ABSTRACT

THE EFFECT OF CREATINE AND/OR CAFFEINE INGESTION ON REPEATED BOUTS OF HIGH-INTENSITY EXERCISE PERFORMANCE

The purpose of this study was to determine what effect caffeine, creatine, or the combination of treatment would have on multiple bouts of high intensity exercise performance. Some research has shown caffeine and creatine to elicit an ergogenic effect on repeated bouts of high-intensity performance, but new research investigating the combination has been done. Subjects were asked to undergo 4 separate treatments (placebo, caffeine only, creatine only, creatine + caffeine) for 9 days and then participate in 2 different experimental conditions; 6 x 6 second Wingate, 6 x 50-meter Track sprints. To determine statistical significance a repeated measure was preformed comparing treatments to sprint, a paired sample t-test was performed to determine during which sprint it had occurred. The primary findings of the study were creatine loading plus acute caffeine ingestion improved peak power and mean power in the 1st and 2nd 6 second Wingate. The ingestion of caffeine only improved 50 m sprint time during the 4th, 5th, and 6th trial over placebo. This is the first study to definitively show that the ergogenic effect of caffeine and/or creatine might be specific to the type of activity performed and the environment in which the supplement is used.

Zoltan Andre Torok
May 2010
THE EFFECT OF CREATINE AND/OR CAFFEINE INGESTION ON REPEATED BOUTS OF HIGH-INTENSITY EXERCISE PERFORMANCE

by

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts in Kinesiology in the College of Health and Human Services California State University, Fresno May 2010
APPROVED

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Chapter 1

INTRODUCTION

Caffeine is one of the most widely used ergogenic aids in athletics today. Research has established that caffeine ingestion can increase aerobic performance (Graham, 2001; Magkos & Kavouras, 2005 Malek et al., 2006; Tarnopolsky, 1994). The research regarding caffeine and its effect on anaerobic performance has not been so established, with few studies examining its effects on multiple sprint performance.

The majority of research suggests that caffeine offers no improvement on sprint performance (Collomp, Ahmaidi, Audran, Chanal, & Prefaut, 1991; Greer, McLean, & Graham, 1998; Hoffman, Stout, Falvo, Kang, & Ratamess, 2005). However, some studies have found that caffeine may improve this type of exercise (Anselme, Collomp, Mercier, Ahmaidi, & Prefaut, 1992; Collomp, Ahmaidi, Chatard, Audran, & Prefaut, 1992; Doherty, Smith, & Hughes, 2004). In light of these studies there still remains no clear distinction as to caffeine’s ergogenic benefit to multiple sprint performance.

It has been suggested that caffeine may increase anaerobic performance by several mechanisms. Caffeine has an inhibitory effect on adenosine (Fredholm, 1995), which may facilitate the recruitment of additional motor units (Williams, Barnes, & Gadberry, 1987). Doherty et al. (2004) found that caffeine had a positive impact on subjects’ fatigue perception. This may improve performance by allowing the subject to remain at an elevated rate for a longer period. Investigations have also found that caffeine increased the release and sensitivity of calcium within skeletal muscle, thus improving their contractile properties.
(Bianchi, 1961). Based on the above-mentioned positive physiological effects, there is probable evidence to suggest that caffeine may offer improvement to sprint performance.

In comparison to caffeine, creatine may be one of the most widely consumed supplements to improve anaerobic type performance. Creatine phosphate is the primary energy source during the first 10 seconds of exercise. Users ingest creatine with hopes of increasing their creatine phosphate stores within skeletal muscle and improve their ability to perform high intensity exercise. Related to the ergogenic benefits of creatine supplementation, research has shown that creatine offers improvement to multiple sprint performance (Dawson, 1995; Flanagan & Jakeman, 2006; Gill, Hall, & Blaxevich, 2004; Kishali, Kiyici, Burmaoglu, Tas, & Bayraktar, 2007; Peyrebrune, Stokes, Hall, & Nevill, 2005; Skare, Skadberg, & Wisnes, 2001; Wright, Grandjean, & Pascoe, 2007).

Research has shown that the ingestion of 5 grams of creatine a day for 7 days increased intramuscular creatine stores by 17-20% (Harris, Soderlund, & Hultman, 1992), and that this may improve high intensity performance. Supplementation has also been shown to aid in the rephosphorylation of adenosine diphosphate to adenosine triphosphate (Demant & Rhodes, 1999), which may allow for a faster turnover of ATP production allowing for the potential increase in anaerobic performance.

However there is also research that suggests creatine lends little or no improvement to multiple sprint performance (Ahmun, Tong, & Grimshaw, 2005; Cornish, Chilibeck, & Burke, 2006; Delecluse, Diels, & Goris, 2003; Glaister et al., 2006; Kinugasa et al., 2003; Silva, Reis, Guidetti, Alves, & Mota, 2007). Due to the conflicting findings there is no definitive answer as to whether creatine is effective for improving multiple sprint performance.
Previous research has demonstrated that there is potential for both creatine and caffeine to improve multiple sprint performance. Although the research is limited, there have been studies that have investigated the combined effects of these two supplements on multiple sprint performance. Research has suggested that the combination may improve running time to exhaustion (Doherty, Smith, Davison, & Hughes, 2002), whereas other investigations have shown that caffeine may counteract the ergogenic benefit of creatine (Hespel, Eijnde, & Van Leemputte, 2002; Vanakoski, Kosunen, Meririnne, & Seppala, 1998; Vandenberghe et al., 1996).

Although the individual effects of caffeine and creatine on high intensity exercise have been studied, the majority of research done on caffeine has been completed in a laboratory environment, using power output as the main measure of performance (Anselme et al., 1992; Doherty et al., 2004; Greer et al., 1998; Hoffman et al., 2005 Jackman, Wendling, Friars, & Graham, 1996) with little research done in the field environment (Collomp et al., 1991; Glaister et al., 2008) and only one study comparing the two environments (Wiles, Coleman, Tegerdine, & Swaine, 2006). The same is not the case with creatine, where there has been a similar number of studies investigating both the field environment (Aaserud, Gramvik, Olsen, & Jensen, 1998; Ahmun et al., 2005; Cox, Mujika, Tumilty, & Burke, 2002; Delecluse et al., 2003; Glaister et al., 2006; Izquierdo, Ibanez, Gonzalez-Badillo, & Gorostiaga, 2002; Kishali et al., 2007; Mujika, Padilla, Ibanez, Izquierdo, & Gorostiaga, 2000; Ostojic, 2004; Peyrebrune et al., 2005; Pluim et al., 2005; Silva et al., 2007; Skare et al., 2001) and the laboratory environment (Balsom, 1993; Barnett, Hinds, & Jenkins, 1996; Cooke, Grandjean, & Barnes, 1995; Cornish et al., 2006; Dawson, 1995; Flanagan & Jakeman, 2006; Gill et al., 2004; Hoffman et al., 2005; Kinugasa et al., 2003; Kreider, Ferreira,
Wilson, Grindstaff, & Plisk, 1998; Ledford & Branch, 1999; Wright et al., 2007). However, no study has compared the effects of creatine and caffeine in both environments.

Thus further research should be conducted to investigate the effects of each supplement in both the laboratory and the field. Furthermore there is no research investigating the combined effects of creatine and caffeine in both the laboratory and field environment. Therefore, the purpose of this study was to determine if the ingestion of creatine and/or caffeine provided ergogenic benefit on repeated bouts of high-intensity exercise in two different environmental conditions. We hypothesized that the combined effects of creatine and caffeine, caffeine only, and creatine only would have a positive ergogenic effect on repeated bouts of high-intensity exercise in both environmental conditions.

Significance

Due to the lack of sufficient research examining the combined effect of creatine plus caffeine on multiple sprint performance, there is need for further research. Such research could possibly shed light whether there is an enhancement in performance when the two supplements are combined, or if the ingestion of these two supplements would be unsuccessful in enhancing performance. Equally, the lack of research comparing two separate environmental conditions in the same protocol was warranted as the outcome could uncover potential ergogenic benefits that yet to have been observed.

Delimitations

1. Subjects were male volunteers (18-25 years of age).
2. Subjects participating in Fresno State Athletics were excluded.
3. All treatments were double-blind and randomized.
4. Supplementation protocols and time lines were established and strictly followed by the principal investigator and subjects.

5. All subjects kept a diet log 48 hours before testing. Subjects must refrain from all outside caffeine consumption 24 hours prior to testing and refrain from consuming creatine-containing substances for the duration of the study.

Limitations
1. This study evaluated males only, because caffeine’s bioavailability is affected by hormonal changes during a female menstrual cycle (Lane, Steege, Rupp, & Kuhn 1992).

2. It was difficult to control for a subject’s individual nutritional regimen and response to training. However most individuals supplemented with creatine and caffeine in conjunction with their individual regimes. Therefore, it was assumed that any ergogenic benefit is due to the scheduled supplemental regimen.

Definition of Terms
For the purpose of this study, the following terms were defined:

1. Anaerobic Exercise: a physical activity which energetic support comes primarily from reactions that can proceed in the absence of oxygen.

2. Caffeine (CAF): a bitter, white crystalline xanthine alkaloid that is a psychoactive stimulant drug.

3. Creatine monohydrate (CR): a form of creatine that is taken as a dietary supplement in order to increase creatine phosphate storage in the muscles.

4. Wingate test (WANT): a popular test performed on a cycle ergometer to assess peak anaerobic power, anaerobic fatigue, and anaerobic capacity.
Caffeine: Introduction

Caffeine (CAF) is one of the most widely used drugs in the world today. It is found in coffee, tea, energy drinks, workout supplements, diet pills, chocolate, and energy bars. It has many physiological functions such as stimulation of the central nervous system, (Davis et al., 2002), alteration of fat and carbohydrate metabolism (Costill, Dalsky, & Fink, 1978), increased motor unit recruitment (Kalmar & Cafarelli, 1999) and Ca\(^{2+}\) release from the sacroplasmic reticulum (Magkos & Kavouras, 2005). Furthermore it has been suggested that caffeine could possibly effect neuromuscular transmission (Williams et al., 1987), block adenosine receptors (Davis et al., 2002), and improve maximal muscle activation (Kalmar & Cafarelli, 1999).

Caffeine: Multiple Sprint Performance

Caffeine’s effect on multiple sprint performance is contentious; research shows caffeine to have both a positive (Anselme et al., 1992; Collomp et al., 1991) and negative (Beck et al., 2006; Glaister et al., 2008; Greer et al., 1998; Hoffman et al., 2005; Paton, Hopkins, & Vollebret, 2001) effect on multiple sprint performance.

Collomp et al. (1991) examined caffeine’s impact on mean swim velocity. Seven trained and untrained subjects ingested 250 mg of caffeine 1 hour prior to completing two, 100-meter freestyle swim bouts, separated by 20 minutes of
passive recovery. Caffeine improved trained subjects’ swim time in the second 100-meter trial, with no improvement observed in the untrained subjects.

Similarly Jackman et al. (1996) investigated the effect of caffeine on supramaximal muscle endurance. Fourteen active adults ingested 6 mg/kg⁻¹ of caffeine or placebo and completed 2 x 2-minute cycle trials at a power output equal to VO₂max, separated by 6 minutes of passive recovery followed by an all-out sprint until voluntary exhaustion. Caffeine ingestion significantly increased time to exhaustion during the final sprint.

Anselme et al. (1992) investigated whether caffeine increased maximal anaerobic power (W) during a force-velocity test performed on a cycle ergometer. Fourteen recreationally trained subjects ingested 250 mg of caffeine or placebo and performed a total of 4 x 6-second maximal sprints interspersed by 5-minutes. The initial sprint load was 2 kg for all subjects. During each subsequent sprint the load was increased by 2 kg. Termination of the test occurred when the subject’s power output in the current trial was lower than the subsequent trial. Although both placebo and caffeine groups completed four sprints, the caffeine group was able to achieve a higher power output in the final trial compared to the placebo group.

In contrast, some studies have reported that caffeine ingestion may actually decrease multiple bouts of high intensity performance. Paton et al. (2001) tested the effect caffeine had on multiple sprint performance. Sixteen male team sport athletes ingested either 6 mg/kg⁻¹ of caffeine or placebo 60 minutes prior to 10 x 20-meter sprints that were separated by 10 seconds of passive rest. While caffeine led to faster sprint times in the early stages of the 10 x 20-meter sprint, overall performance was negatively affected during the caffeine trial.
In similar research, Glaister et al. (2008) investigated caffeine’s effect on repeated sprint running performance. Twenty-one physically active men were given either 5 mg/kg⁻¹ of caffeine or placebo. Subjects then completed 12 x 30-meter sprints separated by 35-seconds of passive rest. Despite a decrease in sprint time in the first five sprints, caffeine supplementation result in an overall increase in fatigue compared to placebo.

Greer et al. (1998), studied the effects of caffeine on repeated Wingate exercise tests. Nine physically active men ingested either 6-mg/kg⁻¹ of caffeine or placebo 60 minutes prior to completing 4 x 30-second Wingate trials separated by 4 minutes of rest. Findings showed that caffeine ingestion had no effect on power output (peak power, average power, rate of power loss) in the first two Wingate tests and had a negative effect on power output (peak power, average power) in the latter two exercise bouts.

Beck et al. (2006) observed the effects a caffeine-containing supplement had on two, 30-second Wingate trials, separated by 6 minutes of rest in 37 males. They found that the caffeine-containing supplement had no effect on anaerobic power (peak power, mean power) as compared to the placebo group.

**Caffeine: Mechanism**

While the exact mechanism by which caffeine may enhance anaerobic exercise performance is debatable, several have been proposed. Caffeine is thought to stimulate the central nervous system (CNS) by inhibiting adenosine binding to specific receptors (Davis et al., 2002). Adenosine concentration increases with exercise intensity, as its concentration is regulated by ATP metabolism (Hellsten, Maclean, Radegran, Saltin, & Bangsbo, 1998). Adenosine acts as a CNS depressant, inhibiting neuroexcitability (Fredholm, 1995),
neurotransmitter release (Okada et al., 1997), arousal (Porkka-Heiskanen, 1999), and spontaneous activity (Barraco, Coffin, Altman, & Winder, 1983). Caffeine’s inhibitory effect on adenosine may increase neuronal activity by increasing neurotransmitter release, which may facilitate the recruitment of additional motor units (Breckenridge, Burn, & Matshinsky, 1967; Williams et al., 1987; Wilson, 1973). Adenosine has also been shown to induce muscle pain in the forearm when injected into the brachial artery in healthy individuals (Sylvan, Jonzono, & Fredholm, 1988). Caffeine is commonly used in pain relief medications such as Midol and Excedrin, due its ability to the block adenosine receptors (Fredholm, 1995). This ability to decrease pain could allow for sustained or increased motor unit recruitment, which could help maintain, or increase force output (Fredholm, 1995).

As previously mentioned, caffeine has been shown to attenuate the perception of pain. However its affect on rate of perceived exertion (RPE) is controversial. Doherty et al. (2004) demonstrated caffeine decreases RPE as compared to placebo. While others (Green, Wickwire, & McLester, 2007; Hudson, Green, & Bishop, 2007; Stuart, Hopkins, & Cook, 2005) have shown no effect.

Caffeine has also been suggested to affect motor unit recruitment. Experimental evidence has shown administration of caffeine increases the contractility of fresh and fatigued isolated rat soleus muscle (Connett, Ugol, Hammack, & Hays, 1983; MacIntosh, Barbee, & Stanisby, 1981). Eke-Okoro (1982) found that caffeine reduces the stimulus threshold required for elicitation of a reflex in an electrically stimulated muscle. This suggests that caffeine may improve the electrical impulse between the motor neuron and the muscle, in such a way that muscle activation in improved. Alternatively, Kalmar and Cafarelli
(1999) found that caffeine increased maximal muscle activation, as well as voluntary motor unit recruitment, without altering the amplitude of H reflex, the reflectory reaction of muscles after electrical stimulation of sensory fiber. However, several studies have shown caffeine supplementation to have no effect on EMG signaling, implying that caffeine may not impact motor unit recruitment (Greer, Morales, & Coles, 2006; Meyers & Cafarelli, 2005; Williams et al., 1987).

Bianchi (1961) found that caffeine rapidly enters the muscle fiber and causes increased myofilament sensitivity to calcium, a rapid release of calcium from the sarcoplasmic reticulum into the myoplasm and increased activation of a “calcium-induced” calcium release mechanism. This would increase the crossbridge activation of actin and myosin, which may increase contractility of skeletal muscle.

It has been suggest that caffeine ingestion may impact the concentration of blood lactate. Previous research has shown blood lactate concentration increased after caffeine ingestion, with a corresponding increase in anaerobic exercise performance (Anselme et al., 1992; Collomp et al. 1991; Glaister et al., 2008; Jackman et al., 1996). Conversely, other studies have shown that caffeine supplementation had little effect on blood lactate concentration, without enhancement to repeated Wingate trials (Greer et al., 1998). Previous research postulated that increased blood lactate resulted from increased muscle metabolism, facilitated by the enhancement caffeine has on glycolytic rate (Anselme et al., 1992). In contrast, Jackman et al. found that caffeine increased postexercise blood lactate concentration without any measurable increase in glycogenolysis and that fatigue occurred without a subsequent impact on muscle glycogen stores. Likewise, caffeine is thought to stimulate epinephrine secretion. Spriet, Ren, and Hultman (1988) found that epinephrine infusion enhanced muscle glycogensis
during prolonged electrical stimulus. At this time future research is needed to ascertained what the exact influence caffeine has on muscle metabolism during anaerobic exercise performance.

Creatine: Introduction

Creatine monohydrate (CR) is perhaps one of the most widely used supplements ingested in an attempt to improve high intensity athletic performance. A large amount of research has been done on CR supplementation in efforts to delineate its sport-specific effects. It has been hypothesized that CR can act through a number of pathways, and appears to be most effective in short-bout, high-intensity physical activities.

Creatine: Repeated Sprint Performance

During the first 6-seconds of vigorous high-intensity exercise, the quantity of ATP consumed is divided between creatine phosphate (PCr) anaerobic glycolysis (Gaitanos, Williams, Boobis, & Brooks, 1993). The quantity of PCr in skeletal muscle is limited and the depletion of PCr may result in fatigue during repeated bouts of high intensity exercise (Bogdanis, Nevil, Boobis, Lakomy, & Nevil, 1995). Peak power has increased and muscle fatigue have been observed to decrease following the resynthesis of PCr (Bogdanis et al., 1995) and the accessibility of skeletal muscle PCr is thought to be one of the potential limiting factor in maintaining work capacity during repeated high intensity exercise (Bogdanis et al., 1995).

Skare et al. (2001) examined the effect creatine supplementation had on multiple sprint performance. Eighteen male sprinters (100m, 200m, and 400m athletes) ingested either placebo or 5 grams of CR, 4 times a day, over a 5-day period and then completed two separate sprint protocols in an indoor track.
The first exercise bout completed was a 100-meter sprint. After 25 minutes of passive rest, subjects completed 6 x 60-meter sprints, interspersed by 50 seconds of passive rest. Creatine supplementation decreased sprint times in five out of six intermittent 60-meter sprints and significantly improved results in the 100-meter sprint. The study concluded that the increase in skeletal muscle PCr might delay the depletion of PCr and maintain ATP turnover rate, suggesting increased energy availability.

Equally, Dawson (1995) investigated whether oral creatine loading could enhance single and repeated short sprint performance. Two separate groups were assigned to either a placebo group or a creatine group, who ingested 5 grams of creatine, four times a day for 5 days. Group 1 completed 1 x 10-second sprint. Work and peak power was measured at 2, 4, 6, 8, and 10 seconds. Group 2 completed 6 x 6-second sprints interspersed by 30 seconds of recovery. Performance in group 1 was unaffected by creatine supplementation, whereas total work was improved in group 2, as compared to placebo. Many other studies have also demonstrated a performance-enhancing effect of creatine on repetitive bouts of high intensity exercise (Aaserud et al., 1998; Balsom, 1993; Cox et al., 2002; Flanagan & Jakeman, 2006; Gill et al., 2004; Izquierdo et al., 2002; Kishali et al., 2007; Kreider et al., 1998; Mujika et al., 2000; Ostojic, 2004; Peyrebrune et al., 2005; Wright et al., 2007).

Ahmun et al. (2005) examined the effect creatine had on multiple sprint running performance and multiple sprint cycling performance. Fourteen highly trained male rugby players ingested placebo or 20 g/day of CR for 5 days. Subjects completed two experimental protocols consisting of 10 x 6-second modified Wingate trials interspersed by 30 seconds of slow pedaling and 10 x 40-meter sprints on an indoor track interspersed by 30 seconds of passive rest. Creatine
did not significantly improve performance on trained rugby players during repetitive and maximal cycling and sprinting. It was suggested that the supplementation of CR was insufficient in increasing muscle PC to level necessary to enhance multiple sprint performance.

In a similar study, Kinugasa et al. (2003), investigated whether creatine supplementation influenced sprint performance during maximum intermittent cycling exercise. Twelve healthy young men ingested 5 grams of CR four times a day for 5 days. Subjects completed 10 x 6-second sprints on a cycle ergometer, interspersed by 30 seconds. The metabolic state of the thigh muscle was also assessed using MR imaging. Peak power, mean power, and total work were recorded on the 2\(^{nd}\), 5\(^{th}\), and 10\(^{th}\) cycle sprint. Creatine supplementation had no effect on sprint cycling performance and blood lactate accumulation. Several other studies have shown creatine supplementation to offer little ergogenic benefit during repeated, high-intensity sprint performance (Ahmun et al., 2005; Barnett et al., 1996; Cooke et al., 1995; Cornish et al., 2006; Delecluse et al., 2003; Glaister et al., 2006; Hoffman et al., 2005; Kinugasa et al., 2003; Ledford & Branch, 1999; Pluim et al., 2005; Redondo, Dowlling, Graham, Almada, & Williams, 1996; Silva et al., 2007).

Creatine: Mechanism

Creatine is naturally occurring in the body, with 95% found in the skeletal muscle and is synthesized in the liver, kidney, and pancreas (Persky, Brazeau, & Hochhaus, 2003). Harris et al. (1992) showed that creatine administration of 5 grams, four times a day for 2-6 days, with a maintenance dosage for 3-5 days increased intramuscular total creatine levels by 17-20%. They also found that by day 3 of loading, urinary loss of creatine was as high as 60%, suggesting that 5
days of creatine loading is not necessary. Similarly, Terjung, Clarkson, and Eichner (2000) suggested that maximal accumulation of intramuscular creatine occurs after 2 days, and loading with 20 grams a day after this time is unnecessary.

Research has suggested that creatine supplementation works through a number of distinct mechanisms. Supplementation of CR increases PCr concentrations in skeletal muscle, which will then aid in the rephosphorylation of adenosine diphosphate (ADP) into adenosine triphosphate (ATP) by the CR kinase enzymatically driven reaction (Demant & Rhodes, 1999; Hespel, Eijnde, & Derave, 2001). Creatine supplementation can enhance the capacity for high-energy phosphate diffusion between the mitochondria and myosin heads, which better enables them to engage the contractile protein in cross-bridge cycling and tension maintenance (Mesa, Ruiz, & Gonzalez-Gross, 2002). Creatine supplementation can act to buffer pH changes brought about by an increasing acidosis by utilizing the hydrogen ions during the CR kinase reaction and the rephosphorylation of ADP to ATP, to improve cellular homeostasis (Mesa et al., 2002). It has also been suggested that PCr supplementation is associated with muscle hypertrophy and increased protein synthesis (Haussinger, Roth, & Lang, 1993). Creatine may have an osmotic effect causing movement of extracellular water into the muscle cell, which is a stimulus for protein synthesis or by decreasing the rate of protein degradation (Haussinger et al., 1993). It has also been suggested that creatine supplementation can shorten relaxation time during intermittent maximal isometric contraction by facilitating calcium uptake by the sarcoplasmic reticulum (Van Leemputte, Vandenberghe, & Hespel, 1999).
Creatine and Caffeine: Repeated Sprint Performance

As mentioned, caffeine and creatine are two of the most widely ingested supplements used to augment performance. Some research has shown that the supplementation of caffeine may increase performance in maximal intensity sprints in trained and untrained subjects (Anselme et al., 1992; Collomp et al., 1991; Doherty et al., 2004; Glaister et al., 2008; Jackman et al., 1996). Research has also demonstrated that creatine may significantly improve performance in short, maximal intensity sprints in trained and untrained subjects (Aaserud et al., 1998; Balsom, 1993; Cox et al., 2002; Dawson, 1995; Flanagan & Jakeman, 2006; Gill et al., 2004; Izquierdo et al., 2002; Kishali et al., 2007; Kreider et al., 1998; Mujika et al., 2000; Ostojic, 2004; Peyrebrune et al., 2005; Skare et al., 2001; Wright et al., 2007).

Currently, very little research has been completed that examines what the combined effects of caffeine and creatine have on repeated high-intensity performance. Doherty et al. (2002) concluded that there is an ergogenic effect from 6 days of creatine loading combined with acute caffeine ingestion and time to exhaustion while running on a treadmill at an intensity 125% VO_{2max}. In contrast, Hespel et al. (2002) and Vandenberghe et al. (1996) reported that caffeine intake counteracts the ergogenic effect of creatine loading. Similarly, Vanakoski et al. (1998) found the combination of caffeine and creatine provided no ergogenic benefit during 3 x 1-minute sprint cycle tests as well as a 45-minute moderate-intensity cycle test. To date, there is a void in the research that examines the ergogenic effect of caffeine and creatine on short, multiple bouts of high-intensity sprint performance.

The bulk of the research done investigating caffeine’s effect on repeated high-intensity exercise has been completed in a laboratory environment (Anselme
et al., 1992; Doherty et al., 2002; Greer et al., 1998; Hoffman et al., 2005; Jackman et al., 1996; William, Cribb, Cooke, & Hayes, 2008; Woolf, Bidwell, & Carlson, 2008). There has been very limited research investigating caffeine’s effect on repeated high-intensity exercise in a field environment (Collomp et al., 1992; Glaister et al., 2008; Paton et al., 2001). This is not the case regarding creatine. There is a similar amount of research done, which examines the effects of creatine supplementation on repeated bouts of high intensity exercise in both the laboratory (Balsom, 1993; Barnett et al., 1996; Cooke et al., 1995; Cornish et al., 2006; Dawson, 1995; Flanagan & Jakeman, 2006; Gill et al., 2004; Hoffman et al., 2005; Kinugasa et al., 2004; Kreider et al., 1998; Ledford & Branch, 1999; Wright et al., 2007), and field environment (Aaserud et al., 1998; Ahmun et al., 2005; Cox et al., 2002; Delecluse et al., 2003; Glaister et al., 2006; Izquierdo et al., 2002; Kishali et al., 2007; Mujika et al., 2000; Ostojic, 2004; Peyrebrune et al., 2005; Pluim et al., 2005; Silva et al., 2007; Skare et al., 2001). However, there has yet to be a study that investigates either supplement’s ergogenic effect in both the laboratory and field environment.

Furthermore, there is a lack of studies comparing a laboratory and field protocol using the same subjects and the same protocol. Due to this lack of this research, future research should investigate the effect of creatine and/or caffeine ingestion on repeated bouts of high intensity exercise performance, in both a laboratory and field setting.
Chapter 3

METHODS

The following chapter will outline the proposed procedure for this investigation. Subjects, research design (research timeline, testing procedure) and statistical analysis will be outlined in this chapter.

Subjects

Twenty male college students from California State University Fresno, between the ages of 18-28 volunteered for this double blind, randomized investigation. Prior to participating in the study, subjects filled out a consent form (Appendix A), and a health questionnaire (Appendix B). All experimental protocols were approved by the committee on the Protection of Human Subjects Department at California State University, Fresno (Appendix C). During the duration of the study subjects were asked to keep a nutritional log (Appendix D) that was submitted at the beginning of each testing period. All were submitted at the beginning of the first trial session. All benefits and risks were verbally explained to the subjects in addition to their written inclusion on the above-mentioned forms.

Procedures

During the course of this investigation, subjects reported to the Human Performance Lab (HPL), located in South Gym room 139, and the Student Recreation Center track on the California State University, Fresno, campus on eight different occasions. The first visit was to South Gym 139. Subjects completed and signed all necessary forms, as well as received verbal explanation
of the benefits and risks associated with the study. The first day in each environment (lab or track), subjects received an introduction to the experimental procedure.

**Treatments**

1. Placebo treatment (PL): Placebo (corn starch, 5 grams, four times daily) loading for 1 week prior to testing plus 1 hour prior on the day of testing, a gelatine capsule (dextrose).

2. Caffeine treatment (CAF): Placebo (corn starch, 5 grams, four times daily) loading for 1 week prior to testing plus 1 hour prior on the day of the test, a caffeine gelatin capsule (5 mg/kg body weight).

3. Creatine supplement (CR): Creatine monohydrate loading (5 grams, four times daily) for 1 week prior to testing plus 1 hour prior on the day of testing, a placebo gelatin capsule (dextrose).

4. Creatine plus caffeine treatment (CRCAF): Creatine monohydrate loading (5 grams, four times a day) for 1 week prior to testing plus 1 hour prior on the day of testing, a caffeine gelatin capsule (5 mg/kg body weight).

Nine days prior to the subsequent four supplement possibilities, subjects were given 9 days worth of prepacked supplements. Each day contained four prepacked supplements, containing either 5 grams of cornstarch or 5 grams of creatine monohydrate. Subjects ingested the four prepacked supplements at evenly spaced intervals. On the 7th day, 1 hour prior to testing, subjects reported to either the Human Performance Lab (HPL) or the track and ingested either placebo pill (dextrose) or caffeine (5 mg/kg body weight). Two days later, subjects reported to the alternate environment and ingested a pill containing the same contents as did previously. Between each experimental protocol there was a
3-week period that served as a “wash out” to ensure that subjects no longer have elevated levels creatine monohydrate from the previous experimental protocol.

For the lab testing subjects reported to the HPL, located in South Gym room 139. After a standardized warm-up consisting of 10 minutes of light pedaling, subjects performed 6 x 6-second all-out Wingate tests on the cycle ergometer. Subjects cycled against a load equaling 15% of their bodyweight in kilograms. Each 6-second sprint was separated by 24 seconds of light unloaded cycling, followed by a 6-second build up period. During the 6-second build up, subjects increased their speed to reach their fastest RPM when the countdown reached zero and the load was applied to the flywheel. During each of the six sprints, subjects’ power output (max power output, mean power output, percent decline power output), as well as heart rate were measured.

For the track testing, subjects reported to the Student Recreation Center track. After a standardized warm-up consisting of 10 minutes of light jogging, subjects performed 6 x 50-meter sprints separated by 30 seconds of light walking. Subjects sprinted on the straightaway of an oval track. Upon finishing a sprint, subjects walked the curved portion of the track to the starting line of the next sprint. Upon arriving at the start line, subjects were given a 5-second verbal countdown, at which point they got into a standing ready stance before initiating the sprint. Heart rates were recorded at the beginning the first sprint and at the end of all other sprints. Subjects’ sprint times were measured by Sparq timing systems (Beaverton, Oregon).

**Statistical Analysis**

In order to test for differences in the dependent measures as a function of the experimental treatments, a One-Way Analysis of Variance (ANOVA) with
repeated measures on the experimental factor (treatment) were run. The dependent measures were Wingate test performance (peak power, mean power, and percent decline power output) and sprint times. The levels of the experimental factor (treatment) were placebo, caffeine only, creatine only, and creatine plus caffeine. The Duncan multiple comparisons test was used to probe the differences between means when a main effect was found. For all statistical tests, significance was set at $p< 0.05$. Descriptive statistics (means ± standard deviations) were calculated for all variables.
Chapter 4

RESULTS

Wingate Trials

The primary findings of this study (see table 1) were a statistical significance in peak power output (PP) during the first (16.5±2.2) and second (15.2±1.8) 6-second Wingate with the combination of creatine and caffeine (CRCAF) as compared to the placebo group (PL) (PP, sprint 1: 14±2.2, PP, sprint 1: 13.4±2.2). There was no statistical significance in any other treatment groups for peak power output. Similarly, mean power (MP) increased in Wingate sprints 1 (15.5±2.3) and 2 (14.1±1.8) following the combined ingestion of CRCAF compared to the PL (sprint 1 13.2±2.2, sprint 2 12.6±2.1). No other statistical interaction was found between any of the other treatment groups for minimum power output.

There were no other statistical interactions between any of the other treatment groups for mean power output (MP), percent decline (PD) and heart rate (HR). As expected, there was a significant difference between trials over time in all four treatments.

Track Trials

Statistical significance (see Table 1) was found in the last three sprint times (sprint 4, 8.09 ± 0.70 seconds; sprint 5, 8.13 ± 0.71 seconds; sprint 6, 8.30 ± 0.60 seconds) in the caffeine only group (CAF) as compared to PL (sprint 4, 8.46 ± 0.66; sprint 5, 8.69 ± 0.65; sprint 6, 8.97 ± 0.90). No other statistical significant
interaction was found between any of the other treatment groups for sprint times, as well as between any of the treatment groups for heart rate.
Table 1. Wingate Measures (Means ± SD) and Sprint Times (Means ± SD).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Sprint 1</th>
<th>Sprint 2</th>
<th>Sprint 3</th>
<th>Sprint 4</th>
<th>Sprint 5</th>
<th>Sprint 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP (W/kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>PL</td>
<td>14.0 ± 2.2</td>
<td>13.4 ± 2.2</td>
<td>12.5 ± 2.5</td>
<td>11.6 ± 2.0</td>
<td>11.3 ± 1.8</td>
<td>10.9 ± 1.9</td>
</tr>
<tr>
<td>CR</td>
<td>16.0 ± 3.7</td>
<td>14.3 ± 2.8</td>
<td>12.5 ± 2.0</td>
<td>11.9 ± 2.0</td>
<td>10.8 ± 1.7</td>
<td>10.1 ± 1.9</td>
</tr>
<tr>
<td>CAF</td>
<td>16.3 ± 2.5</td>
<td>15.5 ± 2.1</td>
<td>13.7 ± 2.4</td>
<td>12.8 ± 1.8</td>
<td>11.3 ± 2.2</td>
<td>10.6 ± 2.1</td>
</tr>
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<td>CR/CAF</td>
<td>16.5 ± 2.2*</td>
<td>15.2 ± 1.8*</td>
<td>13.4 ± 1.4</td>
<td>12.6 ± 1.5</td>
<td>12.1 ± 1.5</td>
<td>11.0 ± 1.9</td>
</tr>
<tr>
<td>MP (W/kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PL</td>
<td>13.2 ± 2.2</td>
<td>12.6 ± 2.1</td>
<td>11.5 ± 2.3</td>
<td>10.7 ± 1.8</td>
<td>10.4 ± 1.8</td>
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<td>CR</td>
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<td>11.0 ± 1.9</td>
<td>9.8 ± 1.7</td>
<td>9.2 ± 2.0</td>
</tr>
<tr>
<td>CAF</td>
<td>15.3 ± 2.7</td>
<td>14.5 ± 2.1</td>
<td>12.6 ± 2.2</td>
<td>11.8 ± 1.7</td>
<td>10.4 ± 2.1</td>
<td>9.6 ± 2.1</td>
</tr>
<tr>
<td>CR/CAF</td>
<td>15.5 ± 2.3*</td>
<td>14.1 ± 1.8*</td>
<td>12.3 ± 1.4</td>
<td>11.5 ± 1.5</td>
<td>11.0 ± 1.5</td>
<td>10.0 ± 1.8</td>
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<tr>
<td>MinP (W/kg)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PL</td>
<td>12.1 ± 2.4</td>
<td>11.3 ± 2.2</td>
<td>10.0 ± 2.2</td>
<td>9.1 ± 1.8</td>
<td>8.7 ± 2.0</td>
<td>8.3 ± 2.0</td>
</tr>
<tr>
<td>CR</td>
<td>13.9 ± 3.9</td>
<td>11.7 ± 2.8</td>
<td>10.0 ± 1.9</td>
<td>9.3 ± 2.1</td>
<td>8.1 ± 1.9</td>
<td>7.3 ± 2.3</td>
</tr>
<tr>
<td>CAF</td>
<td>12.0 ± 4.6</td>
<td>12.7 ± 2.3</td>
<td>10.9 ± 2.3</td>
<td>9.9 ± 2.0</td>
<td>8.6 ± 2.3</td>
<td>7.8 ± 2.2</td>
</tr>
<tr>
<td>CR/CAF</td>
<td>14.1 ± 2.4</td>
<td>12.4 ± 2.0</td>
<td>10.5 ± 1.7</td>
<td>9.6 ± 1.7</td>
<td>9.0 ± 1.7</td>
<td>8.1 ± 2.0</td>
</tr>
</tbody>
</table>
Table 1. Continued.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Sprint 1</th>
<th>Sprint 2</th>
<th>Sprint 3</th>
<th>Sprint 4</th>
<th>Sprint 5</th>
<th>Sprint 6</th>
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<td>PD (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PL</td>
<td>14.1 ± 5.5</td>
<td>16.2 ± 5.2</td>
<td>19.3 ± 5.2</td>
<td>21.3 ± 6.0</td>
<td>22.9 ± 7.1</td>
<td>24.7 ± 7.2</td>
</tr>
<tr>
<td>CR</td>
<td>13.9 ± 5.1</td>
<td>18.5 ± 4.9</td>
<td>20.5 ± 5.4</td>
<td>22.1 ± 7.3</td>
<td>25.4 ± 8.4</td>
<td>28.9 ± 12.3</td>
</tr>
<tr>
<td>CAF</td>
<td>14.3 ± 4.4</td>
<td>18.5 ± 4.4</td>
<td>20.7 ± 4.5</td>
<td>23.4 ± 6.0</td>
<td>25.1 ± 7.0</td>
<td>27.7 ± 7.9</td>
</tr>
<tr>
<td>CR/CAF</td>
<td>15.0 ± 4.0</td>
<td>19.1 ± 4.8</td>
<td>22.1 ± 4.7</td>
<td>24.2 ± 4.6</td>
<td>25.7 ± 5.1</td>
<td>27.6 ± 5.6</td>
</tr>
<tr>
<td>Sprint Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PL</td>
<td>7.23 ± 0.50</td>
<td>7.71 ± 0.52</td>
<td>8.02 ± 0.53</td>
<td>8.46 ± 0.66</td>
<td>8.69 ± 0.65</td>
<td>8.97 ± 0.90</td>
</tr>
<tr>
<td>CR</td>
<td>7.18 ± 0.47</td>
<td>7.63 ± 0.48</td>
<td>7.89 ± 0.56</td>
<td>8.31 ± 0.64</td>
<td>8.51 ± 0.64</td>
<td>8.79 ± 0.76</td>
</tr>
<tr>
<td>CAF</td>
<td>7.32 ± 0.47</td>
<td>7.67 ± 0.55</td>
<td>7.74 ± 0.64</td>
<td>8.09 ± 0.70*</td>
<td>8.13 ± 0.71*</td>
<td>8.30 ± 0.60*</td>
</tr>
<tr>
<td>CR/CAF</td>
<td>7.33 ± 0.55</td>
<td>7.66 ± 0.67</td>
<td>7.83 ± 0.78</td>
<td>8.16 ± 0.76</td>
<td>8.16 ± 0.68</td>
<td>8.36 ± 0.78</td>
</tr>
</tbody>
</table>

* - Indicates significant difference from PL (p < 0.05).
Chapter 5

DISCUSSION

While the ergogenic effect of caffeine (CAF) in endurance exercise is well documented (Bell & McLellan, 2002; Ganio, Klau, Casa, Armstrong, & Maresh, 2009; Ivy et al., 2009), its effect on high-intensity exercise is more controversial (Greer et al., 2006; Glaister et al., 2006; Hoffman et al., 2005; Kinugasa et al., 2003; Kishali et al., 2007; Wright et al., 2007). Furthermore, while some studies investigate the positive ergogenic effect of creatine (CR) on multiple bouts of exercise (Aaserud et al., 1998; Balsom, 1993; Cox et al., 2002; Dawson, 1995; Flanagan & Jakeman, 2006; Gill et al., 2004; Izquierdo et al., 2002; Kishali et al., 2007; Kreider et al., 1998; Mujika et al., 2000; Ostojic, 2004; Peyrebrune et al., 2005; Skare et al., 2001; Wright et al., 2007), some studies have shown no effect (Ahmun et al., 2005; Barnett et al., 1996; Cooke et al., 1995; Cornish et al., 2006; Delecluse et al., 2003; Glaister et al., 2006; Hoffman et al., 2005; Kinugasa et al., 2003; Ledford & Branch, 1999; Pluim et al., 2005; Redondo et al., 1996; Silva et al., 2007). One possible reason for these conflicting results could be the testing environment. There is some evidence that CAF is more likely to be ergogenic when subjects are exposed to activities they are more accustomed to, such as in a field setting (Collomp et al., 1991) while CR studies investigating the ergogenic effect show more positive findings when done in the lab setting (Dawson, 1995; Kishali et al., 2007; Wright et al., 2007). The design of the present study was unique in that it measured the effects of four treatments (CAF, CR, CRCAF and PL) in two separate experimental environments: a lab setting (6 x 6-second Wingate sprints) and a field setting (6 x 50-meter track sprints). Due to the
likelihood for caffeine or creatine to elicit an ergogenic effect in one experimental environment over another, one goal of the present experimental design was to compare an ergogenic benefit not only between the four different treatments, but also to observe whether the ergogenic effects occur in both experimental environments.

In the current study, acute caffeine improved performance in the final three 50-meter sprints compared to PL ingestion but failed to improve sprint performance in the first three exercise bouts. This is similar to previous research, which demonstrated that 250 mg of caffeine improved swimming sprint time in the second of two 100-meter freestyle sprints in trained subjects (Collomp et al., 1992). However, Glaister et al. (2008) found caffeine to have the opposite effect in multiple sprint performance. Caffeine improved sprint time during the first five out of twelve 30-meter sprints. After the first three trials, sprint time in the caffeine treatment was not different than PL. This showed that although caffeine improved performance in the initial sprints, this ergogenic benefit did not last. Greer et al. (1998) observed a decrease in PP in the final fourth Wingate compared to the first three, 30-second cycle sprints. Similarly Paton et al. (2001) found that during ten 20-meter sprints, the mean time to complete the sprints increased by 0.1% with caffeine ingestion relative to placebo. Furthermore, time to complete the 10th sprint was increased by 0.7% following caffeine ingestion compared to placebo.

The physiological mechanisms by which caffeine may elicit its ergogenic effects are poorly understood. Research has failed to show central neural as well as systemic metabolic mechanisms to explain the effects of caffeine in short-term maximal exercise. Tarnopolsky and Cupido (2000) showed at physiological concentrations caffeine can potentiate muscle force production during low
frequency tentantic stimulation. A putative mechanism to explain this finding is caffeine improves sarcoplasmic reticulum calcium release.

Caffeine has frequently been used to enhance mental and physical performance (Delbeke & Bebackere, 1984). At the cellular level, caffeine is mostly thought to act through antagonism of adenosine receptors; these receptors are located at various sites throughout the body (Fredholm, 1995; Lynge & Hellsten, 2000). Whatever the exact mechanism, one consistent outcome of caffeine ingestion despite the mode, duration, or intensity is the attenuation of the participants’ perceptual response to exercise. In a meta-analysis, Doherty et al. (2004) investigated the effects caffeine had on RPE during exercise of various modes, intensities, and durations. They concluded that RPE following caffeine ingestion was lower when compared to placebo during a constant loading exercise protocol. Although the exact mechanism has not been determined, caffeine ingestion may allow participants a greater capacity to tolerate the discomfort associated with fatigue during exercise and in effect mask the perception of fatigue. Doherty et al. (2004) further suggested that the alteration in RPE response following caffeine ingestion is a reduction in the metabolic cost of constant load exercise. Noble, Metz, and Pandolf (1973) concluded that the most important determinant of RPE is the relative metabolic rate of exercise. Further work is needed to more fully understand the possible relationship between caffeine, cardio respiratory dynamics, RPE, and exercise performance.

As mentioned previously, the ergogenic effect of caffeine increases as the duration of exercise increase (Graham, 1994). Even in multiple sprint type of exercise, as the number of sprints increases, so does the aerobic component of the sprint. Thus, it may be that in the present study, where we found an ergogenic
effect of caffeine in the latter sprints, the improvement following caffeine ingestion may be due to its affect on aerobic metabolism.

Another main finding from this study was that 9 days of creatine dosing (5 grams, four times a day) followed by acute caffeine ingestion (5 mg·kg⁻¹) during 6 x 6-second Wingate sprints increased peak power output (PP) and mean power output (MP) during sprints 1 and 2 compared to the PL trials. There are very few studies that have investigated the combined effects of CR and CAF during exercise. Three out of the four studies found that the addition of caffeine ingestion adversely affected the positive ergogenic benefit of creatine (Hespel et al., 2002; Vanakoski et al., 1998; Vandenberghe et al., 1996). Conversely, Doherty et al. (2002) found that 6 days of creatine loading (0.3 g·kg⁻¹·d⁻¹) followed by an acute dose of caffeine (5 mg·kg⁻¹) increased running time at 125% VO₂max to volitional exhaustion by 10% in comparison to baseline and placebo trials.

The exact cellular mechanism linking intracellular creatine concentration in muscle due to creatine ingestion (Harris et al., 1992; Vandenberghe, Van Hecke, Van Leemputte, Vanstapel, & Hespel, 1999) with enhanced contractile performance remains largely unexplained (Greenhaff et al., 1993; Vandenberghe et al., 1997). However, it is obvious that the increase creatine uptake by muscle fibers during creatine loading can cause intracellular responses, which may eventually lead to ergogenic effects. Although the present study did not directly measure intramuscular creatine levels, we assumed that enhanced creatine uptake by muscle occurred as the loading protocol which was used has been shown to increase muscle creatine levels when measured directly through muscle biopies (Harris et al., 1992).

Research has shown that creatine loading improves muscle creatine uptake and thus improves rephosphoralyation of ADP to ATP via the CR kinase reaction.
(Demant & Rhodes, 1999; Hespel et al., 2001). In the present study, given that only the combination group demonstrated an improvement in performance and only during the first and second sprints may suggest the ingestion of caffeine may improve the rate of perceived exertion felt by the subjects. Given this decrease in RPE the subjects may have been able to capitalize on the ability of creatine to improve short-term performance observed in previous studies (Dawson, 1995; Kishali et al., 2007; Wright et al., 2007).

One of the goals of this study was to determine whether the testing environment would affect the ergogeneity the treatment. As mentioned previously, there is some evidence that CAF is more likely to be ergogenic when subjects are exposed to activities they are more accustomed to, such as in a field setting (Collomp et al., 1991) while CR studies investigating the ergogenic effect show more positive findings when done in the lab setting (Dawson, 1995; Kishali et al., 2007; Wright et al., 2007). The current study did find that caffeine ingestion did enhance performance in the field versus the lab setting. To our knowledge, only one study has compared two different testing environments and this was done using only CR. Ahmun et al. (2005) examined if CR ingestion (20 grams a day, for 5 days) would improve power output in 10 x 6-second Wingate and running velocity during 10 x 40-meter sprints. Although the study failed to find a statistically significant ergogenic effect following CR supplementation, they found a 7.6% improvement in the fatigue index. The ergogenic effect following caffeine ingestion in the field portion of this study is in agreement with Collomp et al. (1992). They demonstrated that 250 mg of caffeine improved swimming sprint time in the second of two 100-meter freestyle sprints in trained subjects. This suggests there may be differences in the response to treatment that may have practical benefit to sporting performance.
One possible explanation for the discrepant results in the literature could be the large standard deviation in the data. A large standard deviation may indicate that there is a large variance in the data. This large variance could be due to the lack of homogeneity of the subjects tested. In the present study, while all subjects were males between the ages of 18-28, they had varying degrees of athletic ability. This may have contributed to the large standard deviations. In future studies more control over the testing population may produce a smaller standard deviation and may result in a greater likelihood of finding more statistical significance. One suggestion would be using trained individuals who are used to the specific protocol (e.g., using trained sprinters in the present study may have produced different results). Collomp et al. (1992) demonstrated this where it was found that only trained swimmers benefitted from caffeine ingestion compared to untrained swimmers.

Another reason for the variance in our data may have been due to the lack of control of RPM at the beginning of the Wingate protocol. There is no information on the impact that initial pedaling rate during a Wingate test may have on the subsequent power output. A higher rpm would produce a larger initial power output, which would impact all the subsequent power output values measured. Not all of the subjects began their trials at the same RPM, which could have contributed to the large variation in the data. Future studies using the Wingate should control initial RPM to prevent possible contamination of data.

In the current study, the ergogeneity of both CAF and the combination was shown to improve performance during multiple bouts of short-term, high-intensity performance. It was also shown that the ergogenic effects might be specific to the type of activity and possibly the familiarity of the activity. In more practical terms, when an individual attempts to use a supplement (caffeine, creatine, or
combination) for an ergogenic effect, it may be prudent for the individual to consider whether the supplement is effective in that environment.
REFERENCES
REFERENCES


APPENDIX A
INFORMED CONSENT
INFORMED CONSENT

Title of Project: The impact of caffeine and/or creatine supplementation on repeated bouts of high-intensity exercise

Principal Investigator: Zoltan A Torok (M.A. Student, Department of Kinesiology)

Co-Investigators: Felicia Greer, Ph.D. (Associate Professor, Department of Kinesiology)  
Jacobo Morales, Ph.D. (Professor, Department of Kinesiology)  
Tim Anderson, Ph.D. (Professor, Department of Kinesiology)

The purpose of this study is to determine if there is an ergogenic effect following the ingestion of creatine and/or caffeine in the performance on repeated bouts of high-intensity exercise in two different environmental conditions.

If you decide to participate in this study, we will require your attendance at the Human Performance Laboratory (HPL), located in the South Gym room 139 on 4 separate occasions and at the Save Mart Center track at 4 different times. The first day in each environment (lab or track) will involve an introduction to the experimental procedures.

The treatment possibilities are as follows:

1. Placebo treatment: Placebo (corn starch) loading for one week prior to testing plus a placebo gelatin capsule on day of testing.
2. Caffeine treatment: Placebo (corn starch) loading for one week prior to testing plus a caffeine gelatin capsule (5 mg/kg body weight) on day of testing.

3. Creatine treatment: Creatine monohydrate loading for one week prior to testing plus placebo gelatin capsule on day of testing.

4. Creatine plus caffeine treatment: Creatine monohydrate loading for one week prior to testing plus caffeine gelatin capsule (5 mg/kg body weight) on day of testing.

Nine days prior to the subsequent 4 treatment possibilities, you will be given a pre-packed supplement that you be asked to ingest. This pre-packed supplement will contain either creatine or placebo (corn starch). Typical side effects of creatine ingestion include an increase in body weight. On the seventh day, 1 hour prior to your test, you will report to the HPL or the track and will ingest either a placebo pill (dextrose) or caffeine (5 mg/kg body weight). Two days later, you will report to the alternate environment and will ingest a pill containing the same content as you did previously. The amount of caffeine in the gelatin pill is equivalent to 2-3 strong cups of coffee. Possible side effects include nausea and insomnia. Each of the 4 treatment possibilities will be separated by three weeks to allow full recovery along with complete washout of the assigned treatment from skeletal muscle.

Throughout the duration of the study, you will be asked to abstain from all creatine-containing products other than those contained in your regular diet. In addition, prior to each testing session you will be required to withdraw from all caffeine and alcohol containing products (i.e. chocolate, soft drinks, coffee, beer, etc.) for 48 hours. Furthermore, we ask that you not actively participate in
strenuous exercise 48 hours prior to testing. During each visit to either the HPL or the track for testing, you will be questioned on your adherence to the loading regime explained in the introductory session. You are expected to follow all pre-testing procedures. Should any circumstances occur which prevents you from following these procedures, please notify the investigator as soon as possible.

For the lab testing sessions, you will report to the HPL, and after a standardized warm-up you will be required to perform 6, 6-sec all out Wingate tests on a cycle ergometer separated by 30 sec of recovery (light cycling with little resistance). During each trial you will be asked to perform with a maximal effort.

For the testing sessions at the Save Mart Center track, you will be required to perform 6, 50m sprints as hard as possible. You will begin each 50m sprint after a 30 second recovery period. Once again, prior to the sprints, you will undergo a standardized warm-up. During each sprint you will be asked to perform with a maximal effort.

Any information that is obtained by this investigation is strictly confidential and will only be disclosed with your permission or as required by law. You may request a copy of the results of the study at any time. If you give us permission by signing this document, results from this study will be made available to the general public through submission to scientific journals and presentation at professional conferences, however, you will remain anonymous. It is the intent that publication/presentation of the results will add to the body of knowledge in the related fields of exercise physiology.

Your decision whether or not to participate in this study will not affect your future relations with CSU, Fresno. If you decide to participate you are free to withdraw your consent and to discontinue participation at any time without
penalty. The committee on the Protection of Human Subjects at CSU, Fresno has reviewed and approved the procedures for the present study.

If you have any questions/comments regarding your participation in this investigation, please feel free to contact Dr. Felicia Greer (559) 278-2005.

You are making a decision whether or not to participate in this study; your signature indicates that you have decided to participate in this study having read the information above.

__________________________________________  ______________
Participant’s Signature                        Date

__________________________________________  ______________
Investigator’s Signature                      Date
APPENDIX B
HEALTH QUESTIONNAIRE
All information in this questionnaire is strictly confidential and will be used only by the investigators of this study. From here on out, subjects will be referred to by code numbers and only group data will be presented in any communications hereafter.

Name:
__________________________________________________________________________

Address:
__________________________________________________________________________

Telephone: ____________________________________________________
Age: ______________________________  Weight (kg):

Medical History:

Do you suffer from any of the following:

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<td>Hypertension</td>
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Heart Disease: 

List all medications (if any) you are currently taking:

_________________________________________  _____________________________
_________________________________________  _____________________________
_________________________________________  _____________________________
_________________________________________  _____________________________

Are you on a controlled diet?  Yes  No
If yes, are there any restrictions?

Do you have any allergies?  Yes  No
If yes, what are you allergic to?

Caffeine Habits:

Estimate to the best of your ability the following:

Foods:  Amount per day:

Coffee
_________________________________________
Tea

Chocolate

Soft Drink

Other

**Medications:**

Cold Tablets

Headache

Allergy Relief

Stay Awake Tablets
Creatine Habits:

1. Do you or have you ever taken creatine supplements? Yes

   No

   If yes, how long ago and how much?

2. Do you or have you ever taken any other supplements? Yes No

   If yes, what was it, how long ago, and how much?
APPENDIX C

PROTECTION OF HUMAN SUBJECTS
Ethics for Human Subject Approval

THE EFFECT OF CREATINE AND/OR CAFFEINE INGESTION ON REPEATED BOUTS OF HIGH INTENSITY EXERCISE PERFORMANCE

Investigators: Felicia Greer, Ph.D. (Associate Professor, Department of Kinesiology)
Jacobo Morales, Ph.D. (Professor, Department of Kinesiology)

Abstract

The purpose of this study is to determine if there is an ergogenic effect following the ingestion of creatine and/or creatine plus caffeine in the performance on repeated bouts of high-intensity exercise. Previous research that has been done on the performance enhancing effects of creatine and/or creatine plus caffeine has shown inconclusive results. Fifteen to twenty male athletes accustomed to this type of exercise (sprinters and jumpers) from the Fresno State Track and Field Team will be recruited. All athletes will be screened for medical contraindications that could result from creatine and caffeine ingestion. The supplement possibilities are as follows:

1. Placebo treatment: Placebo (corn starch) loading for one week prior to testing plus a placebo gelatin capsule on day of testing
2. Creatine treatment: Creatine monohydrate loading for one week prior to testing plus placebo gelatin capsule on day of testing
3. Creatine plus caffeine treatment: Creatine monohydrate loading for one week prior to testing plus caffeine (5 mg/kg body weight) gelatin capsule on day of testing.

4. Caffeine treatment: Placebo (corn starch) loading for one week prior to testing plus a caffeine (5 mg/kg body weight) gelatin capsule on day of testing

For each of the four supplement possibilities there will be two trials (one lab and one field). Three weeks will separate each supplement possibility to allow complete washout of creatine from skeletal muscle due to any creatine loading. Nine days prior to the first testing session, subjects will load with either creatine or placebo (corn starch). On day seven, subjects will undergo a testing session (either the lab or the field) and will ingest either a placebo pill (dextrose) or caffeine (5 mg/kg body weight). Forty-eight hours later, subjects will undergo a second testing session under the same supplement conditions but in the opposite testing environment. During the loading period, subjects will ingest creatine monohydrate or placebo four times a day at a dose of 5 grams (for a total of 20 grams per day). This loading protocol is typical in the use of creatine. A typical side effect of creatine ingestion is weight gain attributed to water retention. The amount of caffeine that will be administered (5 mg/kg/body weight) is also consistent with previous research. Some side effects may occur with the ingestion of caffeine but are typically minor, such as stomach irritation and irritation of the inner lining of the intestine. If ingested with fluids, these side effects are minimized. One hour after the ingestion of either placebo or caffeine, and after a standardized warm-up, subjects will be asked to perform six 10 sec Wingate (WG) tests set at a resistance 150 gm/kg body weight. Subjects will have 50 seconds of easy pedaling as recovery in between each WG. This protocol will conducted in the Human
Performance Laboratory. The field portion of this study will take place at the Student Recreation Center track. One hour after the ingestion of either placebo or caffeine, and after a standardized warm-up, subjects will be asked to perform six, 60m sprints as hard as possible along the straight portion of the track. Each sprint will be initiated from a line 30 cm behind the start line to prevent false triggering of the electronic timing device. Subjects will begin each sprint on the minute.

Benefits of participation include: (1) effects of creatine alone and/or the additive effect of creatine plus caffeine on muscle force development and neuromuscular and neuromuscular frequency, and (2) the effects of creatine alone and/or creatine plus caffeine on anaerobic power during multiple short-term high intensity all-out cycling and sprint exercise. Additionally, results from this test can be used to assess the health and physical fitness of the subjects and may be used for the development of a physical fitness program. There will be no charge for any consultations regarding the development of a physical fitness program derived from the results of testing done on the subjects. There will be no monetary compensation for participating in this study.
Protocol

Purpose and Background:
The purpose of this study is to determine if there is an ergogenic effect following the ingestion of creatine and/or creatine plus caffeine in the performance on repeated bouts of high-intensity exercise in two different environmental conditions. The neuromuscular function of the lower extremities using corresponding surface electromyographic records will also be investigated. Caffeine and creatine are the two most common supplements used in sport. It is well established that creatine ingestion enhances performance during short-term high intensity exercise, with its greatest ergogenic effects seen during repeated bouts of high intensity exercise. While the performance-enhancing effect of caffeine during sustained long-duration exercise is well known, there is controversy regarding its impact on high intensity, short-duration exercise (Greer et al., 1998; Glaister, et al., 2008). It has recently been demonstrated that caffeine supplementation significantly reduces the time required to complete multiple sprint exercise (Glaister, et al., 2008). Recently, athletes, coaches and scientists (including myself) have developed interest on the combined effect these substances may have on exercise performance.

Previous research that has been done on the performance enhancing effects of creatine and/or creatine plus caffeine has shown inconclusive results. Doherty et al., (2002) concluded that there is an ergogenic effect of caffeine after oral creatine supplementation on time to exhaustion while running on a treadmill at intensity of 125% VO2 max. Conversely, Hespel et al., (2001) and Vandenberghe et al., (1996) reported caffeine intake counteracts the ergogenic effect of creatine loading. These inconsistencies in published results and the paucity of research in this area warrant
further investigation. One reason for the lack of agreement within the literature on the ergogenic potential of these supplements could be the training status of the individuals and the environment in which the testing takes place. Most studies demonstrating an ergogenic effect of creatine have been conducted using trained subjects within the laboratory setting, while most studies demonstrating an ergogenic effect of caffeine during high intensity exercise have been conducted in trained subjects using field (or real-world) tests. Thus, this study will use athletes accustomed to multiple bouts of anaerobic exercise and will be conducted under controlled laboratory conditions as well as in the field.

**Subjects:**

Fifteen to twenty male athletes who are familiar with this type of exercise (sprinters and jumpers) from the Fresno State Track and Field Team will be recruited for participation in this study. All athletes will be screened for medical contraindications that could result from creatine and caffeine ingestion such as peptic ulcers and cardiovascular disease. Subjects will be required to abstain from all caffeine-containing products for 48 hrs prior to all tests and will be asked to abstain from alcohol consumption and strenuous exercise for 48 hr prior to testing. Furthermore, only subjects who have not supplemented with creatine for the past year will be eligible for participation.

**Methods:**

During the course of this investigation, subjects will report to the Human Performance Laboratory (HPL) located in the South Gymnasium Room 139 for all laboratory testing and to the Student Recreation Center track for all field tests. The first day in each setting will involve an introduction to procedures of the study. During the first visit to each setting, the subjects will be introduced to the data
collection method and given a verbal explanation of the experimental procedures. At this time they will also read and sign an informed consent form. All benefits and risks will be verbally explained to the subjects in addition to their written inclusion on the informed consent form. This familiarization visit will be followed by eight separate trials of data collection (4 in the lab, 4 in the field). The order of testing will be randomized and the order of supplementation will be randomized and double blinded. The supplement possibilities are as follows:

1. Placebo treatment: Placebo (corn starch) loading for one week prior to testing plus a placebo gelatin capsule on day of testing
2. Creatine treatment: Creatine monohydrate loading for one week prior to testing plus placebo gelatin capsule on day of testing
3. Creatine plus caffeine treatment: Creatine monohydrate loading for one week prior to testing plus caffeine (5 mg/kg body weight) gelatin capsule on day of testing.
4. Caffeine treatment: Placebo (corn starch) loading for one week prior to testing plus a caffeine (5 mg/kg body weight) gelatin capsule on day of testing

For each of the four supplement possibilities there will be two trials (one lab and one field). Three weeks will separate each supplement possibility to allow complete washout of creatine from skeletal muscle due to any creatine loading. Nine days prior to the first testing session, subjects will load with either creatine or placebo (corn starch). On day seven, subjects will undergo a testing session (either the lab or the field) and will ingest either a placebo pill (dextrose) or caffeine (5 mg/kg body weight). Forty-eight hours later, subjects will undergo a second testing session under the same supplement conditions but in the opposite testing environment.
During the nine-day loading period, subjects will ingest creatine monohydrate or placebo four times a day at a dose of 5 grams (for a total of 20 grams per day). This loading protocol is typical in the use of creatine (Balsom et al., 1993; Dawson et al., 1995; Doherty et al., 2002). The amount of caffeine that will be administered (5 mg/kg/body weight) is also consistent with previous research (Costill et al., 1978; Graham et al., 1995; Greer et al., 1998, 2000, 2006). The principal investigator will be packaging the supplements but a graduate student assistant will randomize the trials and be responsible for documenting the supplement and the trial number. A key related to this information will be kept by the student assistant and will not be released until the subjects have completed all tests. Subjects involved in this study will be required to ingest 8oz of fluid when ingesting the caffeine.

Subjects will be required to abstain from all caffeine-containing products for 48 hrs prior to all tests and will be asked to abstain from alcohol consumption and strenuous exercise for 48 hr prior to testing. Furthermore, only subjects who have not supplemented with creatine for the past year will be eligible for participation.

One hour after the ingestion of either placebo or caffeine, and after a standardized warm-up, subjects will be asked to perform six 10 sec Wingate (WG) tests set at a resistance 150 gm/kg body weight. Subjects will have 50 seconds of easy pedaling as recovery in between each WG. Data collected from this test will be used to calculate minimal and peak power, and a fatigue index. This protocol will conducted in the Human Performance Laboratory. While performing the WG tests, electromyographic (EMG) data will be collected from the right vastus lateralis and the right gastrocnemius muscles. This EMG will be collected using surface electrodes placed on previously shaved/abraded skin. In preparing the skin
this way, the subjects may experience some minor skin discomforts such as a rash or a minor burning sensation with the application of alcohol. The EMG variables derived will include a mean and median frequency of the signal power spectrum.

The field portion of this study will take place at the Student Recreation Center track. One hour after the ingestion of either placebo or caffeine, and after a standardized warm-up, subjects will be asked to perform six, 60m sprints as hard as possible along the straight portion of the track. Each sprint will be initiated from a line 30 cm behind the start line to prevent false triggering of the electronic timing device. Subjects will begin each sprint on the minute. An electronic timing device will be used to record the time required to complete the 60m sprints. Alternate sprints will be performed in the opposite direction.

In order to ensure reliability of performance, subjects will be asked to monitor their diet for 48 hr prior to each testing session. By doing so, they will adhere to the same regime of meals and snacks for 48 hr prior to each testing session to allow for uniformity during the experimental trials.

**Potential Benefits:**

Benefits of participation include: (1) effects of creatine alone and/or the additive effect of creatine plus caffeine on muscle force development and neuromuscular and neuromuscular frequency, and (2) the effects of creatine alone and/or creatine plus caffeine on anaerobic power during multiple short-term high intensity all-out cycling and sprint exercise. Additionally, results from this test can be used to assess the health and physical fitness of the subjects and may be used for the development of a physical fitness program.
Potential Risks:

The creatine loading protocol used in this study is typical in the use of creatine (Balsom et al., 1993; Dawson et al., 1995; Doherty et al., 2002). A typical side effect of creatine ingestion is weight gain attributed to water retention (Benzi et al., 2001). The amount of caffeine that will be administered (5 mg/kg/body weight) is also consistent with previous research (Costill et al., 1978; Graham et al., 1995; Greer et al., 1998, 2000, 2006). Some side effects may occur with the ingestion of caffeine but are typically minor (Conlee, 1991), such as stomach irritation and irritation of the inner lining of the intestine. If ingested with fluids, these side effects are minimized.

The EMG signal will be collected using surface electrodes placed on previously shaved/abraded skin. In preparing the skin this way, subjects may experience some minor skin discomforts such as a rash or a minor burning sensation with the application of alcohol.

Subjects participating in this study will be required to perform with maximal effort on each trial. This type of high intensity, short-duration maximal effort performance may result in significant muscle fatigue and perhaps nausea. However, with respect to the study population (male athletes who are familiar with multiple sprint activities) further risks associated with participation are minimal. A telephone within the Human Performance Lab is dedicated for the purpose of any emergency that may arise prior to and during tests.

Management of Risk:

Subjects recruited for this study will be familiar with this type of exercise and thus, risks associated with participation are minimal. Subjects will be required to ingest 8oz of fluids when taking caffeine, thus minimizing any stomach irritation. A telephone within the Human Performance Lab is dedicated for the
purpose of any emergency that may arise prior to and during tests. The investigators conducting the research will be equipped with cell phones that can be used in case of any emergency that arises while at the Student Recreation Center. All identifying information will be kept confidential and in the possession of the Principle Investigator and kept in a locked drawer within the Human Performance Laboratory. Subjects will be provided with a numerical code that will be used for identification purposes.

**Subject Compensation:**

Results from this test can be used to assess the health and physical fitness of the subjects and may be used for the development of a physical fitness program. There will be no charge for any consultations regarding the development of a physical fitness program derived from the results of testing done on the subjects. There will be no monetary compensation for participating in this study.

**Academic Qualifications:**

The faculty involved with this study (Drs. Felicia Greer and Jacobo Morales) is well versed in the protocol being used. This will be the fourth investigation conducted by these faculty members using these procedures. The creatine loading protocol and the dose and administration of caffeine being used are typical in this type of research.
APPENDIX D
NUTRITIONAL LOG
NUTRITION LOG

NAME:________________________________________________

DATE:_________________________________________________

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California State University, Fresno

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