et al., 2012; Souza-Junior et al., 2012; Wiroth et al., 2001; Zuniga et al., 2012).

While creatine on its own is beneficial, there is little to no research on creatine coupled with electrolytes. Electrolytes are a common mineral that aids in cell transportation of creatine, which plays a critical role in creatine absorption (Allen, 2012; Greenhaff et al., 1994). The current study aims to examine the effect of a creatine and electrolyte supplement compared to a placebo group on maximal strength, power, and performance while performing a maximal bench press and back squat set at 80% 1RM load.

Review of the Literature

Creatine. Creatine is created and stored in the body to be used for fast acting Adenosine Triphosphate (ATP) generation via the creatine phosphagen (CP) system that phosphorylates ADP. The human body generates a basal amount of creatine daily and stores them as creatine phosphate and free creatine (Greenhaff et al., 1994; Robinson, 2000). The CP system for energy is very short term. Most research has found that the CP system is depleted by ten seconds of acute activity (Greenhaff et al., 1994; Jagim et al., 2012).

Creatine supplementation helps increase the rate of muscular creatine resynthesize (Greenhaff et al., 1994). The body is able to resynthesize muscular creatine at an increased rate of 19±4 mmol/dry matter following an acute supplementation of five days. Once muscular creatine has been depleted through exercise, the CP system is unable to appropriately produce energy until the muscular creatine is resynthesized. Creatine supplementation displays a key role in aiding the rate and amount of creatine resynthesis when preforming physical activity.

Creatine and electrolytes: multi-ingredient performance supplements. Creatine absorption highly depends on electrolytes such as sodium and chloride availability and usage as active transporters (Allen, 2012). Allen, (2012) described that sodium and chloride ions are necessary to actively transport creatine from the blood plasma into the musculature, increasing the amount of creatine storage available for use. Based on creatine transportation, other researchers have examined the effects of combining both creatine and electrolytes such as sodium and magnesium for performance benefits (Barber, McDermott, McGaughey, Olmstead, & Hagobian, 2013; Brilla, Giroux, Taylor, & Knutzen, 2003; Mero, Keskinen, Malyela, & Sallinen, 2004).

Supplementing with both creatine and electrolytes such as sodium has been used to increase creatine transportation (Mero et al., 2004). Mero et al. (2004) found that supplementing with creatine combined with sodium bicarbonate enhances maximal swim tests, approximately 0.9 seconds faster than the placebo group. A similar study used creatine monohydrate combined with sodium bicarbonate compared to creatine supplementation alone during six 10-second wingate tests (Barber et al., 2013). The creatine and sodium bicarbonate group displayed a 7% increase in peak power compared to a 4% increase in the creatine only group. The group supplementing with both creatine and sodium bicarbonate had their power levels significantly higher than both the placebo and creatine groups during the six repeated bouts of cycling (Barber et al., 2013). The combined creatine and sodium bicarbonate only saw a decrease of power on the sixth bout whereas the other groups had decreases in bouts four, five, and six.

Another study examined the effects of a creatine supplement formulated with magnesium over two weeks. Subjects were given either a placebo, magnesium oxide with creatine, or magnesium-creatine chelate (Brilla et al., 2003). Following supplementation, subjects had an increased: intra-cellular water (26.29 L to 28.01 L) and increase quadriceps torque (124.5 to 135.8 Nm). The magnesium-creatine chelate was the only group to display a significant change over time for peak torques compared to both the placebo or magnesium oxide plus creatine groups (Brilla et al., 2003).

Creatine supplementation. Creatine supplementation works to enhance the availability of creatine for absorption and utilization by the cell (Brenner et al., 2000). By increasing the amount of free creatine in the system, creatine supplementation aids in increasing the amount of creatine phosphates stored in the muscle to prolong the use of the

CP system for ATP generation (Greenhaff et al., 1994). The supplementation is taken orally in daily doses to increase the total creatine available for absorption. Due to the enhancement of the CP system, creatine supplementation increases multiple fitness and sport activities revolving around acute bouts of exercise (Cooper et al., 2013). Due to the availability of creatine supplements, the use of creatine is very wide spread across ages, sports, and skill levels.

A 2001 survey and research article found that out of 1,349 high school football players, about 30% responded as taking creatine supplementation (McGuine et al., 2001). Of those who responded as taking creatine, the highest numbers were those in the 12^{th} grade at 50.5% (McGuine et al., 2001). Creatine supplementation has been further researched in high skill groups including NCAA division I athletes, professional Brazilian soccer players, and NCAA division I female soccer players (Bemben et al., 2001; Larson-Meyer et al., 2000). The extent of creatine supplementation reaches far and includes individuals in all sports and activities.

Creatine supplementation is also separated into three variables that are controlled for: the frequency, amount, and timing of supplementation. Researchers continue to examine the effect of creatine based off a daily dose taken by participants and athletes (Bemben et al., 2010; Larson-Meyer et al., 2000; Vandenberghe et al., 1997). Taken daily, creatine supplements increase the amount of PCr available for use in the CP system to produce ATP. The timing of ingestion also seems to play a small role in the effectiveness of the supplement. It was found that taking a creatine supplement post work out was more beneficial at increasing 1RM bench press strength compared to pre-workout (Antonio &

Ciccone, 2013). While the frequency of supplementation seems to not vary at all or little, the dosages taken by individuals are a topic of much debate for benefits and risks.

Dosage of creatine. The dosage of creatine supplementation is widely debated. Primarily, creatine dosages depends on the phase of loading, either a loading dosage phase or maintenance dosage phase (Aedma et al., 2015; Herda et al., 2009; Jagim et al., 2012). A loading dosage phase has subjects ingesting a large amount of creatine daily in the hopes of a rapid increase in PCr to elicit very rapid changes in performance (Aedma et al., 2015; Greenhaff et al., 1994; Wiroth et al., 2001). The typical loading dosage shown in previous research is 20g/day separated into multiple doses per day. Maintenance phases of creatine supplementation typically range from 3g/day to 5g/day (Robinson, 2000; Syrotuik et al., 2000).

A study involving college female lacrosse players used a dosage of 5g/day for four times daily for one week (Brenner et al., 2000). Another study examining creatine's effect over nine weeks in NCAA division I football players used 4g/day for five times daily for a period of five days. After the five days, a maintenance dosage of 5g/day was used for the remainder of their study (Bemben et al., 2001). Vandenberghe et al. (1997) examined the effects of creatine on nineteen female participants over a ten-week period, and both a loading phase followed by a maintenance phase dosage. Following four days of supplementation for 20g/day, the subjects displayed a 6% increase in their PCr concentration ($p<0.05$) and was maintained with a dosage of 5g/day. However, during their loading phase, the rate of creatine excretion was greatly increased to about 7-11g/day.

There is some research that shows even using an average maintenance dose over a prolonged period yields similar results compared to using a loading dose (Herda et al., 2009;

Peeters et al., 1999). A study examining muscular strength and satellite cell numbers only used a dose of 6g/day and found increases in maximal isometric strength performance from 307.2 ± 25.9 to 371.8 ± 69.7 N/m ($p<0.001$). Hultman et al. (1996) specifically compared the muscle creatine increases between using a loading phase vs. only maintenance level doses in 31 male subjects. After supplementing 20g/day of creatine monohydrate, the men saw an increase of 20% of their stored muscular creatine. This increase was maintained using a dose of 2g/day for the remainder 30 days. The loading dose group did similarly see an increase in their creatine excretion via urine during the 20g/day dosage phase. Subjects who only ingested 3g/day for 30 days also saw a similar increase of 20% in muscular creatine storage.

When compared, there were no displays of renal, hepatic, or muscular damage for either loading dosages of creatine versus a dosage equal to maintenance levels (Robinson, 2000). The study compared the risks and effects of creatine supplementation of 20g/day for five days and 3g/day for nine weeks. Blood samples were used for analysis for analysis of the acute and chronic time points of creatine supplementation. All of the measurements were within normal ranges of healthy individuals, indicating no increased risk of creatine supplementation for either dose. There were also increases of muscular creatine concentration in both supplementation groups when compared to pre-testing.

Creatine supplementation doses vary depending on the circumstances and individuals deciding to take the supplement. Dosages vary from very large daily amounts up to 20g/day for a loading phase to a smaller amount of 3g/day for a maintenance phase. Both dosage schemes increase the creatine concentration in healthy individuals with no apparent health risk. People taking large loading doses appear to excrete a much larger volume of about 7 to 11g/day of creatine in their urine when compared to healthy people not taking creatine.

Overall, creatine supplementation of any dosage will have a positive effect on performance, with greater doses being excreted at larger amounts.

Creatine effects on body composition. Creatine supplements have been boasted to improve body composition with increasing the amount of lean body mass (Kresta et al., 2014). Increased muscular creatine allows for an increase in work capacity and intensity, giving individuals increased capacity for increasing lean body mass (Jagim et al., 2012). However, research does conflict on the effects of creatine on body composition either displaying no change over time or very slight changes in lean body mass (LBM).

A 28 day creatine supplementation study on active female participants displayed that supplementation only had an effect on LBM over time but no interaction between the placebo group (Kresta et al., 2014). Another study examined the effects of creatine monohydrate (Creapure) and Kre-Alkalyn, alkaline creatine with soda ash, on 36 resistance trained individuals over 28 days. Their results showed no interaction for time and group for the following: LBM, fat mass, or body fat percentage (Jagim et al., 2012). Hoffman et al. (2006) recruited 33 college aged football players and tested a 10-week intervention of creatine using a Dexa scan to test body composition. They found no interaction in any three of their groups: placebo, creatine, and creatine plus beta-alanine on the following body composition measurements: fat mass, LBM, or body fat percentage. Another acute loading phase of creatine study on 23 males found that they had increased fat free mass from 71.2 ± 10 to 72.8 ± 10.1 kg ($p<0.001$) (Becque et al., 1999). College aged males taking creatine phosphate or monohydrate over six weeks showed increased lean body mass accompanied with significant increases in maximal upper body strength (Peeters et al., 1999). Subjects taking creatine phosphate had an increase of lean body mass of 2.2 ± 1.13% and an increase of 8.83 ± 3.49%

for bench press maximal strength. The creatine monohydrate increased their lean body mass by 2.67 ± 1.92% and 11.15 ± 5.51% for bench press 1RM.

Creatine effects on body water. Increases in muscular creatine storage are usually coupled with an increase of intra-cellular water. However, most research shows that any change in body fluid volume does not significantly change based on creatine supplementation (Francaux et al., 1999). Cellular fluid was analyzed utilizing a BIA unit for compartmental water volumes in college aged males following nine weeks of creatine supplementation. There were no significant changes in the fluid volume in the intra-cellular or extra-cellular compartments for the group supplementing with creatine monohydrate ($p>0.05$) (Francaux et al., 1999). A study examining cell hydration of NCCA Division I football players following nine weeks of resistance training and creatine, following a loading then maintenance phases, found the contrary. Accompanied with increased LBM, these football players were also displayed significantly increased intra-cellular water, following both a loading and maintenance phase of creatine supplementation (Bemben et al., 2001). An increase of intra-cellular water is typically associated with creatine absorption due to the osmotic nature of creatine absorption (Brilla et al., 2003). When creatine is absorbed, water is also taken into the cell and increases the total intra-cellular water content.

Creatine supplementation may or may not affect both body composition and compartmental body water measurements. Changes in either measurement appear to be very miniscule when compared to subjects taking a placebo while on the same training regime over a short period of time, typically around four to eight weeks (Bemben et al., 2001). This effect could be related to creatine responders or non-responders as some individuals are unable to absorb extra available creatine. Overall, if any significant changes do appear due to creatine supplementation, they are increases in LBM and slightly increased intra-cellular water (Bemben et al., 2001; Becque et al., 1999; Francaux et al., 1999).

Potential negative effects of creatine. With an increase of creatine supplementation, there has been concern for potential harmful effects (Allen, 2012; Jäger, Purpura, Shao, Inoue, & Kreider, 2011; McGuine et al., 2001; Robinson, 2000). Research into the potential harmful effects of creatine are directed towards renal dysfunction, creatine concentration, muscle damage, and abnormal hepatic function (Jäger et al., 2011; Robinson, 2000). A study examined both the acute and chronic effects of creatine and its potential side effects using either a loading dose of 20g/day for five days or 3g/day for nine weeks. Researchers took blood samples at baseline, end of supplementation, and six weeks post intervention (Robinson, 2000). All measures of hepatic function, renal function, and muscle damage were within typical healthy ranges. Creatine concentration in the blood samples were increased significantly ($p<0.05$) but were returned to baseline levels following a six week wash out period (Robinson, 2000).

Another study examined the potential negative effects of creatine and found similar results (Jäger et al., 2011). The researchers documented that there were no risks for renal dysfunction, hepatic dysfunction, or muscle damage while taking creatine supplementation for healthy individuals ingesting the supplement. However, it was found that individuals with pre-existing renal dysfunction may have an increased risk of worsening their current condition.

Most commonly, with high doses, creatine supplementation results in a greater amount of creatine excretion through the urinary tract (Hultman et al., 1996). Thirty-one male subjects while ingesting 20g/day for one week of creatine had a significantly increased amount of creatine excretion ($p<0.05$) accompanied with a 20% increase in muscular creatine. There appears to be no increased risk for healthy individuals taking creatine supplementation for hepatic or renal function and muscular damage (Jäger et al., 2011; Robinson, 2000).

Effects of creatine on strength performance. The most common performance aspect that is associated with creatine supplementation is maximal strength (Burke et al. 2003; Bemben et al. 2010; Herda et al. 2009; Vandenberghe et al. 1997). Increased PCr is greatly associated with performance that is intermittent and only lasting ten seconds. Maximal strength testing is calculated through either a single repetition maximum test or other testing using a three to five repetition maximum, making it the perfect candidate for enhancement with creatine supplementation (Antonio & Ciccone, 2013Herda et al. 2009).

Upper body strength increases were found in older populations when supplementing with 5g/day for six weeks. There was a significant ($p<0.0001$) increase of chest press strength from 24.1 ± 3.2 to 40.5 ± 6.8 kg (Tarnopolsky et al., 2009).

Another study examined the acute supplementation effects on participant's bench press 1RM for bench press (Zuniga et al., 2012). Subjects were given 20g/day for seven days and were tested for their absolute 1RM at baseline and post supplementation. The researchers found no significant increases in bench press maximal strength following their acute intervention.

An eight-week intervention study examined the effect of rest time intervals in individuals on their maximal bench press strength (Souza-Junior et al., 20110). Subjects were given creatine monohydrate at maintenance dose levels for eight weeks while performing resistance training. One group maintained a consistent rest time interval with the second group decreasing rest intervals 15 seconds per week (Souza-Junior et al., 2011). The constant interval of rest increased their bench press 1RM from 102 ± 10 kg to 130 ± 10 kg with a large effect size. The decreasing rest interval group increased their bench press 1RM from 100 ± 12 kg to 125 ± 12 kg with a large effect size. There was no significant ($p<0.05$) interaction between groups, displaying that rest intervals played little role in their strength increases.

Another study examined creatine supplementation compared to betaine on maximal bench press strength using untrained individuals (del Favero et al., 2012). Subjects in the creatine groups were given 20g/day and were tested for their bench press 1RM at baseline and following the intervention. Groups that were supplementing with creatine monohydrate had a significantly increased ($p<0.027$) bench press from baseline to post-test. Subjects had an approximate increase of 5% on their bench press 1RM when compared to their baseline values.

While using creatine supplementation, lower body maximal strength increases vary more when compared to upper body strength. College age lacrosse female players did not show any significant effects from a five-week creatine intervention when tested for maximal leg extension strength (Brenner et al., 2000). However, middle-aged men using creatine coupled with resistance training did have increased 1RM strength for the leg curl and leg extension (Bemben et al., 2010). The leg curl and leg extension were also part of the resistance training periodization exclusively done for lower limb exercises during the five weeks. Leg press increased following an intervention of creatine and resistance training in healthy individuals (Herda et al., 2009; Pearson, Hambox Wade Russel, & Harris, 1999; Tarnopolsky et al., 2007). Herda et al. (2009) observed an eight percent increase in leg press 1RM following a 30 day creatine intervention. Creatine supplementation does appear to have an effect on maximal lower limb strength, mostly dealing with exercises that are controlled using machines.

Creatine supplementation aids in both the upper body and lower body maximal strength. These studies utilized both large and small dosages to yield similar results (Bemben et al., 2010; Herda et al., 2009; Tarnopolsky et al., 2007). Creatine coupled with resistance training is beneficial in enhancing the strength performance in both the upper and lower extremities.

C**reatine effects on power**. Most athletic performances require a great deal of work to be produced in a short amount of time. Sprinting and jumping are two common tasks that require power to be performed at a higher level. Researchers to reach the maximal potential of peak power for such performances have examined the effect of creatine. The Wingate test and counter movement jump test are the two most common testing techniques for lower extremity power output for creatine supplementation research (Claudino et al., 2014; Hoffman et al., 2006; Wiroth et al., 2001).

Short duration high intensity cycling has been used to evaluate anaerobic power, primarily named the Wingate test (Herda et al., 2009; Wiroth et al., 2001). A study involving 54 healthy men tested power using 30-second Wingate tests after creatine supplementation (Herda et al., 2009). After the supplementation period, there were no significant differences found in either peak or mean power in subjects supplementing with creatine. Researchers suggested that could be a possibility due to the CP system being depleted prior to the completion of the test and primarily rely on glycolysis for ATP generation.

A similar study examining the effects of creatine in older participants compared old and young volunteers using five all-out ten second cycling sprints for power and total work done (Wiroth et al., 2001). Subjects were separated into three different groups: sedentary old, trained old and sedentary young. Subjects were supplemented with 15g/day doses for a total of five days. Elderly and young sedentary men displayed increases in maximal power, 3.7% and 2.0% respectively ($p<0.05$). The trained elderly old males did not exhibit any creatine effect from pre-test to post-test.

Another power test is done with countermovement jumps on a force platform (Hoffman et al., 2006). A study involving college football players used a 20 akimbo countermovement jump test to examine peak power differences based on ten weeks of creatine supplementation (Hoffman et al., 2006). The group with creatine did not differ significantly from pretest to posttest, 62.6 ± 13.8 to 62.7 ± 10.1 watts (Hoffman et al., 2006).

Claudino et al. (2014) conducted a study using 14 professional Brazilian soccer players testing for lower limb power using a countermovement jump. Supplementation lasted seven weeks and there were no significant differences in power, but there was a trend to increased power compared to placebo, 2.4% versus 0.7% respectively. Creatine supplementation could possibly be used to increase the power demonstrated in countermovement jumps.

Creatine effects on work. Along with strength and power, creatine has been used to increase the work capacity for various exercises and performances (Brenner et al., 2000; Herda et al., 2009; Kreider et al., 1997; Vincent et al., 1998). The performances range from increasing 40 yard dash time, maximal repetitions of bench press, maximal repetitions of back squat, total volume for lifting, and power clean maximum load. A study examining the effect of creatine on cycling work, examined both older and young people after creatine supplementation. Total work during a cycling task was increased, not significantly, in older and young people using creatine, 4.1% and 5.1% (Wiroth et al., 2001).

A study reviewing the effects of creatine monohydrate on college males tested their 40 yard dash time pretest and posttest after a loading phase, 5g/day, and varying maintenance phases, 100 mg/kg/day or 300 mg/kg/day (Noonan et al., 1998). The group supplementing with creatine at 100 mg/kg/day had significantly ($p<0.05$) increased 40 yard dash time compared to both the placebo and 300 mg/kg/day groups (Noonan et al., 1998). Researchers hypothesized that the higher creatine dosage did not correlate to a higher creatine absorption and was above the recommended dose for performance benefits.

A study examining 28 days of creatine supplementation on 18 power lifters tested the maximal number of repetitions done on bench press across five sets using 80% 1RM (Vincent et al., 1998). The creatine group had increased number of bench press repetitions for sets 1, 4, and 5 compared to the placebo group. Overall, there was an increase of 39.7% ± 23.5 % of repetitions for the creatine supplementation group (Vincent et al., 1998).

Herda et al. (2009) used a similar protocol for a single set of bench press to failure using 80% of subject's 1RM. Fifty-four healthy men were used in the study examining creatine monohydrate and polyethylene glycosylated creatine compared to a placebo. All groups in the study displayed an increase for the number of repetitions performed until failure at 80% 1RM (Herda et al., 2009). The creatine supplementation group had a 20% increase in the number of repetitions to failure during their bench press repetition test.

Another study tested the total work done during maximal repetition tests for both bench press and leg press after female lacrosse players were supplemented with creatine. The creatine group was given 20g/day for one-week followed by 2g/day for the remaining four-weeks. Their results displayed no differences for work done comparing the experimental and placebo group, 283.5 ± 387.3 watts (Brenner et al., 2000). Research findings vary on the accounts for total work performed being enhanced after creatine supplementation (Brenner et al., 2000; Vincent et al., 1998). An increase of repetitions at a specified load correlates to a greater amount of work being performed.

Summary

Creatine supplementation plays a key role for increasing the performance through increasing the work capacity by the CP system. Supplementing orally on a daily basis with creatine increases the amount of muscle creatine concentration while supporting a faster resynthesize of PCr (Greenhaff et al., 1994). Doses of creatine do not dramatically change the benefits or risks of creatine use (Allen, 2012; Hultman et al., 1996; Jäger et al., 2011; Robinson, 2000). Increased doses of creatine primarily increase muscular creatine at a faster rate, and also increase creatine excretion (Greenhaff et al., 1996; Hultman et al., 1996). During supplementation, some studies find that both body composition and body water analysis do not vary when compared to placebo groups (Kresta et al., 2014; Jagim et al., 2012). Some research studies have observed increases in intra-cellular water indicating creatine absorption (Brilla et al., 2003) Some small changes in lean body mass may be observed when creatine is used with resistance training (Jagim et al., 2012).

Upper body strength, typically a 1RM bench press, is significantly increased when using creatine at varying doses with resistance training (del Favero et al., 2012; Souza-Junior et al., 2011; Zuniga et al., 2012). Lower body strength may also be improved with a creatine intervention (Candow, Chilibeck, Burke, Mueller, & Lewis, 2011; Bemben et al., 2010; Brenner et al., 2000; Larson-Meyer et al., 2000). Creatine appears to have little effect on power when using 30 second Wingate cycling test and countermovement jump protocols (Herda et al., 2009; Hoffman et al., 2006; Wiroth et al., 2001). However, this may be due to the protocol used and the importance of the CP system in those protocols. Protocols using cycling tests lasting longer than 15 seconds displayed no significant effect of creatine supplementation. Other key factors for performance have been increased with using creatine supplementation including: 40 yard dash times, repetitions to failure, repetitions to failure per set, as well as total work done (Brenner et al., 2000; Cooper et al., 2013; Kreider et al., 1997; Vincent et al., 1998).

The use of creatine has a potential effect on power, strength, and amount of work for people post supplementation (del Favero et al., 2012; Herda et al., 2009; Vincent et al., 1998). However, the majority of research does not examine the effects of creatine formulated alongside electrolytes, a primary form of cell transportation for creatine (Allen, 2012). The current study aims to examine the efficacy of a creatine supplement with electrolytes (Barber et al., 2013; Brilla et al., 2003). This study aims to further examine the effects of a creatine supplementation formulated with several electrolytes over a longer period of time. Few studies have examined maximal strength, work, power, and mRFD for common exercises such as the back squat and bench press.

Chapter III

Methods

Introduction

The current study examined the effects of a multi-ingredient performance supplement (MIPS) on: mean and peak power during an akimbo countermovement jump, one-repetition maximum (1RM) bench press, 1RM back squat, and the concentric work, mean power, peak power, peak force, and mean rate of force development of a maximal repetition set of back squat and bench press at 80% 1RM. Additionally the study examined the MIPS effect on % body fat, lean body mass, fat mass, total body water, intra-cellular water, and extra-cellular water. Creatine supplementation is a very common intervention to enhance athletic performance for both strength and power activities ranging from 1RM strength, power during countermovement jumps, and total work capacity (Kreider et al., 1997; Vincent et al., 1998). Few studies examine the potential benefits of combining creatine with electrolytes to enhance the supplementation effect due to increased availability of cell transporters.

Description of study population

A total of 22 subjects, 16 males and six females, aged 18-35 were included for this study. All subjects were regularly strength training for a minimum of six months prior to the study, free of any injury that would inhibit training, creatine supplementation-free for at least one month prior to participation, and free from any endocrine/kidney disease that would impact their clearance of creatine. Subjects were divided into two groups, the experimental MIPS group (n=12, male=8, female=4) and the placebo group (n=10, male=8, female=2).

Design of the study

This study utilized a double blind, randomized, pre- and post-test repeated measures design to examine the effect of a multi-ingredient supplement on strength and power performance. Subjects were recruited locally from Western Washington University and the surrounding Bellingham area. Subjects were randomly assigned to either the experimental MIPS group or placebo group prior to their arrival for testing. A total of six weeks supplementation was completed between pre-test and post-test measurements to ensure tissue saturation to display the possible effects of the intervention.

Data collection procedures

Instrumentation. Subjects' height weas recorded using a stadiometer and weight was measured using the BodPod weighing scale (COSMED, Rome, Italy). Body composition was determined using a BodPod air displacement plethysmography system (COSMED, Rome, Italy). Total, extracellular, and intracellular water were obtained using the resistance and reactance from a Quantum X bioelectrical impedance unit (RJL Systems, Clinton, MI, USA) input into the manufacturer's online calculator. An AMTI triaxial force platform (AMTI, Watertown, MA, USA) was used to measure the amount of vertical force applied during the akimbo counter movement jump. Data from the force platform was exported into Bioanalysis software version 2.3.1 (AMTI, Watertown, MA, USA) for data processing. A standard barbell squat rack (PR Lifting, Everett, WA, USA) was used to accommodate the performance of the back squat and bench press in the laboratory setting. The barbell trajectory was collected using Qualisys Track Manager 2.7 (Qualisys Motion Capture Systems, Gothenburg, Sweden) and seven Qualisys Proreflex MCU 240 cameras (Qualisys Motion Capture Systems, Gothenburg, Sweden) during the back squat and bench press exercises performed at 80% 1RM for maximal repetitions. Data processing was completed using custom-written LabView version 13.0 (National Instruments, Austin, TX, USA) software for both the akimbo countermovement jump and the concentric back squat and bench press performance tests at 80% 1RM.

BodPod. Air displacement was determined using a BodPod (COSMED, Rome, Italy). Using subject information, a two dimensional model can be made on the body composition of the subjects. The two compartment model includes lean body mass (LBM) and fat mass (FM). The BodPod was calibrated daily for collection using the standard procedure and standardized volume containers. Subjects wore the same clothing for both testing dates to ensure the consistency of the measurements.

Bioelectrical Impedance. Measurements of total body, extra-cellular, and intra-cellular water were determined using the resistance and reactance values obtained from a Quantum X bioelectrical impedance unit (RJL Systems, Clinton, MI, USA) utilizing Ac/Agl surface electrodes placed on the following landmarks: inferior to the ulnar styloid process, inferior of the third metacarpal, directly between the malleoli, and distal to the third metatarsal. Subjects were asked to remain hydrated and refrain from strenuous exercise the day prior to the body water analysis.

AMTI Force Platform. An AMTI OR6-6 in-ground force platform and MSA-6 amplifier (AMTI, Watertown, MA, USA) was used to collect ground reaction force data during the akimbo countermovement jump. The data acquisition rate was set to 50 Hz and kept consistent for every subject.

Qualisys Motion Capture. Qualisys motion analysis system (Qualisys Motion Capture Systems, Gothenburg, Sweden), using 7 ProReflex cameras at 240 Hz were utilized to collect kinematic data of the barbell position throughout the range of motion of both the bench press and back squat exercises performed for maximum number of repetitions at 80% 1RM. One passive retro-reflective marker was placed in the center of the barbell at the end. This marker was used to determine the vertical position of the bar throughout the time of testing. Time elapsed, vertical displacement, and force were calculated to determine the outcome measures for the maximal repetition tests.

Measurement Techniques and Testing Procedures.

All testing procedures were conducted on the Western Washington University campus in the Exercise Physiology and Applied Neuromechanics laboratories. Subjects were given an informed consent form (Appendix A) and a hold harmless agreement (Appendix B) upon their arrival to their pre-testing session. Subjects were given the opportunity to ask any clarifying questions about the informed consent or hold harmless agreement, and then signed the forms. All subjects were given a copy of the informed consent for their own files. Afterwards, subjects completed a general background information form for the subject files (Appendix C). Subjects were also asked to fill out a background information form and to confirm their eligibility for the study Subjects had their height and weight measured prior to data collection.

BodPod. Following their completion of the appropriate paper work, subjects were asked to change into clothing as close to spandex as possible, and fitted with a swim cap. Attire was asked to be kept similar for post-testing to minimize error with air pockets. Subjects were asked to stand quietly on the scale to obtain their weight for the BodPod measurement. Following the calibration, subjects were asked to sit quietly while the BodPod measured their air displacement for body composition measurements. A minimum of two trials were used only requiring a third trial if the first two measurements varied too greatly.

Body Water Analysis. After the BodPod measurements were completed, subjects were asked to lie down supine on a table with their limbs completely supported for the BIA testing. Four Ag/AgCl surface electrodes were placed on the following land marks on the subject's right side: styloid process of the Ulna, base of the third metacarpal, between malleoli, and the base of the second metatarsal. The BIA wires were connected to the electrodes to measure the resistance (ohms) and reactance (ohms). The resistance and reactance were then entered into RJL systems (RJL Systems, Clinton, MI, USA) online calculator to provide the subject's total, extracellular, and intracellular water. Following the BIA measurement, subjects changed into their athletic clothing and walked to the Applied Neuromechanics laboratory for the akimbo countermovement jump, the back squat, and bench press testing.

Warm Up. When the subjects arrived at the WWU Applied Neuromechanics Laboratory, they began with a five-minute warm up on a cycle ergometer (Star Trac, Orange County, California, USA). Subjects were able to choose their own pace and resistance. Following the cycle ergometer warm up, subjects performed a dynamic warm-up consisting of five repetitions of the following: knee hugs bilaterally, Frankenstein's bilaterally, walking quadriceps stretch bilaterally, lunge with a torso twist bilaterally, wall slides, shoulder slaps bilaterally, and push-ups. Upon completion, subjects were given a three-minute self-selected rest while researchers explained the akimbo countermovement jump protocol.

Countermovement Jump. Subjects were asked to stand in the center of the force platform with the entirety of both feet inside the square and their hands resting on their hips

(Figure 3). Researchers gave subjects a countdown of “1, 2, 3, Jump” to initiate the akimbo countermovement jump. Subjects were told to begin their jump after the word “jump” was said with collection beginning on “3” in the countdown. Subjects were given two practice trials to gain familiarly with the protocol and countdown. Following their practice trials, subjects performed three akimbo countermovement jumps separated by one minute of self-selected rest. After the third trial was completed, subjects were given a four-minute self-selected rest period while the squat rack was set up for the back squat 1RM test.

One Repetition Maximum Testing. Subjects watched a pre-recorded video detailing how to perform the back squat exercise made by the Graduate Assistant in charge of Strength and Conditioning at WWU. The testing for both the back squat and bench press followed the National Strength and Conditioning Association guidelines (Souza-Junior et al., 2011). Subjects estimated their current 1RM for the back squat based on their previous strength training programming. This estimation was used for the loading during the 1RM test, with a new 1RM being calculated using the following equation: (1RM = load*(1 + (0.025*number of repetitions)). Subjects then performed ten back squat repetitions at 50% of their predicted 1RM. Subjects were given a four-minute self-selected rest period while the next load was prepared, which was 75% of their predicted 1RM. Subjects performed a total of five repetitions at their second load followed by for minutes of self-selected rest. Following the final rest period, subjects performed as many repetitions as possible at their predicted 1RM. Subjects were told to go until failure or until they decided they could not continue. Subjects were given a four-minute rest period before moving on to the bench press 1RM test.

Subjects were given a pre-recorded video of how to perform the bench press exercise made by the Graduate Assistant in charge of Strength and Conditioning at WWU. Subjects were asked to estimate their current one repetition maximum for the bench press based on their previous strength training programming. The subject's current estimation was used for prescribing the loading during the 1RM test to estimate their current 1RM using the O'Conner formula. Subjects then performed ten bench press repetitions at 50% of their predicted 1RM. Subjects were given a four minute self-selected rest period while the next load was prepared, which was 75% of their predicted 1RM. Subjects performed a total of five repetitions at their second load followed by for minutes of self-selected rest. Following the final rest period, subjects performed as many repetitions as possible at their predicted 1RM. Subjects were told to go until failure or until they decided they could not continue. Once the test was concluded, subjects were given an eight-minute self-selected rest period. Subject's 1RM for the back squat and bench press were calculated using the O'Connor formula: (1RM = load*(1 + (0.025*number of repetitions)) and used to determine the 80% load for the maximal repetition test.

Maximal Repetition Testing. When 80% of the subject's 1RM bench press was determined, the load was adjusted on the barbell and placed inside the capture area of the Qualisys Motion Capture system. One retro-reflective marker was placed on the end of the barbell to track the position of the barbell path. Subjects were instructed to perform as many repetitions as possible and to perform them as forcefully as possible. Data collection occurred when the subject removed the weight from the rack prior to initiating their first repetition. Subjects performed as many bench press repetitions as possible and returned the barbell to its resting position. The range of motion given to subjects was set to start at full elbow extension with the low point being just above their chest. Subjects were given another eight-minute self-selected rest while researchers adjusted the capture area to perform the back squat maximal repetition test. Eighty percent of the subject's calculated back squat 1RM was used for the loading parameters. Data was collected using the Qualisys Motion Capture system similarly to the maximal bench press test. Subjects were told to perform their maximal number of repetitions as forcefully as possible. The back squat range of motion was set to start in the upright position and go until their hips were parallel to their knee. When testing concluded, subjects received a quick briefing of the supplementation period and their requirements.

Subjects were required to pick up supplements weekly in small individual dosages from either the Western Washington University Exercise Physiology or Applied Neuromechanic Laboratory. Supplementation continued for a total of six weeks with subjects taking one dose per day with 16 oz of water accompanied with a meal. The MIPS was formulated with the following: 4g of creatine, 857 mg of phosphorus, 286 mg of magnesium, 171 mg of calcium, 171 mg of potassium, and 114 mg of sodium. The placebo group received maltodextrin in a similar package. Orange Crush powder was provided for flavor at the subjects own discretion. Following the six weeks of supplementation, subjects returned to perform post-testing measurements. Post-testing procedures were kept similar except for the load utilized for the maximal repetition test, which used 80% of pre-testing 1RM. The load was kept similar from pre-testing when performing the maximal back squat and bench press testing to make comparison between the two time points.

Data Processing

Body composition data was exported from the BodPod computer into the final excel data file kept on a password-protected university computer. Data values for body fat percentage, lean body mass (kg), and fat mass (kg) were recorded. Bioelectrical Impedance values were derived from the resistance (ohms) and reactance (ohms) when imported into the manufacturer's website (RJL Systems, Clinton, MI, USA). Data values for total body water (L), extra-cellular water (L), and intra-cellular water (L) were exported into the final excel data file. The akimbo countermovement jump data file was exported into Bioanalysis software (AMTI, Watertown, MA, USA) and converted into text files. Text files were then processed in a custom-made LabView (National Instruments, Austin, TX, USA) program to determine mean power (watts), and average peak power (watts) of the three trials collected. Mean power was obtained using the following linear regression equation: [Mean Power = Jump Height (m) * 21.2 + (Weight (kg) *23) – 1,343] while peak power was obtained using the following regression equation: [Peak Power = Jump Height (m) * 61.9 + (Weight (kg) * 36) + 1,822]. Data were then copied into the final excel data file for statistical analysis. One-repetition maximum data were collected and determined using an excel template utilizing 90% of their current estimate repetitions completed until failure. Data values were recorded into the final excel file for statistical analysis. The retroreflective marker for the maximal repetition tests was identified in Qualisys Motion Tracker (Qualisys Motion Capture Systems, Gothenburg, Sweden) and exported into a C3D file format. The C3D file was then opened using Visual3D (C-Motion, Germantown, MD, USA) and processed using a custom pipeline that performed a 4th order? low pass Butterworth filter before the vertical position data (Z coordinate) was exported into a text file. The text files were analyzed in a custom Labview (National Instruments, Austin, TX, USA) program that identified the concentric phases of completed repetitions before computing the total work, mean power, peak power, mean rate of force development, and peak force. Once the concentric phase of movement was determined, the program took the sum of (force * displacement) for each repetition to obtain the sum of concentric work. Mean power was obtained by averaging the product of force * velocity at each time point during the repetition and set. Similarily, peak power was obtained from finding the maximal product of force and velocity during each repetition, with the greatest value being used for data analysis. The outcome measurements were copied into the excel data file for further statistical analysis.

Data Analysis

Data for the akimbo countermovement jump and maximal repetition tests at 80% 1RM was exported into text files and then processed using Labview (National Instruments, Austin, TX, USA) programs for data computation. Data for the 1RM tests, body composition, and body water analysis were directly entered into an excel file. Data were analyzed between the experimental MIPS supplement group and the placebo group at pre-test and post-test. A two-way mixed analysis of variance (ANOVA) were run with an alpha level of 0.05. The independent variables were group (MIPS vs. placebo) and time (pre-test vs. post-test). The dependent variables were time in flight, mean power, and peak power for the akimbo countermovement jump and total work, mean rate of force development, mean power, peak power, and peak force for the concentric phases of the back squat and bench press at 80% predicted 1RM for maximal repetitions. A two-way mixed analysis of variance (ANOVA) was also run with an alpha level of 0.05 to compare the effects of condition and time on the following: percentage body fat, lean body mass, fat mass, total body water, intra-cellular water, extra-cellular water, mean and peak power during an akimbo countermovement jump, back squat 1RM, bench press 1RM, and concentric work, mean power, peak power, mRFD, and peak force during a maximal repetition test done at 80% 1RM for back squat and bench press.

Chapter IV

Results and Discussion

Introduction

This study examined the effects of a six-week supplementation of a multi-ingredient performance supplement (MIPS) on body composition, body water, power, and strength. The experimental hypothesis was that the group that supplemented with the MIPS would display greater: intra-cellular water, lean body mass, peak and mean power during an akimbo counter movement jump, one repetition maximum (1RM) strength for both back squat and bench press, and total work, mean power, peak power, mean rate of force development (mRFD), and peak force during a maximal repetition test at 80% 1RM back squat and bench press. Data was collected at two time points, just prior to supplementation and immediately thereafter. A two way-mixed analysis of variance (ANOVA) was run with an alpha level of 0.05 for data analysis.

Results

Demographics. Age, sex, height, and weight were all recorded at pre-test and post-test to describe the samples for both the placebo and MIPS groups (Table 1). No statistics were run on the demographics data. The placebo group had a decrease of mass from 73.10 to 72.97 kg. The MIPS groups had a decrease of mass from 71.82 to 71.55 kg.

Table 1. Demographical Data (mean ± SD)

	Placebo		MIPS	
	Pre-Test	**Post-Test**	**Pre-Test**	**Post-Test**
Age (yr)	20.70 ± 1.49	20.7 ± 1.49	21.92 ± 2.71	21.92 ± 2.71
Height (m)	1.74 ± 0.11	1.74 ± 0.11	1.70 ± 0.08	1.70 ± 0.08
Mass (kg)	73.10 ± 13.56	72.97 ± 14.26	71.82 ± 8.84	71.55 ± 6.48
Sex	8 males / 2 females		8 males / 4 females	

Body Composition. Means and standard deviations for % body fat, lean body mass, and fat mass are displayed in Table 2. There was no interaction between time and group on % of body fat (F[1,19]= 1.998, p = 0.174, η^2 = 0.095). There was no main effect of time on % body fat (F[1,19]= 0.725, p = 0.405, η^2 = 0.037). There was no main effect of group observed on % body fat (F[1,19]= 0.061, p = 0.808, η^2 = 0.003). No interaction between time and group was displayed on lean body mass (F[1,19]= 0.047, p = 0.831, η^2 = 0.002). There was a significant main effect of time on lean body mass (F[1,19]= 4.633, p = 0.044, η^2 = 0.196). Both placebo and MIPS group elicited increases in their lean body mass after the six-week intervention, 2% and 1.7% respectively (Figure 1). There was no main effect of group on lean body mass (F[1,19]= 0.287, p = 0.598, η^2 = 0.015). There was no interaction observed between time and group for fat mass (F[1,19]= 2.591, p = 0.124, η^2 = 0.120). There was no main effect of time (F[1,19]= 0.463, p = 0.504, η^2 = 0.024) or group (F[1,19]= 0.040, p = 0.844, η^2 = 0.002) on fat mass.

Table 2. Body Composition Results (mean ± SD)

	Placebo		**MIPS**	
	Pre-Test	**Post-Test**	**Pre-Test**	**Post-Test**
Body Fat (%)	15.41 ± 8.24	13.72 ± 6.95	15.11 ± 7.49	15.53 ± 5.97
Lean Body Mass (Kg)	62.06 ± 13.82	63.30 ± 14.97*	59.51 ± 8.22	60.52 ± 7.53*
Fat Mass (Kg)	11.04 ± 5.72	9.67 ± 4.44	10.48 ± 4.98	11.03 ± 3.99

*p<0.05

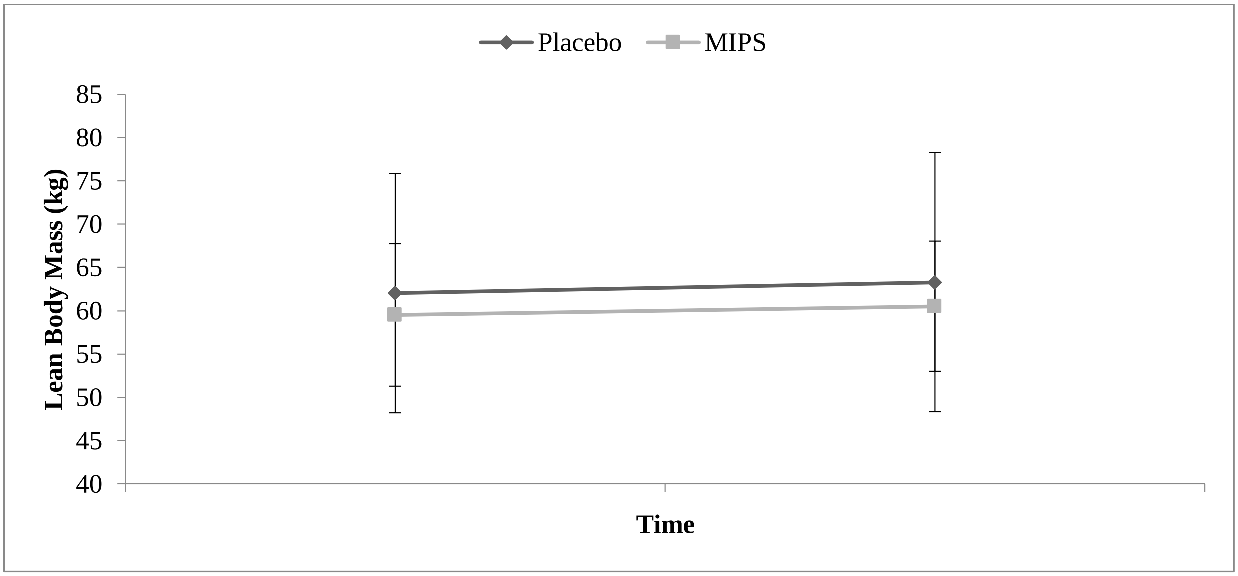

Figure 1. Lean body mass (mean ± SD)

Body Water Analysis. Means and standard deviations for total body water, intra-cellular water, and extra-cellular water are presented in Table 3. There was no interaction between group and time for total body water (F[1,18]= 0.039, p = 0.845, η^2 = 0.002).There was no main effect of time on total body water (F[1,18]= 0.011, p = 0.917, η^2 = 0.001). There was no main effect of group on total body water (F[1,18]= 1.239, p = 0.280, η^2 = 0.064). There was no interaction between time and group on intra-cellular water (F[1,18]= 0.003, p = 0.956, η^2 = 0.00). There was no main effect of time on intra-cellular water (F[1,18]= 0.070, p = 0.794, η^2 = 0.004). There was no main effect of group on intra-cellular water (F[1,18]= 1.133, p = 0.301, η^2 = 0.059). There was no observed interaction between time and group on extra-cellular water (F[1,18]= 0.181, p = 0.676, η^2 = 0.010).There was no main effect of time on exra-cellular water (F[1,18]= 0.002, p = 0.967, η^2 = 0.00). There was no main effect of group on extra-cellular water (F[1,18]= 1.276, p = 0.273, η^2 = 0.066).

Table 3. Body Water Analysis Results (mean ± SD)

	Placebo		MIPS	
	Pre-Test	**Post-Test**	**Pre-Test**	**Post-Test**
Total Body Water (L)	43.31 ± 9.10	43.22 ± 8.64	39.50 ± 6.24	39.53 ± 6.26
Intra-Cellular Water (L)	25.04 ± 5.34	24.99 ± 5.05	22.75 ± 4.41	22.72 ± 4.42
Extra-Cellular Water (L)	18.27 ± 3.85	18.21 ± 3.67	16.75 ± 2.00	16.79 ± 1.94

Akimbo Countermovement Jump. Results for mean and standard deviation are displayed below in Table 4. There was no interaction between time and group observed for peak power (F[3,16]= .724, p = 0.406, η^2 = 0.039). There was no main effect of time on peak power (F[3,16]= 2.756, p = 0.114, η^2 = 0.133). There was no main effect of group on peak power (F[3,16]= 934, p = 0.347, η^2 = 0.049). There was no interaction between time and group observed for mean power (F[3,16]= 2.103, p = 0.164, η^2 = 0.105). There was no main effect of time on mean power (F[3,16]= 1.408, p = 0.251, η^2 = 0.073). No main effect of group was observed for mean power (F[3,16]= 908, p = 0.353, η^2 = 0.048).

Table 4. Akimbo countermovement jump results (mean ± SD)

	Placebo		MIPS	
	Pre-Test	**Post-Test**	**Pre-Test**	**Post-Test**
Mean Peak Power (W)	6,506.0 ± 848.9	6,635.8 ± 833.8	6,235.9 ± 583.1	6,277.7 ± 676.1
Mean Power (W)	1,009.9 ± 402.0	1,054.3 ± 396.7	896.3 ± 242.6	891.9 ± 254.0

One Repetition Maximum Strength Testing. Maximum strength means and standard deviations are displayed below (Table 5). There was a significant interaction between time and group for back squat 1RM (F[2,19]= 4.944, p = 0.038, η^2 = 0.198). There was a main effect of time for the back squat 1RM (F[2,19]= 4.572, p = 0.045, η^2 = 0.186). There was no main effect of group on back squat 1RM (F[2,19]= 0.419, p = 0.525, η^2 = 0.021). The MIPS group increased their back squat 1RM significantly from 95.1 ± 32.7 kg to 107.8 ± 39.3 kg following six weeks of supplementation (Figure 2). There was a significant interaction between time and group for the bench press 1RM (F[2,19]= 5.565, p = 0.045, η^2 = 0.218). There was a main effect of time on bench press 1RM (F[2,19]= 9.597, p = 0.006, η^2 = 0.324). There was no main effect of group on the bench press 1RM (F[2,19]= 882, p = 0.0359, η^2 = 0.042). The MIPS group displayed a significant increase from 69.2 ± 28.3 kg to 73.3 ± 30.7 kg following the intervention (Figure 3).

Table 5. One-repetition maximum results (mean ± SD)

	Placebo		**MIPS**	
	Pre-Test	**Post-Test**	**Pre-Test**	**Post-Test**
Back Squat 1RM (kg)	106.0 ± 44.5	105.8 ± 42.5	95.1 ± 32.7*	107.8 ± 39.3*
Bench Press 1RM (kg)	84.3 ± 34.6	84.9 ± 36.1	69.2 ± 28.3*	73.3 ± 30.7*

*p<0.05

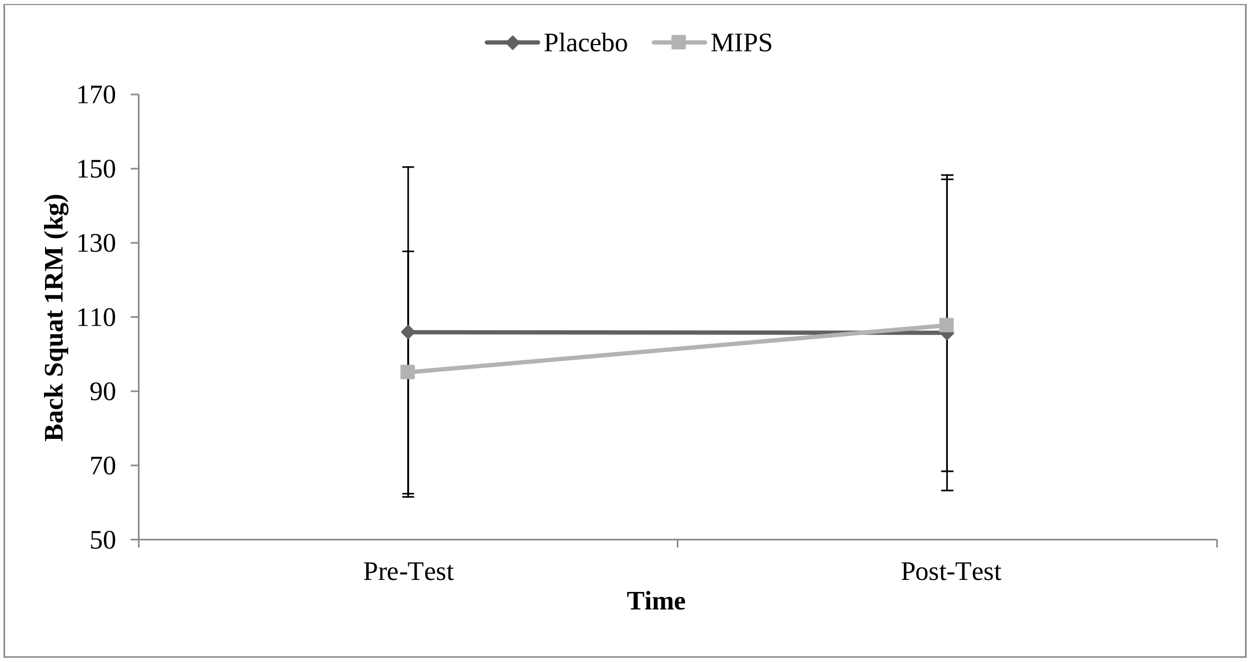

Figure 2. Back squat 1RM (mean ± SD)

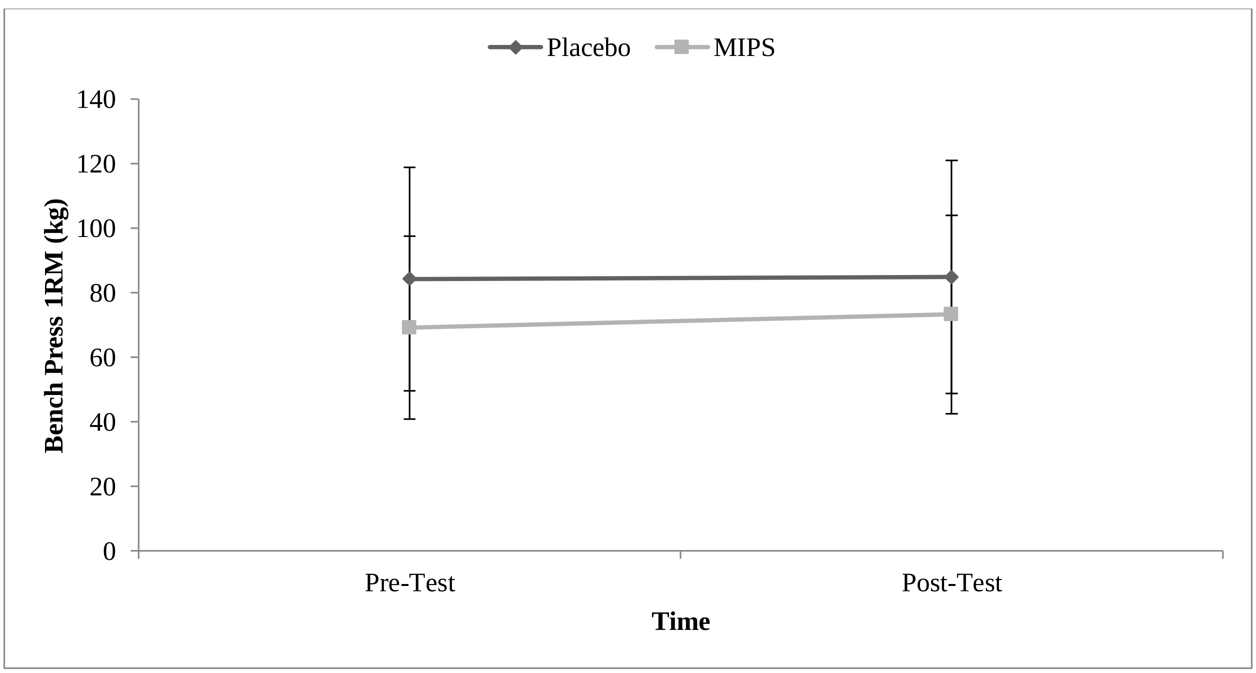

Figure 3. Bench press 1RM (mean ± SD)

Back Squat Maximal Repetition Test. Results for sum of concentric work, mRFD, mean power, peak power, and peak force are displayed below (Table 6). There was no interaction between time and group for the sum of concentric work (F[1,14]= 0.762, p = 0.397, η^2 = 0.052). There was no main effect of time (F[1,14]= 0.749, p = 0.401, η^2 = 0.051) or group (F[1,14]= 0.707, p = 0.415, η^2 = 0.048) for the sum of concentric work. There was no interaction of time and group on mRFD (F[1,14]= 0.717, p = 0.412, η^2 = 0.049). There was no main effect of time (F[1,14]= 0.780, p = 0.392, η^2 = 0.053) or group (F[1,14]= 0.769, p = 0.395, η^2 = 0.052) on mean rate of force development. There was no interaction between time and group on mean power (F[1,14]= 0.809, p = 0.384, η^2 = 0.055). There was no main effect of time (F[1,14]= 0.809, p = 0.384, η^2 = 0.055) or group (F[1,14]= 0.808, p = 0.384, η^2 = 0.055) on mean power. There was no interaction between time and group observed on peak power (F[1,14]= 1.821, p = 0.199, η^2 = 0.115). There was no main effect of time (F[1,14]= 1.812, p = 0.200, η^2 = 0.115) or group (F[1,14]= 1.805, p = 0.200, η^2 = 0.114) on peak power. There was no interaction between time and group observed on peak force (F[1,14]= 0.750, p = 0.401, η^2 = 0.051). There was no main effect of time (F[1,14]= 0.734, p = 0.406, η^2 = 0.050) or group (F[1,14]= 0.744, p = 0.403, η^2 = 0.50) on peak force.

Table 6. Maximal back squat repetition test results (mean ± SD)

	Placebo		MIPS	
	Pre-Test	**Post-Test**	**Pre-Test**	**Post-Test**
Concentric Work (J)	3,547.7 ± 2,385.0	3,122.6 ± 1,437.9	3,351.9 ± 2,436.5	3,556.9 ± 2,066.3
mRFD (N/s)	1,850.4 ± 618.3	2,962.0 ± 1,387.1	3,086.9 ± 1,625.6	5,928.1 ± 7,396.0
Mean Power (Watts)	260.5 ± 144.1	287.1 ± 170.3	292.7 ± 158.6	292.7 ± 184.5
Peak Power (Watts)	2,613.1 ± 1,988.4	2,491.6 ± 1,270.3	2,969.3 ± 1,869.4	2,162.0 ± 1,017.7

Peak Force (N)	3,829.3 ± 2,020.0	3,564.3 ± 1,387.9	4,220.7 ± 2,328.4	3,350.9 ± 1,172.2

Bench Press Maximal Repetition Test. Means and standard deviations for bench press are displayed below (Table 7). There was a significant interaction between time and group for sum of concentric work (F[1,19]= 6.031, p = 0.024, η^2 = 0.241). There was no main effect of time (F[1,19]= 2.736, p = 0.115, η^2 = 0.126) or group (F[1,19]= 0.063, p = 0.805, η^2 = 0.003) on sum of concentric work. The MIPS group displayed an increased sum of concentric work from 1,853.9 ± 829.8 to 2,344.7 ± 1,121.2 J (26%) (Figure 4). There was a significant interaction between time and group for mRFD (F[1,19]= 4.397, p = 0.050, η^2 = 0.188). There was no main effect of time (F[1,19]= 0.942, p = 0.344, η^2 = 0.047) or group (F[1,19]= 3.140, p = 0.092, η^2 = 0.142) on mRFD. The placebo group had a significant decreased mRFD from 7,293.9 ± 6,240.7 to 5,385.4 ± 5,034.0 N/s (-26%) and the MIPS group had a significant increase from 3,620.4 ± 2,358.7 to 4,432.0 ± 3,152.2 N/s (+22.4%) (Figure 5). There was a significant interaction between time and group for mean power (F[1,19]= 5.946, p = 0.025, η^2 = 0.238). There was no main effect of time (F[1,19]= 2.136, p = 0.160, η^2 = 0.101) or group (F[1,19]= 0.714, p = 0.409, η^2 = 0.036) on mean power. The MIPS displayed an increased mean power from 169.7 ± 73.6 to 200.1 ± 83.0 watts (+17.9%) (Figure 6). There was no observed interaction between time and group for peak power (F[1,19]= 0.122, p = 0.731, η^2 = 0.006). There was no main effect of time (F[1,19]= 1.009, p = 0.328, η^2 = 0.050) or group (F[1,19]= 0.562, p = 0.463, η^2 = 0.029) on peak power. There was no interaction between time and group on peak force (F[1,19]= 0.535, p = 0.473, η^2 = 0.027). There was no main effect of time (F[1,19]= 0.355, p = 0.559, η^2 = 0.018) or group (F[1,19]= 0.738, p = 0.401, η^2 = 0.037) displayed on peak force.

Table 7. Maximal bench press repetitions test (mean ± SD)

	Placebo		MIPS	
	Pre-Test	**Post-Test**	**Pre-Test**	**Post-Test**
Sum of Concentric Work (J)	1,990.6 ± 864.7	1,923.6 ± 703.8	1,853.9 ± 829.8*	2,344.7 ± 1,121.2*
Mean Rate of Force Development (N/s)	7,293.9 ± 6,240.7	5,385.4 ± 5,034.0	3,620.4 ± 2,358.7*	4,432.0 ± 3,152.2*
Mean Power (Watts)	197.9 ± 113.6	191.3 ± 110.4	169.7 ± 73.6*	200.1 ± 83.0*
Peak Power (Watts)	1,204.7 ± 604.0	1,295.8 ± 629.1	1,134.8 ± 679.6	1,275.5 ± 579.8
Peak Force (N)	2,524.0 ± 1,141.8	2,789.0 ± 1,363.9	2,564.9 ± 1,450.8	2,507.6 ± 1,074.7

*$p<0.05$

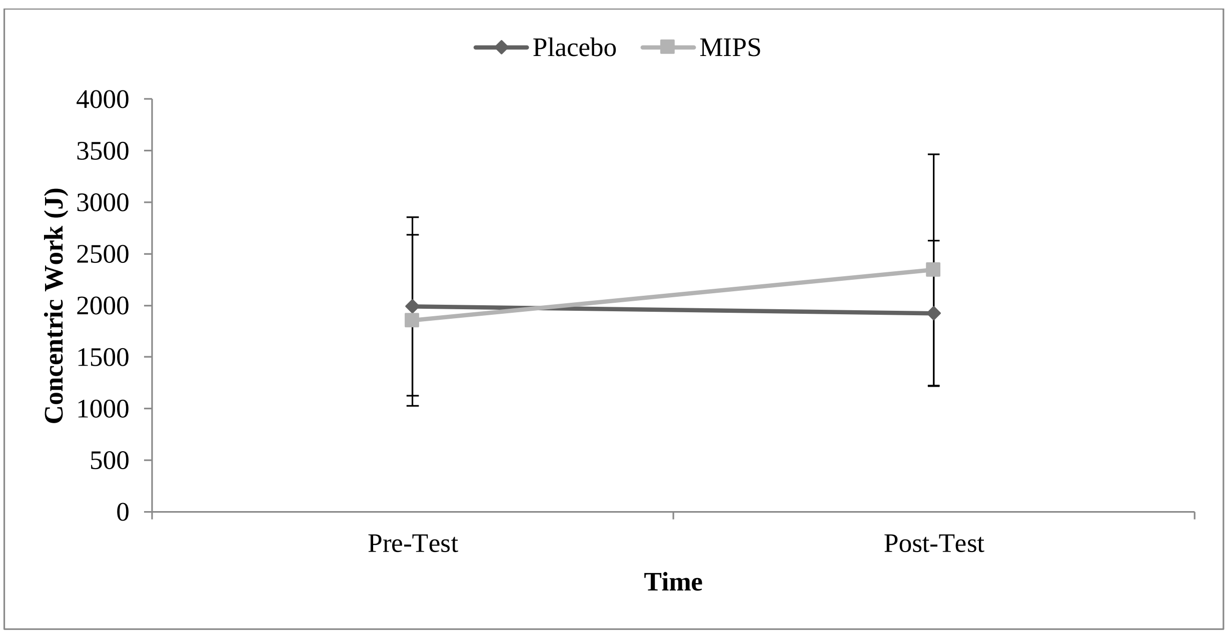

Figure 4. Bench press total concentric work (J) (mean ± SD)

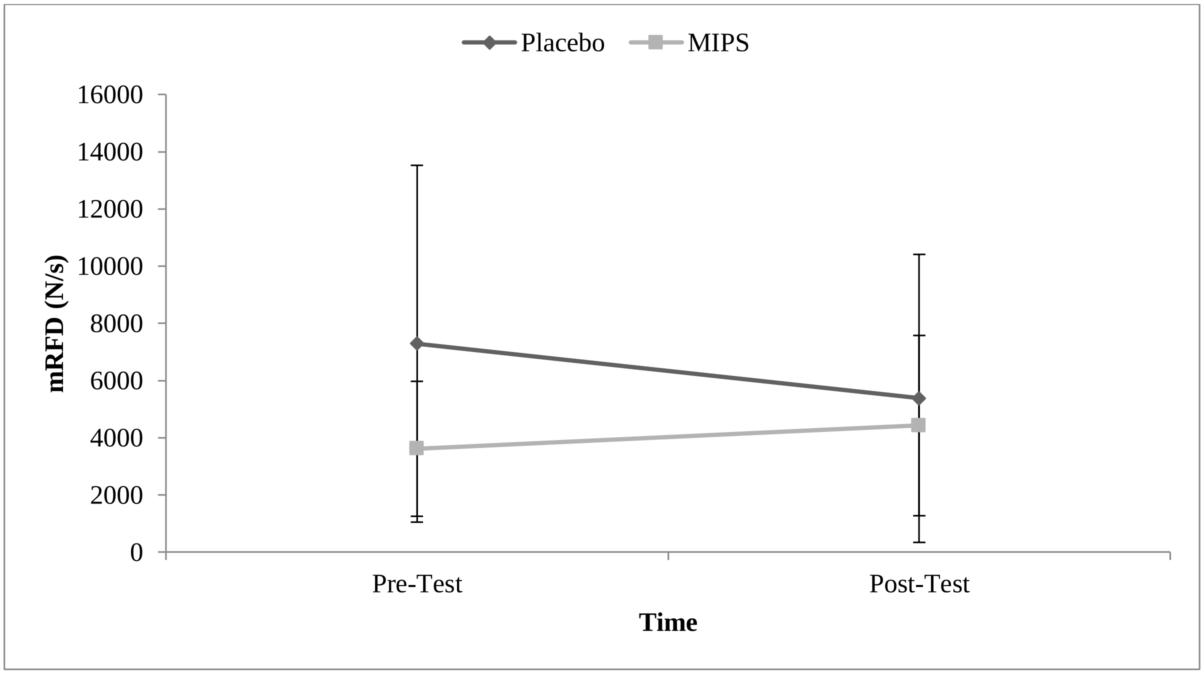

Figure 5. Bench Press mean RFD (N/s) (mean ± SD)

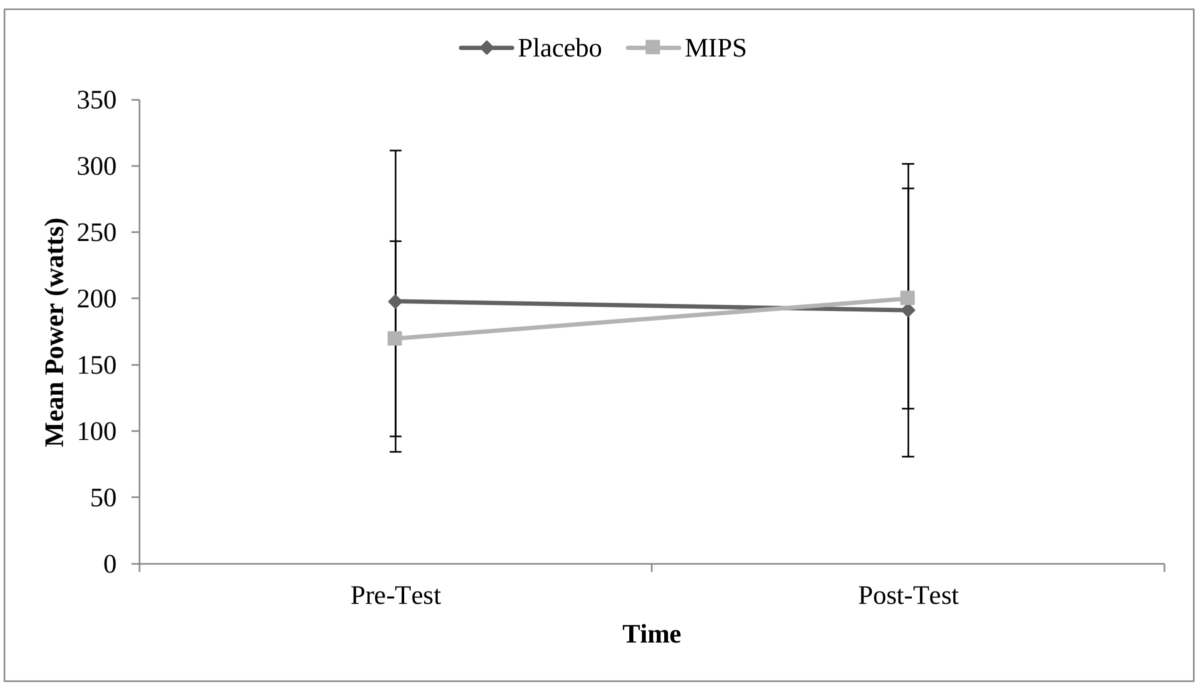

Figure 6. Bench Press mean power (Watts) (mean ± SD)

Discussion

The purpose of this study was to examine the effects of a multi-ingredient performance supplement (MIPS) of creatine and electrolytes on several performance variables for back squat, bench press, countermovement jump, body composition, and body water in recreational trained individuals. The results of this study supported the hypothesis displaying an increase in back squat maximal strength and bench press maximal strength, concentric work, mRFD, and mean power. This study used a maximal repetition test to predict a one repetition maximum for both back squat and bench press. There was a significant increase in maximal strength (1RM) for both back squat and bench press in the MIPS group after the six weeks of supplementation. During a maximal repetition test at 80% of subject's 1RM bench press, subjects displayed a significant increase of average concentric work, average mean rate of force development, and average mean power for the MIPS group across the repetitions. There were no observed differences for average concentric work, average mean rate of force development, average mean power, average peak power, or average peak force during the back squat maximal repetition test.

There is little to no change for any variable for the akimbo countermovement jumps in either group. This could be largely based on the sampling rate being set too low for data collection of a countermovement jump. Data collection was set to 50 Hz sampling rate compared to the typical 1200 Hz used for countermovement jumps. With such a low sampling rate, valuable data could be lost during collections for a movement that occurs in one to two seconds.

The results of this study demonstrated significant increases for the MIPS group for both 1RM back squat of 12.7 kg (95.1 ± 32.7 to 107.8 ± 39.3 kg) and 1RM bench press of 4.1 kg (69.2 ± 28.3 to 73.3 ± 30.7 kg*)*. The MIPS supplementation group had a significant increase over time on maximal strength for both lower and upper body. This same increase was not observed in the placebo group. The MIPS group displayed a significant increase in average concentric work of 490.8 J (1,853.9 ± 829.8 to 2,344.7 ± 1,121.2 J, p = 0.024), average mean rate of force development (3,620.4 ± 2,358.7 to 4,432.0 ± 3,152.2 J, p = 0.05) and average mean power of 30.4 watts (169.7 ± 73.6 to 200.1 ± 83.0 watts, p = 0.025). Based on these results, the MIPS supplement was beneficial in enhancing various performance characteristics over a six-week time frame. Subjects taking the MIPS exhibited a greater increase of work performed following the supplementation period, and were able to reach their power at a faster rate demonstrated by the significant increase in their mRFD after six weeks of supplementation.

Creatine supplementation is used to increase the amount of stored intramuscular creatine and phosphocreatine (PCr) for use during short bouts of anaerobic activity (Allen, 2012; Greenhaff et al., 1994). Creatine supplementation increases the PCr stores as well as the re-synthesis in the human body (Greenhaff et al., 1994). PCr has a role in phosphorylating ADP into ATP for movement. The use of electrolytes aids in providing transporters for creatine from the plasma into the muscles (Allen, 2012; Jäger et al., 2011).

Studies employing creatine supplementation for improvement in power output have involved lower body activities such as countermovement jumps and Wingate tests to measure power (Earnest et al., 1995; Herda et al., 2009; Hoffman et al., 2006). Hoffman et al. (2006) collected kinetic data during a total of 20 akimbo countermovement jumps to measure power output following 10 weeks of creatine supplementation in college football players. Similar to the current study, Hoffman et al. (2006) found no significant change in peak power while using creatine monohydrate for 10 weeks (62.6 ± 13.8 to 62.7 ± 10.1 W/kg). Researchers also displayed no significant increase in mean power for the creatine groups (52.8 ± 12.1 to 54.8 ± 9.2 W/kg) (Hoffman et al., 2006). The current data indicate similar results, in that both mean and peak power were not significantly affected by a creatine and electrolyte supplementation intervention. The results in the current study could have been greatly affected by a very low sampling rate of 50 Hz when compared to the standard 1200 Hz collection rate. However, Hoffman et al. (2006) used 20 consecutive akimbo countermovement jumps instead of three trials of one akimbo countermovement jump. The use of 20 akimbo countermovement jumps could affect their results due to the phosphagen system being depleted long before the collection was completed. The study by Hoffman et al. (2006) appears to be a study more designed for fatigue rather than raw power output.

Creatine supplementation has increased the maximal strength for both the back squat and leg press exercises following supplementation (Hoffman et al., 2006; Pearson et al., 1999; Larson-Meyer et al., 2000). Hoffman et al. (2006) found an increase of about 25 ± 6 kg from a baseline of 115.9 ± 17.7 kg, for groups supplemented with creatine for 10 weeks using 10.5g/day doses. Pearson et al. (1999) also found results that indicated a significant increase in back squat 1RM following 10 weeks of creatine supplementation. Subjects were given 5g/day for the supplementation period and experienced similar results (Pearson et al., 1999). Another study tested maximal back squat strength in female soccer players at five and 13 weeks of creatine supplementation (Larson-Meyer et al., 2000). Supplementation consisted of a 15g/day for one-week loading phase followed by a four-week maintenance phase of 5g/day. The soccer players displayed significant increases in their 1RM back squat at both five weeks and 13 weeks intervention compared to their baseline testing (Larson-Meyer et al., 2000). These results are very similar to the current data, which showed an increase of 13.4% following only a six-week MIPS intervention. The literature and current study seem to agree that creatine supplementation lasting at least five weeks can increase back squat maximal strength across various populations ranging from recreational to competitive athletes. Benefits from the MIPS were also very similar to those using creatine monohydrate at relatively similar doses, 4-5 g/day.

Along with increases in lower body strength, creatine supplementation has significantly increased the upper body maximal strength in a range of people (del Favero et al., 2012; Earnest et al., 1995; Hoffman et al., 2006; Souza-Junior et al., 2011; Syrotuik et al., 2000). Commonly, researchers use a 1RM test of bench press to assess the approximate increases in upper body strength following an intervention. Hoffman et al. (2006) found a 2.5 fold increase in bench press 1RM when comparing creatine to a placebo group following 10 weeks of supplementation. Another study using 28 days of creatine supplementation found a 6% increase in bench press 1RM when compared to their baseline values (Earnest et al., 1995). Pearson et al. (1999) used a 5 g/day creatine supplementation over 10 weeks and found that bench press maximal strength significantly increased. A recent study involving recreational bodybuilders used 5g/day doses and observed an increase in bench press 1RM over a four week period (6.6 ± 8.2 kg to 7.6 ± 6.1 kg) (Antonio & Ciccone, 2013). While most studies display a significant increase with bench press 1RM, some recent studies have found no significant improvements in creatine supplementation compared to placebo counterparts (Souza-Junior et al., 2011; Zuniga et al., 2012). Such studies are examining the acute effects of a large loading dose, typically only covering five to seven days rather than occurring over weeks. The current study showed results similarly in line with significant upper body strength increases using a moderate duration of supplementation, 6 weeks, and using maintenance level doses of 4 g/day. This study was able to conclude that MIPS supplementation over six weeks was beneficial for both back squat and bench press maximal strength.

Very few studies using creatine supplementation have been done using the performance variables in the current study, repetitions to failure under certain loading conditions (Cooper et al., 2013; Herda et al., 2009; Vincent et al., 1998). With the current study examining the total concentric work during the maximal repetition set. A 28-day supplementation study using male power lifters examined creatine's effect on maximal repetition tests across five subsequent sets of bench press (Vincent et al., 1998). Following supplementation, the groups supplementing with creatine had an increased number of repetitions in sets one, four, and five (Vincent et al., 1998). This finding could primarily be due to the effect of creatine supplementation increasing PCr based on a repetition test occurring at 80% 1RM is heavily dependent on the CP. Other variables could play a role in the increase of repetitions including: motor unit recruitment or increased muscle mass. The current study only used a single set at 80% of their determined 1RM to closely examine the effect of MIPS supplementation on maximal repetitions to failure. A more recent study examined a similar protocol of performing repetitions to failure at 80% 1RM (Herda et al., 2009). Following 30 days of supplementation, all groups in the study had increased amount of repetitions when compared to baseline testing. The groups included in the study included a creatine monohydrate and creatine polyethylene glycosylated supplements (Herda et al., 2009). The significant increase of 26.5% in the current study appears to be in line with current knowledge of creatine increasing the work capacity until failure while performing the bench press exercise at 80% 1RM.

Subsequently, the current study found an increase in mRFD and mean power during the bench press maximal repetition test. A maximal repetition test at this specified load is heavily dependent on the CP system (Vincent et al., 1998). While no research was found on mRFD during the bench press, an increase of mRFD shows a possibility of decreased rate of fatigue. Subjects that displayed an increased mRFD were achieving their peak power at a much faster rate throughout their repetition test. Mean RFD has two major components that could be influenced due to fatigue: velocity and force. With an increase in mRFD, it is a possibility that it took MIPS participants longer to have a velocity drop off to their peak force being applied, displaying a reduced rate of fatigue.

There were some limiting factors to the current study that could have influenced the results. The maximal repetition strength test was conducted using as many repetitions as possible at 80% of their predicted 1RM. Subjects could have given an inaccurate value for their current 1RM strength for either bench press or back squat when entering the study, potentially decreasing the accuracy of the estimation. Subjects were told to refrain from strenuous exercise prior to testing, but this could not be controlled for. The timeframe of testing was also a limitation of the study with the back squat maximal repetition test being conducted with almost 16 minutes of rest following the back squat 1RM. Subjects may have lost their warm up in the lower extremities while performing the bench press exercise. There was also no control used for back squat depth for subjects to maintain. Subjects were told to squat low enough where their hips were parallel or below their knees (90° knee flexion). Finally, due to an equipment error, all force platform data was collected at 50 Hz rather than the typical 1200 Hz used for counter movement jumps. With a low capture rate, the data may not be accurate.

Summary

Six weeks of MIPS supplementation can be beneficial for increasing multiple facets of athletic performance in recreational trained individuals. The MIPS increased both back squat and bench press 1RM strength and an increase in lean body mass. Subsequently, the MIPS also displayed increases in the sum of concentric work, average mRFD, and average mean power while performing a maximal repetition test of bench press at 80% 1RM load. There was no significant difference or effect on the following outcome measures: % body fat, fat mass, total body water, intra-cellular water, extra-cellular water, mean or peak power in the akimbo countermovement jump, sum of work, mRFD, mean power, peak power, and peak for during the back squat, and peak power and force during the bench press. The current study appears to be in line with previous research. This MIPS consisting of creatine and electrolytes could be beneficial for people wishing to increase their performance.

Chapter V

Summary, Conclusions, and Recommendations

Summary

This study examined the effects of a multi-ingredient performance supplement (MIPS) formulated with creatine and electrolytes on body composition, body water, and performance during akimbo countermovement jumps, back squat, and bench press. Subjects were randomly assigned to either the placebo or experimental group and supplemented for a period of six weeks. Subjects were tested at baseline (pre-test) and immediately following supplementation (post-test). Testing consisted of body composition tested through air displacement plethysmography, body water analysis, an akimbo countermovement jump, 1RM test for both back squat and bench press, and a maximal repetition test at 80% load for both back squat and bench press. Supplementation resulted in a significant increase in both the back squat and bench press 1RM tests in the MIPS group. Accompanied with the strength increases, there was a significant increase in bench press sum of concentric work, mean rate of force development (mRFD), and average mean power. There were no observed differences in body composition, body water, akimbo countermovement jump performance, and concentric work, mRFD, mean power, peak power, and peak force during the back squat repetition test.

Conclusions

The MIPS used in the current study consisting of creatine and electrolytes can be beneficial for recreationally training individuals. Specifically, recreationally active people can use this MIPS to increase their maximum strength for both upper and lower body exercises such as bench press and back squat. Accompanied with increase strength, is an increase performance during a higher repetition sets to failure in the bench press exercise.

Recommendations

Future Research. This current study suggests that both bench press and back squat maximal strength can increase with MIPS supplementation. Bench press performance increased during a maximal strength test and repetitions to failure test done at 80% 1RM. Future research could focus on expanding to more resistance training exercises using similar repetitions to failure that rely greatly upon the creatine phosphagen system. Since creatine supplementation has been noted to have the greatest effect on repeated bout exercises (Cooper et al., 2013; Herda et al., 2009; Vincent et al., 1998). Future research should also aim to examine the effects across multiple sets and repetition parameters through fatigue. Expanding research to different groups of people would greatly enhance the knowledge around the MIPS. Using competitive athletic teams to test the supplementations effect on people at a higher level of training. Doing so would also give a more accurate comparison since subjects will typically be more uniformed whereas recreationally training status does have a wider variation. More research could repeat repetition to failure testing across multiple days to allow for appropriate CP system recovery and to add more data for accuracy. Researching the effects of the supplementation on rest intervals could be used to gain insight of PCr resynthesize and recovery of the CP system compared to standard creatine supplementation.

Practical Applications. The results presented in the current study indicated that a supplement formulated with creatine and electrolytes can improve performance for recreationally trained people compared to a placebo. People who are recreationally trained and want to improve strength and bench press performance could take the supplement daily and see results in about six weeks. This study was the first to examine a creatine supplement formulated with this balance of electrolytes and further research is required to confirm benefits.

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Appendices

Appendix A: Informed Consent

Consent to Take Part in a Research Study

Project: Effect of a Multi-ingredient Performance Supplement (MIPS) on Strength and Power in Weight-trained Subjects

You are invited to participate in a study investigating the effects of a multi-ingredient performance supplement (MIPS), containing creatine and electrolytes (like those in a sports drink), on strength and power in weight-trained subjects. To improve upon past studies, this analysis aims to objectively evaluate a soluble creatine supplement versus placebo on strength and power in an athletic population. The results of this study will enhance our understanding of this supplement and how it may affect physical performance.

I UNDERSTAND THAT:

1. This experiment will begin with measurement of height, weight, body fat with a Bod Pod Unit, and body water determination using a bio-impedance unit. Height will be measured with a stadiometer and weight with a standard physician's balance beam scale. Body fat will be measured with the subject in minimal clothing like a swim suit or spandex. The subject will enter a small chamber and remain seated for the duration of the test. There is a window in the chamber door which allows the subject to have visual contact with the researcher at all times. For determining total body water, an impedance device is used. For this test, you will lie on a table and have electrodes attached to your wrists and ankles. It takes less than a minute, and then the electrodes are removed. My participation for these tests will be approximately 30 minutes.

2. Supplementation will be either treatment (creatine and electrolytes, like those in a sports drink) or placebo (sugar) for 6 weeks in a blinded fashion. Blinded is that neither the subject nor the researcher providing the numbered supplement will know whether the supplement is the treatment or placebo until the end of the 6-week period. Each week, the packet for that week will be picked up at the lab. For this study, consistent dietary and exercise programs should be maintained. During the first and sixth week of supplementation, I will keep a 3-day diet record and 3-day physical activity record that will be submitted for analysis.

3. Both groups will undergo pre- and post-supplementation testing sessions to assess strength and power. Countermovement vertical jump testing will be assessed with a force platform, prior to maximal strength testing. After a dynamic warmup, two practice jumps will be allowed for familiarization with the test. Following this, three trials on the force plate will be completed. After completion of the countermovement jump trials, estimated one repetition maximums (1RM) for the squat and bench press

will be according to the National Strength and Conditioning Association (NSCA) testing procedures. A three repetition maximum will be determined, than the O'Conner formula used to estimate the 1RM. Velocity measurements during testing of both the back squat and bench press exercises will be taken with a PUSH armband. Subjects wear armbands during testing on the forearm. To operate, the armband will be turned on prior to the beginning of the session and synced with the PUSH Team monitor. Prior to initiating a set, the subject taps his/her icon on the Team screen. Once in position, prior to unracking the barbell, the subject will push the button on his/her armband to start recording. After completion of the set, the subject then will push the button again to terminate the recording. This procedure will be completed during squat and bench press. The total positive work performed during lifting will be determined using data collected via a single camera collecting at high speed. One passive retro reflective marker will be placed on the barbell to track vertical position. Force exerted by the lifter on the barbell at every time point during the motion will be calculated using video to derive the acceleration of the bar. Total work will then be calculated as the product of the average force on the bar and the positive displacement.

4. There may be risks during the strength and power tests, such as falling during the vertical jump, but this will be minimized with a spotter. I understand that exercise can lead to muscular soreness, cramping, pain, and fatigue. During testing, there is a risk of experiencing muscle soreness that should disappear after a period of rest. I understand that if exercise testing is painful, I can stop at any time. In addition, I am aware that I could experience delayed onset muscle soreness (DOMS) after the session that could last for 24-72 hours. The safeguards that will be used minimize potential muscle soreness include a warm-up, acclimation, and cool down period. If I feel like I cannot or should not perform any of these tasks, I could opt out from the participation in this study.

5. Possible benefits include that subjects may be have performance benefits associated with supplementation. The results of this study may aid in future research.

6. There is twenty dollars ($20) compensation for my participation in the complete project: supplementation, pre- and post-testing. My participation is voluntary, I may choose to withdraw my consent and discontinue participation without penalty.

7. All information collected is confidential. My signed consent form will be kept in a locked cabinet separate from the data collection forms for the project data. My name will not be associated with any of my data collected throughout the study.

8. My signature on this form does not waive my legal rights of protection.

9. Any questions you may have regarding the study procedures will be answered by the primary researchers (Lorrie Brilla, Dave Suprak) who can be contacted at

Lorrie.Brilla@wwu.edu (360-650-3056) or Dave.Suprak@wwu.edu (360-650-2586). Any questions about your rights as a research subject should be directed to Janai Symons, the WWU Research Compliance Officer (RCO), 360-650-3082. If any injury or adverse effect of this research is experienced you should contact Lorrie Brilla, Dave Suprak, or the RCO.

♦♦♦
I have read the above descriptions and agree to participate in this study.

_______________________________________ ____________________

Participant's Signature Date

____

Participant's PRINTED NAME

Note: Please sign both copies of the form and retain the copy marked "Participant"

___________________________ ___________________________

Participant Name (printed) Date

____

Participant Signature

Appendix B: Hold Harmless Agreement

WESTERN WASHINGTON UNIVERSITY	**Health and Human Development Department**

ACKNOWLEDGEMENT OF RISK AND HOLD HARMLESS AGREEMENT

Acknowledgment of Risk:
I hereby acknowledge that I have voluntarily chosen to participate in the activities of the Kinesiology and Physical Education Program (hereinafter called "Program") through Western Washington University's Health and Human Development Department. I understand the risks involved. I recognize that the classes and other activities which include but are not limited to **motor skills, fitness, outdoor recreation, games, sports, modified, creative, rhythmic, individual, dual and team,** involve risk of injury and I agree to accept any and all risks associated with the activities, including but not limited to property damage or loss, minor bodily injury, severe bodily injury, illness and death. Furthermore, I recognize that my participation in the Program involves activities incidental thereto, including but not limited to, travel to/from Program activities, limited availability of medical aid and the possible negligent or reckless conduct of other participants. By voluntarily participating in the Program with the knowledge of the risks involved, I hereby agree to accept any and all inherent risks of property damage, bodily injury, or death.

I understand that I am responsible for researching and evaluating the risks that I may face and am responsible for my actions. Any activities that I may take part in, whether as a component of the Program or separate from it, will be considered to have been undertaken with my approval and understanding of any and all risks involved.

Indemnification and Hold Harmless:
In consideration of my participation in the Program and to the extent permitted by law, I agree to indemnify, defend and hold harmless Western Washington University, its trustees, officers, directors, employees, agents, volunteers and assigns from and against all claims arising out of or resulting from my participation in the Program. "Claim" as used in this agreement means any financial loss, claim, suit, action, damage, or expense, including but not limited to attorney's fees, attributable to bodily injury, sickness, disease or death, or injury to or destruction of tangible property including loss of use resulting therefrom. In addition, I hereby voluntarily hold harmless Western Washington University, its trustees, officers, directors, employees, agents, volunteers and assigns from any and all claims, both present and future, that may be made by me, my family, estate, heirs or assigns.

I hereby expressly agree to indemnify, defend and hold harmless Western Washington University, its trustees, officers, directors, employees, agents, volunteers and assigns for any claim arising out of my participation in the activity, except for claims arising out of the sole negligence or willful misconduct of Western Washington University, its trustees, officers, directors, employees, agents, volunteers and assigns.

I understand that Western Washington University does not provide any medical, dental or life insurance to cover bodily injury, illness or death; nor insurance for personal property damage or loss; nor insurance for liability arising out of my negligent acts or omissions; and I acknowledge that I am completely responsible for my own insurance or financial resources to cover expenses related to these things.

I further understand that this acknowledgement of risk and hold harmless is intended to be as broad and inclusive as permitted by the laws of the State of Washington, or any other applicable laws, and that if any portion hereof is held invalid, I agree that the balance shall, notwithstanding, continue in full legal force and effect.

I agree that this acknowledgment of risk and hold harmless is effective for as long as I participate in the Program.
I have read and understand this acknowledgement of risk and hold harmless agreement.

Participant Name (please print)	Signature of Participant	Date

Appendix C: Subject Background Information Form

<u>BACKGROUND INFORMATION FORM</u>

Name:____Date:_____________

Height in inches: ____ Weight in lbs.: ____

Age:________ Sex:__ Birth date:_____________________

Street Address:____

City:__________________________ State:_______ Zip:______________

Phone: ____________

In case of emergency notify: Name:____

Phone Number: ________________ Relationship: __________________

Have you had a physical examination within the past two years? ________

Name of your physician:______________ Phone Number:_________________

Do you have a family history of heart disease? ________________

If so, describe?____

Do you have any renal problems?____

Do you experience any uncomfortable sensations while exercising?__________________

How active are you? What type of exercise do you engage in and how many times a week do you exercise?_____________________________________

Do you drink alcohol?_____ If so, how much?______________________

Please list everything not already included on this questionnaire that might cause you problems in a strength or jump test:

____

Appendix D: Protocol Check List

Albion Research Study Part I

Fall

Date		**Time (Begun, Completed)**	
Subject Number		**Age (yrs)**	
Height (cm)		**Weight (kg)**	
Injury History			
Dominant Limb	Right / Left	**Years of Training (Strength & Power)**	
Consent Form?	Yes / No	**Videotaping Form?**	N/A
Explanation of test?	Yes / No	**Subject on Master Sheet?**	Yes / No
Questions?	Yes / No		
Room set-up?	☐ Area around the equipment is free of obstructions and hazards ☐ BIA equipment is next to the treatment table, electrodes included ☐ Bod Pod is plugged in and ready to begin calibration/collection ☐ Force plate is turned on and zeroed o Vertec is easily accessible near the force plate ☐ Qualisys cameras on turned on and calibrated ☐ Squat rack is in place and free from obstructions ☐ Barbell and weights are in appropriate positions for use		

Body Composition ***Bod Pod***	☐ Computer and equipment are plugged in & Turned on ☐ Area around scale and equipment is clear ☐ Calibration weights and cylinders are within close reach for calibration protocols ☐ Researcher is logged into the computer o Guest o Podarama ☐ Create new subject information for specific subject ☐ Ensure that the subject is wearing appropriate clothing for testing o Blue cap worn to cover hair o No loose fitting ☐ Follow onscreen directions for calibration of the scale and collection space o Directions are specifically given on screen and run through the entire process o Include weight of the subject for accuracy ☐ Follow collection procedure on screen once calibration has be completed o On screen directions are given for entire collection process o Two trials are taken to ensure accuracy of measurement ☐ Following collection, the subject can change back into their clothes and return the blue swim cap. Export all relevant data.
Bio-Electrical Impedance	☐ Treatment table is set up for comfortable positioning ☐ Equipment is on a stable surface next to the table ☐ Prep the subject for collection: o Right shoe and sock are removed o Lay down on the table in a supine position o Swab area with alcohol swabs prior to electrode placement ☐ Place electrodes on the right hand and foot ☐ Run collection and record relevant results from machine read-out ☐ Remove electrodes from the subject
Dynamic Warm-Up	☐ Jog on a treadmill for 2 minutes at 6 miles per hour ☐ Walking knee hugs (5 repetitions on each leg) ☐ Lunge to torso twist (5 repetitions on each leg) ☐ Walking quad stretches (5 repetitions on each leg) ☐ Inverted hamstring stretch (5 repetitions on each leg) ☐ Wall slides (5 repetitions) ☐ Cross-body shoulder slaps (5 repetitions)

	☐ Push-ups (5 repetitions) ☐ 4 minute rest period
Counter Movement Jump Protocol	☐ Force plate is on and zeroed ☐ The vertec is set up next to the force plate ☐ Subjects are shown a demonstration of a countermovement jump with their hands on their hips ☐ Subjects are allowed two practice trials to become accustomed to the protocol ☐ Have the subject start off of the force plate to tare ☐ Have the subject step onto the force plate to record their weight (in Newton's) ☐ Subjects will confirm they're ready to proceed. ☐ One researcher will start a countdown of "3,2,1, GO" o Collection will start at "1" o Subjects will be instructed to initiate movement at "GO" ☐ Once subjects land, collection is concluded ☐ Repeat the steps above for second trial

Strength Session (1RM & Concentric Work)

Date		**Time (Begun, Completed)**	
Subject Number		**Age (yrs)**	
Height (in)		**Weight (lbs)**	
Injury History			
Warm-up completed? Yes / No		☐ Protocol prior to jump testing (above)	
Bench Press Technique Explained?	Yes / No	**Back Squat Technique Explained?**	Yes / No
Predicted 1-RM Bench Press (lbs)		**Predicted 1-RM Back Squat (lbs)**	
50%		**50%**	
75%		**75%**	
90%		**90%**	

<table>
<tr>
<td>

- Complete 10 repetitions at 50% of their self-estimated 1-RM
- Rest 4 minutes
- Complete 5 repetitions at 75% of their self-estimated 1-RM
- Rest 4 minutes
- Complete as many repetitions as possible (until failure) at 90% of their self-estimated 1-RM

LOAD _________ lbs
REPS TO FAILURE ________
</td>
<td>

- Complete 10 repetitions at 50% of their self-estimated 1-RM
- Rest 4 minutes
- Complete 5 repetitions at 75% of their self-estimated 1-RM
- Rest 4 minutes
- Complete as many repetitions as possible (until failure) at 90% of their self-estimated 1-RM

LOAD _________ lbs
REPS TO FAILURE ________
</td>
</tr>
<tr>
<td colspan="2">

Enter data into equation: (1-RM = Load * (1+(0.025 * RTF))

Predicted 1-RM bench press: ________ lbs Predicted 1-RM back squat: ________ lbs
</td>
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Following 1RM testing, determine load equivalent to 80% of their estimated 1RM. Have the subject perform their maximal number of repetitions at this load. During the set, collect video analysis using the Qualisys Camera system.
</td>
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Appendix E. Raw Data

Raw Data for the body composition testing

	Pre				Post			
Group #	Body Density (g*cc^-1)	Body Fat (%)	Fat Free Mass (kg)	Fat Mass (kg)	Body Density (g*cc^-1)	Body Fat (%)	Fat Free Mass (kg)	Fat Mass (kg)
1	1.094	2.6	72.955	1.975	1.087	5.3	70.888	3.969
1	1.037	27.3	43.984	16.522	1.045	23.7	44.131	13.73
1	1.066	14.6	88.357	15.05	1.078	9	94.781	9.369
1	1.044	24.3	59.863	19.216	1.056	18.6	64.664	14.822
1	1.082	7.6	70.337	5.823	1.086	5.7	71.8	4.369
1	1.069	13.2	57.478	8.752	1.07	12.7	58.301	8.463
1	1.067	14.1	68.344	11.221	1.060	17.2	67.459	14.009
1	1.048	22.1	55.766	15.859	1.054	19.4	56.85	13.699
1	1.084	6.7	61.672	4.427	1.087	5.5	61.803	3.605
1	1.05	21.6	41.857	11.527	1.053	20.14	42.289	10.664
2	1.075	10.7	68.757	8.204	1.058	17.7	65.14	14.02
2	1.081	7.8	66.726	5.638	1.076	9.9	67.738	7.415
2	1.044	24.1	48.242	15.324	1.039	26.5	48.084	17.379
2	1.095	2.2	66.698	1.473	1.083	7.2	68.74	5.322
2	1.057	18.1	65.126	14.391	1.063	15.7	67.018	12.501
2	1.075	10.4	56.096	6.491	1.08	8.5	58.602	5.467
2	1.069	13.2	70.21	10.648	1.063	15.5	68.938	12.627
2	1.048	22.5	52.686	15.316	1.051	20.8	52.08	13.685
2	1.042	25.2	49.802	16.78	1.055	19	54.059	12.668
2	1.051	20.9	51.806	13.704	1.054	19.5	54.084	13.069
2	1.074	11.1	58.442	7.284	1.075	10.5	61.214	7.2

Raw data for the body water analysis

	Pre			Post		
Group	Total Body Water (L)	Intra-Cellular Water (L)	Extra-Cellular Water (L)	Total Body Water (L)	Intra-Cellular Water (L)	Extra-Cellular Water (L)
1	47.8	27.9	19.9	46.5	27.1	19.4
1	31.4	16.9	14.4	30.7	16.7	14
1	61.4	34.8	26.6	59.1	33.3	25.8
1	40.6	23.6	17.1	40.3	23.5	16.9
1	46.4	27.4	19	47.9	28.4	19.4
1	37.8	22.2	15.5	37.4	22	15.4
1	49.1	28.5	20.6	50	28.9	21
1	33.9	19.5	14.4	35.1	20.1	14.9
1	41.4	24.6	16.9	42	24.9	17.1
2	43.8	25.7	18.1	43.2	25.1	18.1
2	41.2	24.1	17.2	43	25.1	17.9
2	29.8	15.7	14.1	31	16.4	14.6
2	42.8	25.5	17.3	43.1	25.4	17.7

2	49.4	29.1	20.2	48.3	28.5	19.8
2	39.2	23.5	15.7	40.8	24.3	16.5
2	46.3	26.5	19.8	45.3	25.9	19.3
2	30.7	15.9	14.8	28.1	14.4	13.8
2	33.7	18	15.7	33.6	18.2	15.2
2	36.9	22	14.9	38	22.7	15.3
2	40.7	24.3	16.4	40.4	23.9	16.5

Raw data for the akimbo countermovement jump

	Pre		Post	
Group #	Peak Power	Ave Power	Peak Power	Ave Power
1	6957.54	1165.4	6732.87	1088.45
1	5175.22	401.66	5177.25	401.76
1	7760.06	1744.11	7650.76	1706.68
1	6370.13	1008.49	6828.59	1165.5
1	7674.85	1424.19	7808.44	1469.94
1	5860.72	654.23	5910.31	671.22
1	6254.03	973.91	6792.45	1158.31
1	5917.59	773.96	6006.65	804.46
1	6583.97	943.22	6814.72	1022.25
2	7265.46	1293.53	7146.04	1251.63
2	5987.71	805.86	5738.74	720.59
2	5285.38	471.44	5206.44	444.41
2	6714.26	1009.96	6889.34	1069.93
2	6688.28	941.47	7122.46	1090.17
2	5944.23	1000.37	5977.63	1011.81
2	6238.96	1188.03	6630.47	1116.62
2	5644.92	626.75	5644.82	626.75
2	5696.11	659.416	5567.58	615.44
2	6560.7	928.96	6618.39	948.71
2	6568.48	933.93	6512.81	914.86

Raw Data for the 1RM bench press and back squat

	Pre		Post	
Group #	Bench	Squat	Bench	Squat
1	74.09091	91.81818	77.44318	88.29545
1	53.69318	78.40909	54.88636	81.02273
1	138.4091	177	140.625	166.9318
1	96.70455	128.0682	99.31818	130.3977
1	112.1591	161.0795	112.5	163.6364
1	62.89773	57.27273	62.5	56.19545
1	112.1591	109.7727	107.5	112.3864
1	83.06818	107.3864	84.37727	105.0591
1	25.625	43.46591	25	48.29545
2	100.9091	N/A	106.8182	N/A
2	65.90909	75	70.90909	90.34091
2	34.94318	53.125	35.45455	53.69318
2	95.51136	138.5227	101.4773	137.5
2	125	155.9659	133.5227	165.5682
2	77.95455	90.625	84.54545	108.4091
2	36.59091	69.03409	40	79.20455
2	60	69.54545	64.09091	74.77273
2	41.93182	76.36364	40.56818	80.11364
2	41.53409	70.90909	43.63636	77.95455
2	78.23864	105.6818	73.97727	102.6136
2	72.38636	102.2727	84.03409	151.4205
2	76.36364	134.375	85.22727	171.6477

Raw data for the back squat maximal repetition set at 80% 1RM

	Pre-Back Squat					Post-Back Squat				
grp #	Total Conc. Work	Mean RFD	Peak Power	Mean Power	Peak Force	Total Conc. Work	Mean RFD	Peak Power	Mean Power	Peak Force
1	2641.67	1298.4	1070.27	168.74	2457	2132.37	2333.77	1429.79	166.17	2603.62
1	4579.5	1823.33	2869.65	359	6069.48	4475.93	3063.63	3193.7	375.76	4714.57
1	8739.87	2989.31	6656.11	542.19	6736.62	8554.46	4560.8	4772.39	624.21	5803.9
1	1739.28	1268.67	1361.81	162.75	2121.55	924.46	1943.22	1575.92	182.66	2317.91
1	3899.19	2336.39	4117.44	324.39	5386.5	4206.91	3917.84	3017.51	357.52	4491.08
1	1736.57	1393.2	1682.03	158.46	2733.75	2514.35	1895.38	2359.87	188.96	3126.48
1	3571.32	2227.9	2580.47	262.07	3881.7	2626	4916.32	2877.97	315.95	3782.21
1	1474.2	1466.26	566.66	106.16	1247.52	1380.74	1065.22	705.35	85.69	1674.61
2	2468.53	991.16	1204.78	134.78	1978.16	1214.91	1141.7	1439.57	156.82	2146.05
2	4273.98	3548.04	5911.26	425.4	8208.78	3661.09	2232.78	1670.85	211.52	3440.5
2	6040.25	4111.58	5421.79	613.49	7022.25	7679.22	23794.19	4522.39	717.71	5924.25
2	2528.98	5876.43	1691.74	333.19	2818.47	4726.03	2909.45	2052.71	388.57	3038.4
2	1334.63	4245.33	1921.72	218.65	2475.16	1280.28	4032.48	1368.11	222.21	2160.98
2	3011.96	2006.02	3997.44	187.82	5279.24	3589.87	6033.07	2313.75	205.2	3244.91
2	2329.94	2006.81	2096.44	203.74	3076.16	2642.48	5048.65	2257.47	228.3	3411.94
2	2992.71	1909.92	1509.38	224.23	2907.7	3661.09	2232.78	1670.85	211.52	3440.5

Raw data for the bench press maximal repetition set at 80% 1RM

	Pre-Bench Press					Post-Bench Press				
Grp #	Total Conc. Work	Mean RFD	Peak power	Mean Power	Peak Force	Total Conc. Work	Mean RFD	Peak power	Mean Power	Peak Force
1	2370.86	9837.5	1056.4	207.06	2298.52	2234	3154.54	1407.62	200.58	2204.92
1	1194.19	1493.39	630.67	96.14	1698.34	1238.91	2335.96	705.47	97.52	1717
1	3634.81	19153.66	2344.01	443.49	4395.97	2825.51	14814.94	2617.22	417.15	5566.62
1	2494	11811.19	1266.07	224.16	3183.79	2710.59	4252.29	1716.98	237.85	3984.95
1	2476.53	12325.99	1809.52	286.63	3664.76	2424.03	13440.08	1392.44	289.46	3179.74
1	1481.64	3072.07	1068.99	164.28	2088.9	1283.47	2703.55	1179.88	136.85	2412.9
1	1507.3	3677.35	819.52	127.45	1542.07	1541.88	1374.08	652.45	111.84	1748.25
1	1996.71	2839.04	1459.69	162.44	3057.26	2176.54	3701.89	1358.66	164.64	3152.17
1	759.1	1435.33	387.54	69	786.8	877.49	2691.43	631.62	65.45	1134.37
2	2260.38	4974.21	2819.92	178.71	6045.55	3280.73	2936.85	1203.55	255.02	2899.8
2	1887.73	1387.69	842.89	126.34	1995.67	2616.29	2362.94	925.76	166.39	1995.67
2	655.79	2168.69	319.09	57.29	899.84	847.01	1433.47	520.01	71.41	1320.05
2	2074.12	2593.79	1095.38	166.97	2949.75	3428.05	7839.54	1672.94	261.04	2811.07
2	2799.48	3905.46	1852.55	340.23	4192.2	3869.86	10890.43	2673.19	368.42	5257.8
2	1747.01	1449.87	1044.46	167.7	2784.56	2841.27	6702.22	1375.39	251.27	2855.25
2	1189.96	2877.21	673.04	149.08	919.51	691.94	3296.1	704.98	139.25	1140.75
2	3004.25	6940.45	1068.37	135.64	2152.02	2577.53	2162.2	1476	186.65	2536.9
2	718.52	728.98	446.67	98.67	1198.43	823.07	855.1	782.29	101.78	1478.25
2	1038.56	3073.11	856.35	147.3	2475.33	1586.69	2320.9	950.51	144.79	2292.05
2	1877.66	4727.93	1033.59	218.1	2169.2	2145.43	4544.4	1348.02	194.18	2692.84
2	2993.65	8616.83	1565.82	249.94	2996.63	3428.05	7839.54	1672.94	261.04	2811.07

Appendix F. Statistical Outputs

Body Composition

Tests of Within-Subjects Contrasts

Source	Measure	test	Type III Sum of Squares	df	Mean Square	F	Sig.
test	BodyDensity	Linear	1.299E-005	1	1.299E-005	.430	.520
	BodyFat	Linear	4.210	1	4.210	.725	.405
	FatFree	Linear	13.199	1	13.199	4.633	.044
	FatMass	Linear	1.730	1	1.730	.463	.504
test * Group	BodyDensity	Linear	5.966E-005	1	5.966E-005	1.974	.176
	BodyFat	Linear	11.596	1	11.596	1.998	.174
	FatFree	Linear	.133	1	.133	.047	.831
	FatMass	Linear	9.673	1	9.673	2.591	.124
Error(test)	BodyDensity	Linear	.001	19	3.023E-005		
	BodyFat	Linear	110.281	19	5.804		
	FatFree	Linear	54.130	19	2.849		
	FatMass	Linear	70.934	19	3.733		

Tests of Within-Subjects Contrasts

Source	Measure	test	Partial Eta Squared
test	BodyDensity	Linear	.022
	BodyFat	Linear	.037
	FatFree	Linear	.196
	FatMass	Linear	.024
test * Group	BodyDensity	Linear	.094
	BodyFat	Linear	.095
	FatFree	Linear	.002
	FatMass	Linear	.120
Error(test)	BodyDensity	Linear	
	BodyFat	Linear	
	FatFree	Linear	
	FatMass	Linear	

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	BodyDensity	47.523	1	47.523	91798.228	.000
	BodyFat	9356.538	1	9356.538	95.879	.000
	FatFree	157701.625	1	157701.625	608.406	.000
	FatMass	4667.805	1	4667.805	109.605	.000
Group	BodyDensity	3.585E-005	1	3.585E-005	.069	.795
	BodyFat	5.911	1	5.911	.061	.808
	FatFree	74.452	1	74.452	.287	.598
	FatMass	1.687	1	1.687	.040	.844
Error	BodyDensity	.010	19	.001		
	BodyFat	1854.147	19	97.587		
	FatFree	4924.891	19	259.205		
	FatMass	809.160	19	42.587		

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Partial Eta Squared
Intercept	BodyDensity	1.000
	BodyFat	.835
	FatFree	.970
	FatMass	.852
Group	BodyDensity	.004
	BodyFat	.003
	FatFree	.015
	FatMass	.002
Error	BodyDensity	
	BodyFat	
	FatFree	
	FatMass	

Body Water Analysis

Tests of Within-Subjects Contrasts

Source	Measure	test	Type III Sum of Squares	df	Mean Square	F
test	TotalBodWater	Linear	.009	1	.009	.011
	TotalBodWaterPerc	Linear	.000	1	.000	1.918

	IntraCellularLiters	Linear	.021	1	.021	.070
	IntracelluarPercentage	Linear	.000	1	.000	1.813
	ExtracellularLiters	Linear	.000	1	.000	.002
	ExtraCellularPercetange	Linear	6.194E-005	1	6.194E-005	2.677
test * Groups	TotalBodWater	Linear	.033	1	.033	.039
	TotalBodWaterPerc	Linear	.000	1	.000	2.368
	IntraCellularLiters	Linear	.001	1	.001	.003
	IntracelluarPercentage	Linear	.000	1	.000	2.674
	ExtracellularLiters	Linear	.025	1	.025	.181
	ExtraCellularPercetange	Linear	4.470E-005	1	4.470E-005	1.932
Error(test)	TotalBodWater	Linear	15.235	18	.846	
	TotalBodWaterPerc	Linear	.003	18	.000	
	IntraCellularLiters	Linear	5.354	18	.297	
	IntracelluarPercentage	Linear	.001	18	6.923E-005	
	ExtracellularLiters	Linear	2.515	18	.140	
	ExtraCellularPercetange	Linear	.000	18	2.313E-005	

Tests of Within-Subjects Contrasts

Source	Measure	test	Sig.	Partial Eta Squared
test	TotalBodWater	Linear	.917	.001
	TotalBodWaterPerc	Linear	.183	.096
	IntraCellularLiters	Linear	.794	.004
	IntracelluarPercentage	Linear	.195	.092
	ExtracellularLiters	Linear	.967	.000
	ExtraCellularPercetange	Linear	.119	.129
test * Groups	TotalBodWater	Linear	.845	.002
	TotalBodWaterPerc	Linear	.141	.116
	IntraCellularLiters	Linear	.956	.000
	IntracelluarPercentage	Linear	.119	.129
	ExtracellularLiters	Linear	.676	.010
	ExtraCellularPercetange	Linear	.181	.097
Error(test)	TotalBodWater	Linear		
	TotalBodWaterPerc	Linear		
	IntraCellularLiters	Linear		
	IntracelluarPercentage	Linear		
	ExtracellularLiters	Linear		
	ExtraCellularPercetange	Linear		

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	TotalBodWater	67840.528	1	67840.528	602.702	.000
	TotalBodWaterPerc	12.663	1	12.663	1834.382	.000
	IntraCellularLiters	22575.484	1	22575.484	496.868	.000
	IntracelluarPercentage	4.208	1	4.208	1053.174	.000
	ExtracellularLiters	12132.400	1	12132.400	723.098	.000
	ExtraCellularPercetange	2.269	1	2.269	4169.188	.000
Groups	TotalBodWater	139.444	1	139.444	1.239	.280
	TotalBodWaterPerc	.003	1	.003	.413	.529
	IntraCellularLiters	51.478	1	51.478	1.133	.301
	IntracelluarPercentage	.001	1	.001	.324	.576
	ExtracellularLiters	21.413	1	21.413	1.276	.273
	ExtraCellularPercetange	.000	1	.000	.545	.470
Error	TotalBodWater	2026.091	18	112.561		
	TotalBodWaterPerc	.124	18	.007		
	IntraCellularLiters	817.841	18	45.436		
	IntracelluarPercentage	.072	18	.004		
	ExtracellularLiters	302.011	18	16.778		
	ExtraCellularPercetange	.010	18	.001		

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Partial Eta Squared
Intercept	TotalBodWater	.971
	TotalBodWaterPerc	.990
	IntraCellularLiters	.965
	IntracelluarPercentage	.983
	ExtracellularLiters	.976
	ExtraCellularPercetange	.996
Groups	TotalBodWater	.064
	TotalBodWaterPerc	.022
	IntraCellularLiters	.059

	IntracelluarPercentage	.018
	ExtracellularLiters	.066
	ExtraCellularPercetange	.029
Error	TotalBodWater	
	TotalBodWaterPerc	
	IntraCellularLiters	
	IntracelluarPercentage	
	ExtracellularLiters	
	ExtraCellularPercetange	

Akimbo Countermovement Jump

Tests of Within-Subjects Contrasts

Source	Measure	test	Type III Sum of Squares	df	Mean Square	F	Sig.
test	FlightTime	Linear	.000	1	.000	.876	.362
	PeakPower	Linear	72887.958	1	72887.958	2.756	.114
	MeanPower	Linear	3948.480	1	3948.480	1.408	.251
test * Group	FlightTime	Linear	.001	1	.001	2.876	.107
	PeakPower	Linear	19136.316	1	19136.316	.724	.406
	MeanPower	Linear	5897.393	1	5897.393	2.103	.164
Error(test)	FlightTime	Linear	.009	18	.001		
	PeakPower	Linear	476080.302	18	26448.906		
	MeanPower	Linear	50488.880	18	2804.938		

Tests of Within-Subjects Contrasts

Source	Measure	test	Partial Eta Squared
test	FlightTime	Linear	.046
	PeakPower	Linear	.133
	MeanPower	Linear	.073
test * Group	FlightTime	Linear	.138
	PeakPower	Linear	.039
	MeanPower	Linear	.105
Error(test)	FlightTime	Linear	
	PeakPower	Linear	
	MeanPower	Linear	

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	FlightTime	9.995	1	9.995	665.708	.000
	PeakPower	1629038676.129	1	1629038676.129	1558.306	.000
	MeanPower	36732068.470	1	36732068.470	177.023	.000
Group	FlightTime	.005	1	.005	.348	.562
	PeakPower	976815.195	1	976815.195	.934	.347
	MeanPower	188472.346	1	188472.346	.908	.353
Error	FlightTime	.270	18	.015		
	PeakPower	18817033.718	18	1045390.762		
	MeanPower	3734971.418	18	207498.412		

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Partial Eta Squared
Intercept	FlightTime	.974
	PeakPower	.989
	MeanPower	.908
Group	FlightTime	.019
	PeakPower	.049
	MeanPower	.048
Error	FlightTime	
	PeakPower	
	MeanPower	

1RM Testing

Tests of Within-Subjects Contrasts

Source	Measure	test	Type III Sum of Squares	df	Mean Square	F	Sig.
test	Bench	Linear	263.821	1	263.821	8.199	.010
	Squat	Linear	1920.909	1	1920.909	5.197	.034
test * Group	Bench	Linear	145.292	1	145.292	4.515	.047
	Squat	Linear	2064.529	1	2064.529	5.586	.029
Error(test)	Bench	Linear	611.361	19	32.177		
	Squat	Linear	7022.670	19	369.614		

Tests of Within-Subjects Contrasts

Source	Measure	test	Partial Eta Squared
test	Bench	Linear	.301
	Squat	Linear	.215
test * Group	Bench	Linear	.192
	Squat	Linear	.227
Error(test)	Bench	Linear	
	Squat	Linear	

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	Bench	1209285.349	1	1209285.349	124.033	.000	.867
	Squat	2140580.337	1	2140580.337	145.969	.000	.885
Group	Bench	8887.158	1	8887.158	.912	.352	.046
	Squat	995.667	1	995.667	.068	.797	.004
Error	Bench	185244.094	19	9749.689			
	Squat	278627.887	19	14664.626			

Maximal Repetition Sets (Back Squat)

Tests of Within-Subjects Contrasts

Source	Measure	test	Type III Sum of Squares	df	Mean Square	F
test	Totalconcwork	Linear	113717.997	1	113717.997	.287
	MeanRFD	Linear	31249512.613	1	31249512.613	2.399
	PeakRFD	Linear	111799836057.547	1	111799836057.547	2.103
	MeanPower	Linear	1427.249	1	1427.249	.585
	PeakPower	Linear	1725520.001	1	1725520.001	2.153
	PeakFor	Linear	2575388.884	1	2575388.884	2.779
test * Group	Totalconcwork	Linear	793916.554	1	793916.554	2.003
	MeanRFD	Linear	5983283.115	1	5983283.115	.459
	PeakRFD	Linear	63888956272.967	1	63888956272.967	1.202

	MeanPower	Linear	1412.594	1	1412.594	.579
	PeakPower	Linear	940818.167	1	940818.167	1.174
	PeakFor	Linear	731641.682	1	731641.682	.789
Error(test)	Totalconcwork	Linear	5548473.110	14	396319.508	
	MeanRFD	Linear	182395545.055	14	13028253.218	
	PeakRFD	Linear	744135533714.672	14	53152538122.477	
	MeanPower	Linear	34160.036	14	2440.003	
	PeakPower	Linear	11220803.674	14	801485.977	
	PeakFor	Linear	12976272.645	14	926876.618	

Tests of Within-Subjects Contrasts

Source	Measure	test	Sig.	Partial Eta Squared
test	Totalconcwork	Linear	.601	.020
	MeanRFD	Linear	.144	.146
	PeakRFD	Linear	.169	.131
	MeanPower	Linear	.457	.040
	PeakPower	Linear	.164	.133
	PeakFor	Linear	.118	.166
test * Group	Totalconcwork	Linear	.179	.125
	MeanRFD	Linear	.509	.032
	PeakRFD	Linear	.291	.079
	MeanPower	Linear	.459	.040
	PeakPower	Linear	.297	.077
	PeakFor	Linear	.389	.053
Error(test)	Totalconcwork	Linear		
	MeanRFD	Linear		
	PeakRFD	Linear		
	MeanPower	Linear		
	PeakPower	Linear		
	PeakFor	Linear		

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.

Intercept	Totalconcwork	368783709.934	1	368783709.934	42.959	.000
	MeanRFD	382399719.913	1	382399719.913	22.766	.000
	PeakRFD	15643932348887.908	1	15643932348887.908	69.039	.000
	MeanPower	2567281.696	1	2567281.696	49.328	.000
	PeakPower	209547246.441	1	209547246.441	49.335	.000
	PeakFor	447917040.994	1	447917040.994	81.822	.000
Group	Totalconcwork	96895.724	1	96895.724	.011	.917
	MeanRFD	35323588.455	1	35323588.455	2.103	.169
	PeakRFD	3023309188.800	1	3023309188.800	.013	.910
	MeanPower	2859.003	1	2859.003	.055	.818
	PeakPower	1421.911	1	1421.911	.000	.986
	PeakFor	63452.578	1	63452.578	.012	.916
Error	Totalconcwork	120184538.872	14	8584609.919		
	MeanRFD	235154242.076	14	16796731.577		
	PeakRFD	3172357998118.401	14	226596999865.600		
	MeanPower	728627.756	14	52044.840		
	PeakPower	59464093.274	14	4247435.234		
	PeakFor	76640472.400	14	5474319.457		

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Partial Eta Squared
Intercept	Totalconcwork	.754
	MeanRFD	.619
	PeakRFD	.831
	MeanPower	.779
	PeakPower	.779
	PeakFor	.854
Group	Totalconcwork	.001
	MeanRFD	.131
	PeakRFD	.001
	MeanPower	.004
	PeakPower	.000
	PeakFor	.001
Error	Totalconcwork	

	MeanRFD	
	PeakRFD	
	MeanPower	
	PeakPower	
	PeakFor	

Maximal Repetition Sets (Bench Press)

Tests of Within-Subjects Contrasts

Source	Measure	test	Type III Sum of Squares	df	Mean Square	F
test	TotalConcWork	Linear	461769.456	1	461769.456	3.759
	MeanRFD	Linear	3093952.181	1	3093952.181	.526
	PeakRFD	Linear	4200761742.227	1	4200761742.227	.322
	PeakPower	Linear	138075.659	1	138075.659	1.152
	MeanPower	Linear	1462.584	1	1462.584	3.070
	PeakForce	Linear	110907.944	1	110907.944	.307
test * Group	TotalConcWork	Linear	799798.367	1	799798.367	6.510
	MeanRFD	Linear	19026574.916	1	19026574.916	3.236
	PeakRFD	Linear	9769654964.470	1	9769654964.470	.750
	PeakPower	Linear	6305.099	1	6305.099	.053
	MeanPower	Linear	3525.838	1	3525.838	7.402
	PeakForce	Linear	266966.175	1	266966.175	.740
Error(test)	TotalConcWork	Linear	2334300.864	19	122857.940	
	MeanRFD	Linear	111707342.098	19	5879333.795	
	PeakRFD	Linear	247597078262.501	19	13031425171.711	
	PeakPower	Linear	2277165.284	19	119850.804	
	MeanPower	Linear	9050.822	19	476.359	
	PeakForce	Linear	6856233.743	19	360854.408	

Tests of Within-Subjects Contrasts

Source	Measure	test	Sig.	Partial Eta Squared
test	TotalConcWork	Linear	.068	.165
	MeanRFD	Linear	.477	.027
	PeakRFD	Linear	.577	.017

test * Group	PeakPower	Linear	.297	.057
	MeanPower	Linear	.096	.139
	PeakForce	Linear	.586	.016
	TotalConcWork	Linear	.019	.255
	MeanRFD	Linear	.088	.146
	PeakRFD	Linear	.397	.038
	PeakPower	Linear	.821	.003
	MeanPower	Linear	.014	.280
	PeakForce	Linear	.400	.037
Error(test)	TotalConcWork	Linear		
	MeanRFD	Linear		
	PeakRFD	Linear		
	PeakPower	Linear		
	MeanPower	Linear		
	PeakForce	Linear		

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	TotalConcWork	169243357.619	1	169243357.619	110.842	.000
	MeanRFD	1105207667.418	1	1105207667.418	36.642	.000
	PeakRFD	8217804285909.402	1	8217804285909.402	95.199	.000
	PeakPower	62013392.987	1	62013392.987	93.623	.000
	MeanPower	1480873.011	1	1480873.011	86.021	.000
	PeakForce	277353516.164	1	277353516.164	97.027	.000
Group	TotalConcWork	208004.066	1	208004.066	.136	.716
	MeanRFD	55052964.794	1	55052964.794	1.825	.193
	PeakRFD	6343761789.859	1	6343761789.859	.073	.789
	PeakPower	20929.880	1	20929.880	.032	.861
	MeanPower	962.055	1	962.055	.056	.816
	PeakForce	148757.840	1	148757.840	.052	.822
Error	TotalConcWork	29010869.291	19	1526887.857		

	MeanRFD	573089535.794	19	30162607.147		
	PeakRFD	1640124302072.833	19	86322331688.044		
	PeakPower	12585126.802	19	662375.095		
	MeanPower	327088.549	19	17215.187		
	PeakForce	54311902.649	19	2858521.192		

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Partial Eta Squared
Intercept	TotalConcWork	.854
	MeanRFD	.659
	PeakRFD	.834
	PeakPower	.831
	MeanPower	.819
	PeakForce	.836
Group	TotalConcWork	.007
	MeanRFD	.088
	PeakRFD	.004
	PeakPower	.002
	MeanPower	.003
	PeakForce	.003
Error	TotalConcWork	
	MeanRFD	
	PeakRFD	
	PeakPower	
	MeanPower	
	PeakForce	