

THE EFFECTS OF 8 WEEKS OF LOW DOSE SUPPLEMENTATION OF CREATINE  
AND SODIUM BICARBONATE ON EXERCISE PERFORMANCE

A Thesis

presented to

the Faculty of California Polytechnic State University,

San Luis Obispo

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Kinesiology

by

Amanda Jessica Morris

November 2013

© 2013

Amanda Jessica Morris

ALL RIGHTS RESERVED

## COMMITTEE MEMBERSHIP

TITLE: The Effects of 8 Weeks of Low Dose Supplementation of  
Creatine and Sodium Bicarbonate on Exercise Performance

AUTHOR: Amanda Jessica Morris

DATE SUBMITTED: November 2013

COMMITTEE CHAIR: Todd Hagobian, PhD  
Professor of Kinesiology

COMMITTEE MEMBER: Suzanne Phelan, PhD  
Professor of Kinesiology

COMMITTEE MEMBER: Kellie Hall, PhD  
Professor of Kinesiology

COMMITTEE MEMBER: Jennifer Olmstead, M.S.  
Full Time Lecturer Kinesiology

## ABSTRACT

### The Effects of 8 Weeks of Low Dose Supplementation of Creatine and Sodium Bicarbonate on Exercise Performance

Amanda Jessica Morris

Short-term (3-7 days), high doses of creatine (20g/d) and/or sodium bicarbonate (0.5g/kg body weight) supplementation increase exercise performance during short term high intensity activities; however, it remains unclear whether long-term, low doses of these supplements have a positive impact on exercise performance. The purpose of this study was to determine the effects of long-term (8 weeks), low dose creatine supplementation on exercise performance, and whether combining creatine and sodium bicarbonate supplementation has an additive effect. Sixty-three healthy, habitually active, adults (28 M, 35 W;  $22 \pm 2$  years;  $23 \pm 3$  BMI) were randomly assigned by sex to one of three supplement groups: placebo (PL), creatine only (3g/day; Cr), or creatine plus sodium bicarbonate (3g creatine plus 1g sodium bicarbonate; Cr+Sb) for 8 weeks. Before and after supplementation subjects completed two exercise performance tests on separate days. Subjects completed repeated Wingate sprint tests (6 x 10 second sprints) and changes in the slope across the 6 sprints (rate of decline) was analyzed between groups. We also collected 5 km time-trial and the data were analyzed using repeated measures ANOVA. In the repeated sprint test, peak power output slope was significantly decreased ( $P=0.04$ ) in PL (-83%) and Cr+Sb (-82%) but did not change in Cr alone and was significantly better ( $P=0.03$ ) than PL and Cr+Sb. Similarly, mean power output slope significantly decreased ( $P<0.001$ ) in PL (-73%) and Cr+Sb (-150%), but not in Cr alone. In the 5 k time-trial, PL (-0.4%) and Cr+Sb (+0.5%) had no significant change ( $P>0.05$ )

in time to completion. However, Cr alone significantly improved time to completion (-3%; P=0.01). Taken together, these data suggest that long-term, low dose creatine supplementation increases exercise performance but adding sodium bicarbonate supplementation has no beneficial impact on exercise performance.

Keywords: creatine, sodium bicarbonate, low dose, cycling, exercise performance

## ACKNOWLEDGMENTS

I would like to express my deepest appreciation to my committee chair and mentor, Dr. Todd Hagobian, for his excellent guidance, patience, and knowledge. I am extremely grateful for all the time and energy that he invested and for the research skills that he taught me. The skills that I have learned from Dr. Hagobian are invaluable and will undoubtedly help me throughout my career. Without his supervision and assistance, this thesis would not have been possible.

I would also like to thank my thesis committee members, Dr. Suzanne Phelan and Jennifer Olmstead. They were always willing to take time out of their busy schedules to assist me with any questions I had. I am especially grateful for Dr. Phelan's assistance with interpreting statistics. Additionally, I would like to thank Dr. Steve Rein from the statistics department for his advice and help with the statistical program.

I am especially appreciative of Dr. Kellie Hall, for being an excellent mentor for both my undergraduate and graduate studies. She has always been extremely helpful and her passion for teaching and research is inspiring. Dr. Hall's support and motivation were integral to my success at Cal Poly.

I would like to further extend my appreciation to my parents, Doug and Donna, my sister, Jen, and my brother Ryan for their continued love and support. I am truly appreciative for the investment my parents have made in my education.

Finally, a special thank you to my fellow graduate students, especially KT Streder, who spent countless hours studying with me and provided me with support and feedback on my thesis.

## TABLE OF CONTENTS

	Page
LIST OF TABLES .....	x
LIST OF FIGURES .....	xi
CHAPTER	
I. INTRODUCTION .....	1
Statement of the Problem .....	1
Statement of Purpose .....	4
Research Hypotheses .....	4
Significance.....	5
Definition of Terms.....	5
II. LITERATURE REVIEW .....	7
Creatine.....	7
Creatine Supplementation.....	8
Sodium Bicarbonate.....	11
Sodium Bicarbonate Supplementation.....	12
Combined Creatine and Sodium Bicarbonate.....	15
5-K Time Trial .....	15
Conclusion .....	16
III. METHODS .....	17
Overview.....	17
Subjects.....	17
Preliminary Tests .....	18

Exercise Protocol .....	19
Repeated Sprint Test .....	19
Time Trial Test .....	20
Supplementation Procedure .....	21
Statistical Analysis .....	21
Sample Size Calculation .....	22
Limitations .....	23
IV. RESULTS .....	24
Wingate Repeated Sprint Test .....	24
Peak Power .....	24
Relative Peak Power .....	26
Mean Power .....	27
Relative Mean Power .....	28
Fatigue Index .....	29
Rate of Perceived Exertion .....	30
Gastrointestinal Distress Questionnaire .....	30
Time Trial .....	33
Time to Completion .....	33
Mean Speed .....	34
Peak Speed .....	35
Mean Power .....	36
Peak Power .....	37
Mean RPM .....	38



Peak RPM .....	39
Mean Heart Rate .....	40
Peak Heart Rate.....	40
Rate of Perceived Exertion .....	40
Gastrointestinal Distress Questionnaire .....	41
V. DISCUSSION .....	43
BIBLIOGRAPHY .....	49
APPENDICES	
APPENDIX A: Informed Consent.....	58
APPENDIX B: Health History Questionnaire .....	62
APPENDIX C: GI Distress Questionnaire .....	65
APPENDIX D: Physical Activity Log.....	67

## LIST OF TABLES

Table		Page
1.	Table 3-1. Subject Characteristics. Values are mean $\pm$ SD. P= Placebo, Cr= Creatine, CrSb = Creatine and Sodium Bicarbonate.....	18
2.	Table 4-1. Mean Values of Variables by Sprint. Values are in means $\pm$ SD. W = watts, W/kg = Watts per kilogram of body mass, W/s = watts per second, RPE = rate of perceived exertion. *significantly lower than sprint 1 .....	31
3.	Table 4-2. Gastrointestinal Distress Questionnaire Responses (Wingate). CrSb = Creatine and Sodium Bicarbonate. Values are in means $\pm$ SD. *Post value significantly lower than Pre value; ** Post value significantly higher than Pre value .....	32
4.	Table 4-3. Mean Values of Variables by Sprint. Values are in means $\pm$ SD. W = watts, Min = minutes, kph = kilometers per hour, RPE = rate of perceived exertion. * (p<0.05) Post value significantly different than pre value. **End RPE significantly different (p<0.0001) than Half Way RPE. ....	41
5.	Table 4-4: Gastrointestinal Distress Questionnaire Responses (5-K). Values are in means $\pm$ SD. ** Post value significantly higher than Pre value. ....	42

## LIST OF FIGURES

Figure		Page
1.	<p>Figure 4.1. Peak Power Slope in the Three Groups. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation. * Cr is significantly higher than P and CrSb.....</p>	25
2.	<p>Figure 4.2. Relative Peak Power Slope in the Three Groups. P = placebo, Cr = Creatine, CrSb = Creatine and Sodium Bicarbonate; Pre = before 8 week supplementation, Post = after 8 week supplementation. * Placebo post slope significantly worse (p = 0.009); Creatine and Sodium Bicarbonate post slope significantly worse (p = 0.04).....</p>	26
3.	<p>Figure 4.3: Mean Power Slope in the Three Groups. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation. *P post slope significantly worse (p=0.0008); CrSb post slope significantly worse (p=0.001). .....</p>	27
4.	<p>Figure 4.4: Relative Mean Power Slope in the Three Groups. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation.*P post slope significantly worse (p = 0.002); CrSb post slope significantly worse (p = 0.004). .....</p>	28

5. Figure 4.5. Fatigue Index in the Three Groups. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation.\*Cr post slope significantly higher (p = 0.03). ..... 29
6. Figure 4.6. 5-K Time to Completion in the Three Groups. Values are mean  $\pm$  SEM. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation. \* Cr time to completion was significantly higher than CrSb (p=0.01). \$ Cr post time to completion was significantly lower than pre time to completion (p=0.01)..... 33
7. Figure 4.7. 5-K Mean Speed in the Three Groups. Values are mean  $\pm$  SEM. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation.\* Cr had a significantly lower mean speed than CrSb (p=0.01)\$ Cr post supplementation mean speed is significantly higher than pre mean speed (p=0.01). ..... 34
8. Figure 4.8. 5-K Peak Speed in the Three Groups. Values are mean  $\pm$  SEM. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; KPH = kilometers per hour; Pre = before 8 week supplementation, Post = after 8 week supplementation. \* Cr peak speed significantly lower (p=0.04) than CrSb. .... 35
9. Figure 4.9. 5-K Mean Power in the Three Groups. Values are mean  $\pm$  SEM. P = placebo group, Cr = creatine group, CrSb = creatine and

	sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation. *Cr significantly lower mean power than CrSb (p=0.03) \$ Cr post supplementation mean power is significantly higher than pre mean power (p=0.01). .....	36
10.	Figure 4.10: 5-K Peak Power in the Three Groups. Values are mean $\pm$ SEM. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation.....	37
11.	Figure 4.11. 5-K Mean RPM in the Three Groups. Values are mean $\pm$ SEM. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation. *Cr post supplementation mean RPM is significantly lower than pre mean RPM (p=0.03). .....	38
12.	Figure 4.12. 5-K Peak RPM in the Three Groups. Values are mean $\pm$ SEM. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation. * P (p=0.03), Cr (p=0.04), and CrSb (p=0.04) post supplementation peak RPM is significantly lower than pre peak RPM. ....	39

## Chapter 1

### **Introduction**

#### *Statement of the Problem*

Endurance athletes are constantly seeking ways to increase exercise performance. This includes, but is not limited to altering carbohydrate intake, environmental training (e.g. live high, train low) and nutritional ergogenic aids. Dietary supplements have a potential ergogenic effect, and are the most common method used by athletes to increase exercise performance as up to 76% of athletes use some dietary supplement (3). These dietary supplements include antioxidants, herbal supplements, aspartates, caffeine, amino acids, and many others but empirical data is limited. However, two of the most investigated dietary supplements are creatine and sodium bicarbonate supplements.

Creatine supplementation is widely regarded as having a major impact on high intensity exercise performance. Many studies have shown the positive effects of creatine on high intensity, short duration activities (22, 24, 25, 28, 35). For example, Ziegenfuss et al (62) found that 3 days of creatine supplementation (0.35g/kg fat free mass), relative to placebo, improved total work in repeated cycle sprint performance. Total work in the first sprint was significantly ( $P < 0.04$ ) higher in the creatine group than in placebo, and peak power in sprints 2 through 6 was significantly ( $p < 0.01$ ) higher in the creatine group than in placebo. Balsom et al (4) found that 6 days of creatine supplementation (20g/day), compared to placebo significantly (2.3% vs. 3.2%,  $p < 0.05$ ) attenuated the decline in repeated cycling sprints. Similarly, others found (2, 58) that short-term creatine supplementation compared to placebo significantly increased running and weight lifting

performance. Taken together, these data indicate that short-term creatine supplementation can markedly increase exercise performance.

Despite the well-documented efforts of creatine supplementation, most studies have examined the short-term effects of creatine (<7days), with a dosage of 15-20g/day (16, 17, 22, 24, 25). However, these higher doses of creatine may cause gastrointestinal distress such as nausea, vomiting, and diarrhea, which may impair or hinder exercise performance (55). Thus athletes need an optimal way to ingest creatine supplementation to increase exercise performance and minimize side effects.

Surprisingly, few studies have examined the benefits of long term (>3 weeks), low dose creatine supplementation, which may minimize unwanted side effects (11, 25, 26, 28). For example, Rawson et al (49) found that 6 weeks of low-dose creatine supplementation (1.7-2.9 g/day) significantly ( $p<0.05$ ) increased resistance to fatigue during resistance exercise in men and women compared to placebo. Similarly, Burke et al (11) found that 21 days of creatine supplementation (~7.7g/day), compared to placebo, significantly increased peak force (23% vs. 13%,  $p<0.05$ ), power output (21% vs. 12%,  $p<0.05$ ), total work (68% vs. 16%,  $p<0.05$ ) and time to fatigue during resistance exercise ( $p=0.05$ ). These studies provide initial evidence that creatine supplementation lasting  $\geq 3$  weeks increased resistance exercise performance. However, it remains unclear whether cycling exercise, which is more common for endurance athletes, is effected by long-term (>3 weeks) creatine supplementation.

In addition to the well-documented effects of creatine supplementation, sodium bicarbonate has gained considerable attention on increasing exercise performance through its buffering capacity (35). Several studies have shown positive effects of short-

term and long-term supplementation of sodium bicarbonate on exercise performance (18, 27, 33, 23, 28). Lavender and Bird (33) found that short-term sodium bicarbonate supplementation, compared to placebo, significantly improved performance of cycling sprints. Average power output was significantly higher ( $p < 0.05$ ) in 8 out of 10 sprints and peak power output was significantly higher ( $p < 0.02$ ) in 2 out of 10 sprints. Similarly, other studies found that sodium bicarbonate supplementation, versus placebo, significantly increased exercise performance (27). Only one previous study examined the long-term effect of sodium bicarbonate supplementation. Edge et al (18) studied the effect of 8 weeks of sodium bicarbonate ingestion during interval training on muscle buffer capacity and short-term endurance capacity. Supplementation with sodium bicarbonate, compared to placebo, resulted in a significantly greater improvement in lactate threshold (26% vs. 15%,  $p = 0.05$ ) and a greater improvement in time to fatigue (164% vs. 123%,  $p = 0.05$ ). These data suggest that both short-term and long-term (8 weeks) sodium bicarbonate supplementation may be beneficial in increasing exercise performance.

Interestingly, only two published studies have examined the effects of combined creatine and sodium bicarbonate supplementation. Mero et al (39) found that a short-term creatine and sodium bicarbonate supplement significantly decreased swim time ( $p < 0.05$ ) compared to placebo. Recently, Barber et al (6) found that combined short-term creatine and sodium bicarbonate supplementation, compared to placebo and creatine alone, significantly increased relative peak power ( $p = 0.002$ ) and mean power in repeated cycling sprints. Also, combined creatine and sodium bicarbonate supplementation, compared to placebo and creatine alone, had the slowest rate of decline in relative peak



power during the six sprints. These data suggest that combined creatine and sodium bicarbonate supplementation may have a potential additive effect on performance. However, no published study has examined the long-term effects of combining these two supplements on exercise performance. Thus, there is a need to examine the effects of a low dose, long-term (>3 weeks) supplementation of creatine and sodium bicarbonate.

### *Statement of Purpose*

The primary purpose of this study is to determine whether 8 weeks of creatine supplementation increases exercise performance. The secondary purpose is to determine if a combined supplementation of creatine and sodium bicarbonate has an additive effect on exercise performance.

### *Research Hypotheses*

Primary Hypotheses:

A low-dose, 8 week supplementation of creatine, compared to placebo:

1. Will significantly improve performance in repeated sprints (increase: peak power, relative peak power, mean power, and relative peak power; decrease fatigue index).
2. Will significantly increase performance in a 5-kilometer time trial (reduce time to completion).

Secondary Hypotheses:

A low-dose, 8 week combined supplementation of creatine and sodium bicarbonate, compared to placebo and creatine alone:

3. Will significantly increase performance in repeated sprints (increase: peak power, relative peak power, mean power, and relative peak power; decrease fatigue index).
4. Will significantly increase performance in a 5-kilometer time trial (reduce time to completion).

### *Significance*

This study is in response to the American College of Sports Medicine recommendation for more long-term (> 3 weeks) creatine supplementation studies on exercise performance and alleviating side effects (55). This study will be the first to determine the effects of 8 weeks of creatine supplementation on two different types of cycling exercise. To our knowledge, this is the first study to investigate the effects of a low dose, 8 week creatine and creatine plus sodium bicarbonate supplementation on exercise performance, both of which might minimize gastrointestinal distress and other potential side effects. Moreover, we will show evidence to help determine whether creatine plus sodium bicarbonate is more beneficial than creatine alone. The results of this study will benefit endurance athletes and coaches by providing a convenient, low-dose, supplement to increase exercise performance.

### *Definition of Terms*

ATP (adenosine triphosphate): ATP is a high-energy phosphate compound from which energy is derived (46).

Creatine: Creatine is stored in the muscles as phosphocreatine, which serves as a readily available source of ATP (46). Supplementation with creatine is theorized to increase

stores of PCr in the muscle allowing for greater exercise performance through better maintenance of ATP levels. (46)

Sodium Bicarbonate (NAHCO<sub>3</sub>): Supplementation with sodium bicarbonate is theorized to improve performance by increasing buffering capacity, reducing the interference of hydrogen ions on ATP production and the contractile process (35).

Peak Power: Highest mechanical power seen during the test (1).

Mean Power: Average mechanical power seen during the test (1).

Relative Peak Power (Anaerobic Power): Measure of anaerobic power. Peak power relative to the subject's body weight. Expressed in Watts/kilogram (1).

Relative Mean Power (Anaerobic Capacity): Mean power divided by body weight. Measured in watts/kilogram (1).

Fatigue Index: Peak watts minus minimum watts divided by test duration. Measured in Watts/second (1).

## Chapter 2

### **Literature Review**

#### *Introduction*

The primary purpose of this study is to determine whether 8 weeks of creatine supplementation increases exercise performance. The secondary purpose is to determine if a combined supplementation of creatine and sodium bicarbonate has an additive effect on exercise performance. This literature review will cover the mechanism of creatine and sodium bicarbonate and evaluate the current research on the impact of supplementation of these on exercise performance.

#### *Creatine*

Creatine is a non-essential nutrient found naturally in the body (7), which can either be ingested or endogenously produced (7). Dietary sources of creatine include meat, some fish, and other animal products (61), with a typical dietary intake of creatine of approximately 1 gram (61). Endogenously, creatine is formed in the kidney, pancreas, and mainly the liver (61). Creatine is formed from the amino acids glycine, arginine, and methionine in a two-step process (61). Arginine and glycine combine to form guanidinoacetate (7). Then, a methyl group from S-adenosylmethionine is added to form creatine (7).

Nearly all creatine is stored in skeletal muscle with 60% as phosphocreatine (PCr) and 40% in the free form (7, 19). Type II muscle fibers tend to have slightly higher levels of PCr than Type I fibers (7), most likely due to their reliance on non-oxidative metabolism. Thus, phosphocreatine utilization during high-intensity exercise is higher in Type II fibers than in Type I fibers (22, 53, 56)

Creatine plays an important role in energy metabolism. When energy demand is increased, phosphocreatine (PCr) donates its phosphate to adenosine diphosphate (ADP) to produce adenosine triphosphate (ATP) (46). This reaction can be summarized as:  $\text{PCr} + \text{ADP} + \text{H}^+ \rightarrow \text{Cr} + \text{ATP}$ . This rapid method of producing energy is called the ATP-PCr system. This system is used by short-duration, high intensity activities like running, cycling, and swimming sprints and weight lifting.

As the body tries to maintain performance during high intensity activities, the PCr stores become depleted. As PCr is depleted, there is a reduction in the rate of ATP produced by the ATP-PCr system resulting in a decline in performance (46). Creatine monohydrate, taken as a supplement, has been shown to increase total creatine and creatine phosphate (4, 22, 24, 26, 58). Supplementation with creatine increased muscle PCr concentration up to 20% (55). Increasing muscular creatine levels may improve performance by aiding in the rephosphorylation of ADP to ATP, enhancing cross bridge cycling and maintenance of tension, and buffering changes in pH (7).

### *Creatine Supplementation*

Many studies have examined the effects of short-term (<10 days) creatine supplementation on high-intensity, short duration, anaerobic activities such as cycling and running sprints (16, 17, 22, 24, 25).

Aaserud et al (2) and Skare et al (52) both examined the effects of short-term creatine supplementation on repeated running sprints. Aaserud et al (2) examined the effect of 5 days of creatine supplementation (15g/day) on repeated running sprints. Eight maximal sprints of 40 meters with 25 seconds of rest in between were performed. Supplementation resulted in a significant ( $p < 0.05$ ) improvement in sprint times in sprints

4,6,7, and 8. Skare et al (52) studied the effect of 5 days of creatine supplementation (20g/day) on repeated running sprint performance. One 100m sprint and six 60m sprints were performed. Supplementation with creatine significantly ( $p<0.02$ ) decreased time to complete the 100m sprint and significantly ( $p<0.01$ ) decreased total sprint time of the six sprints. Taken together, these studies indicate that short term supplementation with creatine can delay onset of fatigue and improve sprint times in runners.

Several studies have examined the effect of short-term creatine supplementation on repeated cycle ergometer sprints. Balsom et al (4) studied the effect of 6 days of creatine supplementation (20 g/day) on repeated cycle sprints. Five, 6-second sprints at 140 rpm with 30-second recovery periods were performed. Following a 40 second rest period, after the last sprint, resistance was increased by 5% and subjects were asked to maintain 140 rpm for another 10 seconds. The percent decline in performance was significantly ( $p<0.05$ ) less in creatine supplementation, compared to placebo. Ziegenfuss et al (62) studied the effect of 0.35g/kg (fat free mass) of creatine, compared to placebo, for 3 days on repeated sprints on a cycle ergometer. Subjects were randomly assigned to a placebo group or creatine supplementation group. Subjects performed six 10-second sprints with 60 seconds of rest between each sprint. Peak power (watts) in the creatine group was significantly ( $p<0.01$ ) higher than in the placebo group. Birch et al (8) studied the effect of 5 days of creatine supplementation (20g/day) on isokinetic repeated cycle sprints. Subjects were asked to perform three sprints of 30 seconds with four minutes of passive recovery. Supplementation with creatine, compared to placebo, significantly ( $p<0.05$ ) increased peak power output (watts) during sprint one and significantly ( $p=0.05$ ) increased mean power output (average watts) in sprints one and two. Taken together,

these studies indicate that short-term supplementation with creatine improves performance in cycling sprints.

Despite the well-documented effects of creatine supplementation increasing exercise performance, most studies (including the studies listed above) have used higher doses for a short period of time (<7 days). Higher doses of creatine may cause gastrointestinal distress such as nausea, vomiting, and diarrhea, which may impair or hinder exercise performance (10). Thus athletes need an optimal way to ingest creatine supplementation to increase exercise performance and minimize side effects.

Surprisingly, few exercise studies have evaluated long-term (>3 weeks) creatine supplementation on exercise performance. Rawson et al (49) examined the effects of 6 weeks of low dose (1.7-2.9 g/day) creatine, compared to placebo, on strength training. Subjects performed a 3-repetition maximal concentric knee extension with 60 seconds of rest to measure maximal strength. Subjects were also asked to perform 5 sets of 30 concentric knee extensions with 60 seconds of rest between each set to measure muscle fatigue. Creatine supplementation, compared to placebo, significantly ( $P<0.05$ ) increased plasma creatine concentrations and increased significantly ( $p<0.05$ ) resistance to fatigue (Nm). Burke et al (11) studied the effects of 21 days of supplementation with  $\sim 7.7$ g/day of creatine on strength training. Subjects followed a specific exercise program using free weights and completed a maximal concentric bench press and rowing to exhaustion before and after supplementation (or placebo). Creatine supplementation, relative to placebo, significantly ( $p<0.05$ ) increased peak force (23% vs. 13%) and significantly ( $p=0.05$ ) increased power output (21% vs. 12%). Time to fatigue was significantly ( $p<0.05$ ) increased and number of repetitions until exhaustion were significantly ( $p=0.05$ )

increased in the creatine group versus placebo groups (17 to 24 vs. 19 to 20 reps, respectively). These studies indicate that long-term (>3 weeks) supplementation with creatine increases plasma creatine levels, resistance to fatigue, and power output in resistance exercise. No studies have examined the effect of long-term (>3 weeks), low-dose creatine supplementation on exercise performance, which may lower gastrointestinal distress and other potential side effects.

In review, the available literature suggests:

- Increased creatine levels, theoretically, improve performance by aiding in the rephosphorylation of ADP to ATP, enhancing cross bridge cycling and maintenance of tension, and buffering changes in pH (46).
- Short term supplementation with creatine increases exercise performance and reduces fatigue in short term, high intensity activities like running and cycling sprints.
- Long-term supplementation with creatine increases performance and reduces fatigue in resistance exercise however; it is unclear whether cycling exercise is affected.

#### *Sodium Bicarbonate*

The body maintains acid-base balance through three mechanisms: chemical buffers, the pulmonary system, and the kidneys (37). Buffers minimize changes in hydrogen ion concentration by accepting or releasing hydrogen ions (35). Bicarbonate is one of the body's most important buffer systems. The reaction of hydrogen ions with plasma bicarbonate results in carbonic acid and carbon dioxide, which is expelled through the lungs (35). An increase in extracellular bicarbonate raises the extracellular



pH, which promotes hydrogen ion and lactate efflux from muscles, reducing interference with ATP production and the contractile process (50). As the bicarbonate store is depleted, buffering ability is reduced and hydrogen ion concentration will increase, resulting in a decline in performance (35).

Moderate to high intensity exercise produces disturbances in the acid-base balance due to an increase in hydrogen ions. Increases in hydrogen ions can be attributed to: increased production of carbon dioxide, the break down of ATP, and the production of lactic acid and lactate (46). Hydrogen ions can hinder performance by altering the size and shape of molecules (46). Enzymes needed for ATP production can be affected by this change in size and shape and as a result, the muscle cell's ability to produce ATP is reduced (46). In addition, hydrogen ions compete for binding sites with calcium, disturbing contraction and lowering force production (46). There must be balance between the formation and removal of hydrogen ions for the body to maintain homeostasis (38).

#### *Sodium Bicarbonate Supplementation*

Several studies have examined the effect of short-term and long-term supplementation of sodium bicarbonate (15, 36). Lavender and Bird (33) studied the effects of short-term sodium bicarbonate supplementation on repeated cycling sprints. Sodium bicarbonate supplementation, compared to placebo, 60 and 120 minutes prior to exercise resulted in a significantly ( $p < 0.05$ ) higher average power output in 8 out of 10 sprints and a significantly ( $p < 0.02$ ) higher peak power output in 2 out of 10 sprints. Higgins et al (27) also examined the effects of short-term sodium bicarbonate supplementation on cycling. Sodium bicarbonate supplementation, compared to placebo,

significantly increased exercise capacity at 100% peak watts ( $p < 0.02$ ). McNaughton et al (37) studied the effects of 0.5g/kg body mass of sodium bicarbonate, compared to placebo, for 5 days on 60 seconds of intense exercise on a cycle ergometer. Peak power was significantly ( $p < 0.05$ ) higher in the sodium bicarbonate supplement group versus placebo ( $799 \pm 23.4$  vs.  $711 \pm 19.1$ ). Moreover, Price et al (47) investigated the effects of sodium bicarbonate (0.3g/kg) ingested one-hour prior to exercise on maximal cycle sprints. Power output was significantly greater ( $p < 0.05$ ) in the sodium bicarbonate group compared to placebo. These studies indicate ingesting sodium bicarbonate 60-120 minutes prior to cycling exercise increases performance.

While most studies on sodium bicarbonate have investigated its effects on cycling, Gao et al (20) studied the effect of sodium bicarbonate supplementation (2.9 mmol/kg 60 minutes before exercise) on swimming sprints. Subjects were asked to perform five 100-yard swim sprints with two-minute rests in between. Sodium bicarbonate supplementation resulted in a significant ( $p < 0.05$ ) improvement in sprints 4 and 5.

Surprisingly, only one study has examined the effect of long-term (>3 weeks) sodium bicarbonate supplementation on exercise performance. Edge et al (18) studied the effect of 8 weeks of sodium bicarbonate ingestion during interval training on muscle buffer capacity and short-term endurance capacity. Sodium bicarbonate supplementation group, compared to placebo, had significantly ( $p = 0.05$ ) greater improvements in lactate threshold (26% vs. 15%) and improvements in time to fatigue (164% vs. 123%,  $P < 0.05$ ). This study indicates that long-term sodium bicarbonate use could be beneficial but more research needs to be completed.

Sodium bicarbonate supplementation has been demonstrated to increase exercise performance. However, large doses are known to cause gastrointestinal distress, which may hinder or impair exercise performance (27, 50). The long-term (>3 weeks) effects of a low dose sodium bicarbonate supplement remain unclear, but data from pharmaceutical drug studies suggest that ~1g of sodium bicarbonate increases absorption and bioavailability. Nuereberg and Brune (41) studied the effect of adding 1g of sodium bicarbonate to medication. Results showed that the addition of sodium bicarbonate enhanced absorption due to the increased gastric pH. Banerjee et al (5) also investigated the effects of sodium bicarbonate on drug absorption. Results showed that the sodium bicarbonate protected the medication against acid degradation of the drug by increasing gastric pH.

In review, the available literature suggests:

- Supplementation with sodium bicarbonate is theorized to improve performance by increasing buffering capacity by reducing the interference of hydrogen ions on ATP production and the contractile process.
- Supplementation with sodium bicarbonate 60-120 minutes before exercise results in increased exercise performance.
- One study showed that long-term supplementation with sodium bicarbonate also results in increased exercise performance.
- Sodium bicarbonate has been shown to increase absorption and speed up transport of certain medications.

### *Combined Creatine and Sodium Bicarbonate*

Interestingly, only two published studies have examined the effects of combined creatine and sodium bicarbonate supplementation. Mero et al (39) studied the effects of combined creatine and sodium bicarbonate supplementation on 100m swimming performance. Subjects performed two 100m freestyle swims with 10 minutes of recovery between each swim. Supplementation included 20g/day for 6 days of creatine and 0.3g/kg of body weight of sodium bicarbonate on the day of testing. Creatine plus sodium bicarbonate, supplementation compared to placebo, significantly ( $p<0.05$ ) decreased 100-meter swim time. However, there was no creatine only or sodium bicarbonate only condition, so the true effectiveness of combined supplementation is not known. Barber et al (6) examined the effect of combined creatine and sodium bicarbonate supplementation, compared to placebo and creatine alone, on repeated cycling sprint performance. Subjects completed six 10-second Wingate sprints with 60 seconds of rest between each sprint. Combined creatine and sodium bicarbonate supplementation, compared to placebo, significantly ( $p=0.002$ ) increased peak power and mean power in repeated cycling sprints. Also, creatine plus sodium bicarbonate had the slowest rate of decline in peak power in the 6 sprints. Taken together, these data suggest that combined creatine and sodium bicarbonate supplementation may have an additive effect on performance. However, no published study has examined the long-term ( $>3$  weeks) effects of these two supplements.

### *5-K Time Trial*

Studies on creatine supplementation with exercise lasting longer than two minutes are limited. Additionally, only one study has examined the effects of creatine

supplementation on a cycling time trial (58). However, the ergometer (Velotron Dynafit Pro cycle ergometer, RacerMate Inc, Seattle, WA, USA) that we had access to was not used in that study. Jacobs et al (32) studied the effect of Sildenafil on 6-km time trial performance using the Velotron cycle ergometer. One hour before exercise, subjects ingested either placebo or 50 mg of sildenafil in a randomized, counterbalanced fashion. After a 5 minute warm up, subjects were instructed to complete a 6-K time trial as fast as possible and received no feedback other than when they were half way. Subjects were allowed to change gears to alter resistance. Therefore their speed and power output were a function of the resistance they selected and their RPM (32). Results indicated that Sildenafil versus placebo did not have an effect on exercise performance (time to completion, mean power output)(32).

#### *Conclusion*

Creatine and sodium bicarbonate are two of the most tested ergogenic aids. Many studies on both creatine and sodium bicarbonate have been short term, high dose studies. The findings are generally robust for short term, high doses. These studies suggest that both creatine and sodium bicarbonate independently have a positive effect on short duration, high intensity exercise. Less research has been completed on long term, low doses of creatine and sodium bicarbonate. The few studies that have focused on longer supplementation have indicated that lower doses over a long period of time work just as well as a shorter loading period. Additionally, long-term supplementation may be preferred by athletes to avoid the common side effects of high doses of both creatine and sodium bicarbonate.

## Chapter 3

### **Methods**

#### *Overview*

The effects of 8 weeks of creatine supplementation and creatine plus sodium bicarbonate supplementation on exercise performance were assessed in adult men and women. Using a randomized, double-blinded, study design, subjects were assigned to one of three conditions for eight weeks: 1) placebo, 2) creatine supplement alone, 3) creatine plus sodium bicarbonate supplement. Exercise performance, perceptions of fatigue and gastrointestinal distress were assessed before and after each condition.

#### *Subjects*

Sixty-three healthy, habitually active men and women were recruited from California Polytechnic State University and the surrounding area (Table 1). Inclusion Criteria included: (1) 18 to 40 years old, (2) body mass index (BMI) of 18.5 to < 35, (3) non-smoking, (4) > 2 hours of weekly physical activity, (5)  $VO_{2Peak} \geq 30\text{ml/kg}\cdot\text{min}$  (6) free of any chronic or metabolic disease as assessed by a Health History Questionnaire, and (7) no current use or use in the past 3 months of creatine, sodium bicarbonate, or any other dietary supplement. Exclusion Criteria includes: (1) history of infertility, (2) pregnant or trying to become pregnant, (3) Type I or II diabetes, (4) cardiovascular disease or any other metabolic disease/complication, (5) more than 3 kg of weight loss in the last 6 months, (6) history of bariatric surgery, (7) major medical conditions that prohibit physical activity, and (8) extreme diets (eg. Paleo diet, Atkins) that may influence performance. Subjects were informed of the requirements, risks, and benefits

of the study. The Human Subjects Committee at Cal Poly approved this study, and all subjects gave verbal and written consent.

<b>Variables</b> N = 63 (M 28, F 35)	<b>P</b> N = 20 (M 8, F 12)	<b>Cr</b> N = 21 (M 10, F 11)	<b>CrSb</b> N = 22 (M 10, F 12)	<b>p-value</b>
<b>Age (yr)</b>	23 $\pm$ 3.6	21 $\pm$ 0.7	22 $\pm$ 1.2	0.06
<b>Height (cm)</b>	170.5 $\pm$ 9.3	172.8 $\pm$ 9.7	172.1 $\pm$ 9.4	0.73
<b>Weight (kg)</b>	69.3 $\pm$ 11.2	69.7 $\pm$ 15.8	70.2 $\pm$ 14.5	0.98
<b>BMI</b>	23.8 $\pm$ 3	23.1 $\pm$ 3.6	23.4 $\pm$ 2.9	0.83
<b>VO<sub>2</sub> Peak</b>	42.1 $\pm$ 9.3	42.2 $\pm$ 5.8	40 $\pm$ 7.9	0.61

**Table 3-1.** Subject Characteristics. Values are mean  $\pm$  SD. P= Placebo, Cr= Creatine, CrSb = Creatine and Sodium Bicarbonate.

#### *Preliminary Tests*

Subjects completed a Health History Questionnaire, a 7-day physical activity recall, and the Physical Activity Readiness Questionnaire (PAR-Q) (See appendices A, B, D).

Subjects then completed a VO<sub>2Peak</sub> test using the Astrand protocol (25). Briefly, after a 5-minute warm-up, workload on a cycle ergometer (Quinton Cycle Ergometer, Lode B.V., Grinigen, Holland) was increased 50 W every 3 minutes for men and 30 W every 3 minutes for women. During the test, oxygen consumption and carbon dioxide production were assessed using an online metabolic system (Parvomedics TrueMax 2400, Consentius Technologies, Sandy, UT), and VO<sub>2 Peak</sub> was defined as the highest VO<sub>2</sub> value obtained (30 second average). Termination criteria included 3 out of 4: (1) respiratory exchange ratio > 1.15, (2) heart rate within 10 beats of age predicted heart rate max (220 – age), (3) the subject voluntarily stopped the test, and 4) RPE>18. Subjects were asked to complete the test again at another date if they did not meet three of these conditions.

### *Exercise Protocol*

All subjects completed 6 exercise tests (2 practice, 2 baseline, 2 post-supplement). The practice trials of the repeated sprint test and time-trial test were selected to minimize any learning effects of the exercise protocols (see below for description of exercise tests). Subjects completed the practice and baseline exercise tests first, and then were randomly assigned to one of the three conditions (see Supplement Procedure below) for 8 weeks. The final exercise test was completed after the 8 weeks of supplementation.

Subjects were asked to refrain from exercise, alcohol, and caffeine for 24 hours prior to testing. After a 12-hour overnight fast, subjects arrived in the morning in the Kinesiology Department and completed either a repeated sprint test or time-trial test, in a counterbalanced order. There was a minimum of 48 hours between exercise tests.

### *Repeated Sprint Test*

Subjects performed a modified Wingate test (6x10second sprints) on a Velotron Dynafit Pro cycle ergometer (Racer-Mate Inc, Seattle, WA, USA), as previously used in the kinesiology laboratory (6). This test consists of six 10-second sprints with a 60-second active recovery after each sprint. The test started with a 5-minute warm-up at 50 W with three 5-second practice sprints. At the end of the warm-up, the test administrator gave a 10-second countdown in which subjects built up their maximal effort. At the end of the countdown, resistance equal to 0.075 kg per kilogram of body weight was magnetically added at the beginning of the sprint (31, 62). Subjects were instructed to perform maximally throughout each sprint. No feedback or encouragement was given. Immediately following each sprint, there was a 60-second active recovery at 50W. This procedure was repeated six times. Performance measures assessed include: Primary



Measures: peak power (W), mean power (W); Secondary Measures: relative peak power (W/kg), relative mean power (W/kg), and fatigue index (W/second).

Gastrointestinal distress was assessed before and after the test using a validated questionnaire (44). The questionnaire addresses upper abdominal problems, lower abdominal problems and systemic discomfort. Each question is rated on a 0 – 10 point scale that ranged from 0 = no problem at all to 10 = the worst it has ever been (See Appendix C). Perceived level of exertion was assessed using the Borg Ratings of Perceived Exertion (RPE) scale before and after each sprint (9, 40).

#### *Time Trial Test*

Subjects completed a 5-kilometer time trial test as previously described by Jacobs et al (32). Subjects warmed up for 5 minutes prior to the time-trial. Using a gated-style start, subjects remained motionless on the time-trial bike (Velotron Dynafit Pro cycle ergometer, RacerMate Inc, Seattle, WA, USA) until the test was initiated by the researcher. The subjects were allowed to change gears as often as desired to simulate actual outdoor racing and were instructed to complete the 5 km time-trial as quickly as possible. Subjects were not allowed to view their time, watts, speed, or distance on the monitor. They were informed when they completed half of the distance but were given no other feedback. RPE and heart rate were recorded at the halfway point and in the last minute.

Performance measures assessed include: Primary Measure: time to completion; Secondary Measures: max watts, average watts, max speed, average speed, heart rate, average rpm, and max rpm. Subjects also completed the gastrointestinal distress questionnaire before and after the time trial.

### *Supplementation Procedure*

After the familiarization trial and baseline tests were completed, subjects were randomly assigned (by sex) to a placebo (P), creatine only (Cr), or creatine plus sodium bicarbonate supplement (CrSb), in a double-blind fashion, for 8 weeks. The placebo was a calcium pill (Costco Wholesale Corporation, Seattle, WA.). Calcium was chosen as a placebo because current research suggests that carbohydrates, or a sugar pill, even in the form of a mouth rinse, have a positive effect on exercise performance (13, 45). The creatine supplement (Now Sports, Bloomingdale, IL) consisted of 3 grams per day, as recommended by the American College of Sports Medicine (55). The creatine plus sodium bicarbonate supplement consisted of 3 grams of creatine plus 1 gram of sodium bicarbonate (Church & Dwight Co. Inc., Princeton, NJ). Subjects were asked to take their assigned pills everyday, in the morning with food and their adherence and GI distress was recorded using a weekly pill log. Subjects were given one week worth of pills and at the end of each week met a researcher in the kinesiology lab to get new pills for the next week. Subjects were reminded to take pills 3 to 4 times a week via phone call or text message. At the end of 8 weeks, subjects were asked to take their pills one hour prior to exercise testing.

### *Statistical Analysis*

JMP by Statistical Analysis Software Inc. (SAS Institute, Cary, North Carolina) was used for data analysis. For the Wingate sprint test, slope (rate of decline) for each performance measure over the six sprints was determined by calculating the individual slope for each subject through a regression analysis. Slope was calculated for each performance measure, both pre and post supplementation. A repeated measures ANOVA

was used to determine treatment, sprint, and treatment by sprint interactions for peak power, relative peak power, mean power, relative mean power, and fatigue index. Sex, VO2 Peak, and BMI were used as covariates. Moreover, general linear model was used to determine differences in individual sprints. For the time trial data, a repeated measures ANOVA was used to determine treatment and treatment by time interactions using the same covariates. By convention,  $\alpha < 0.05$  was considered significant and when significant, Tukey's Honestly Significant Difference test was used to determine where the difference lied. In exploratory analyses, paired t-tests were used to determine differences within groups over time. Statistical analyses used intent-to treat analysis (i.e. baseline data was carried forward) when subjects were lost to follow up. Two subjects dropped out before finishing the second round of testing.

#### *Sample Size Calculation*

In conducting our power analysis (N=60) we assumed intent to treat analyses and that 5% would be lost to follow up.

Primary Hypothesis: The power calculation and sample size for this study is based on a study by Burke et al. (2000) that found a significant increase ( $p < 0.05$ ) in total work in low dose creatine supplementation versus placebo (68% vs. 16%). Using a similar small to moderate effect size, a sample size of 57 (19 in each group) would have 93.5% power to detect a significant difference in creatine versus placebo using an  $\alpha = 0.05$  and a two-sided test of significance.

Secondary Hypotheses: Relative peak power (Watts/kg body weight) during the repeated sprint exercise test was used to calculate the effect size and determine the necessary sample size, because relative peak power is a critical marker of exercise

performance. The calculation is based on a previous study by Barber et al (2012) showing a significant increase in relative peak power after creatine plus sodium bicarbonate supplementation vs. placebo ( $13.5 \pm 1.0$  vs.  $12.5 \pm 1.0$  watts/kg body weight). Using a similar small to moderate effect size, a sample size of 57 (19 in each group) would have 86.9% power to detect a significant difference in relative peak power with the creatine plus sodium bicarbonate supplement vs. placebo using an  $\alpha = 0.05$  and a two-sided test of significance.

Barber et al (6) also showed a significant difference in relative peak power after creatine plus sodium bicarbonate supplementation vs. creatine only supplementation ( $1.5 \pm 1.0$  vs.  $0.6 \pm 1$  watts/kg body weight). Using a similar small to moderate effect size, a sample size of 57 (19 in each group) would have 85.2% power to detect a significant difference in relative peak power with the creatine plus sodium bicarbonate supplement vs. creatine only supplement using an  $\alpha = 0.05$  and a two-sided test of significance.

#### *Limitations*

No blood analyses were completed in this study. Therefore, we cannot conclude if the low doses of creatine and sodium bicarbonate actually increased serum levels. Subjects were expected to follow the supplementation protocol. Subjects were required to return pill containers weekly and report to a research assistant. However, since they were not monitored daily, we can't be sure how well they adhered to the supplementation protocol. In addition, maximal effort may vary by person and we cannot be sure that subjects were giving maximal effort during the exercise tests.

## Chapter 4

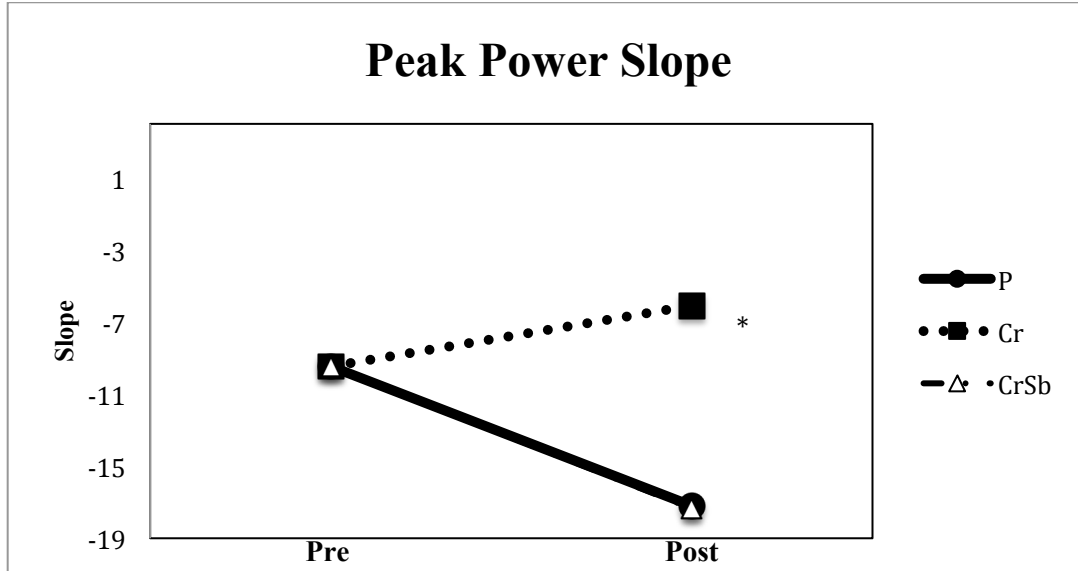
### Results

#### *Wingate Repeated Sprint Test*

##### *Peak Power*

There was a significant interaction of treatment \* time ( $p = 0.035$ ) in peak power slope between the three groups. The slope (rate of decline) in the placebo group and creatine and sodium bicarbonate group was significantly worse ( $p = 0.03$  and  $p = 0.025$  respectively) than the slope (rate of decline) in the creatine group (Figure 4.1). There was no significant ( $p = 0.94$ ) difference in slope (rate of decline) between the placebo group and creatine and sodium bicarbonate group.

There was no significant difference in placebo or creatine across sprints. A general linear model was used to compare differences in individual sprints. Peak power output was significantly lower ( $p < 0.05$ ) in sprint 4, 5, and 6 compared to sprint 1 in the creatine and sodium bicarbonate group (Table 4-1).

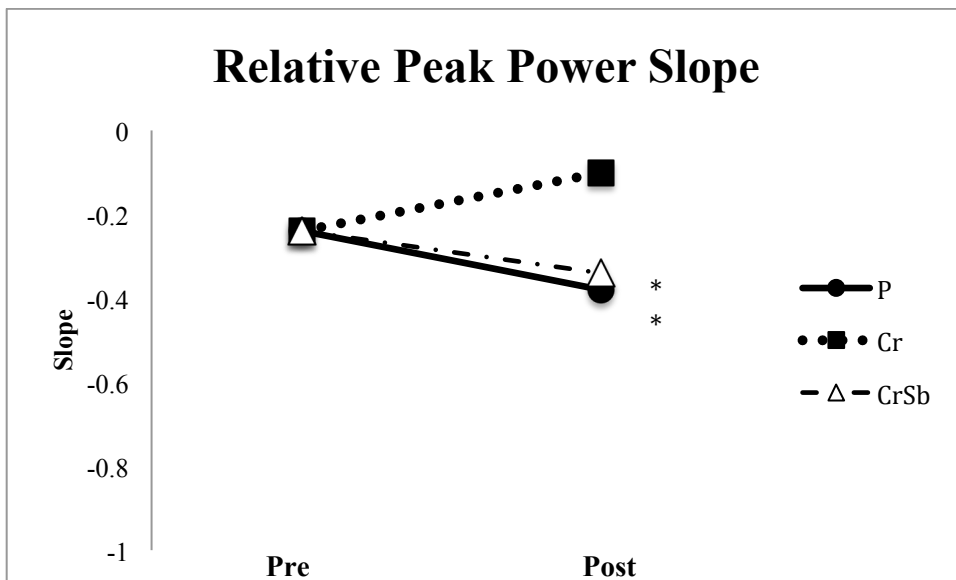


**Figure 4.1.** Peak Power Slope in the Three Groups. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation. \* Cr is significantly higher than P and CrSb

### Relative Peak Power

There was no significant difference ( $p=0.15$ ) in rate of decline (slope) between the three groups (Figure 4.2). Moreover, using a general linear model, there was no significant difference within or between groups in relative peak power (Table 4-1).

In exploratory analysis, placebo ( $p=0.009$ ) and creatine and sodium bicarbonate ( $p=0.04$ ) slope (rate of decline) was significantly worse from pre to post. There was no significant difference ( $p=0.26$ ) in creatine slope (rate of decline) from pre to post.

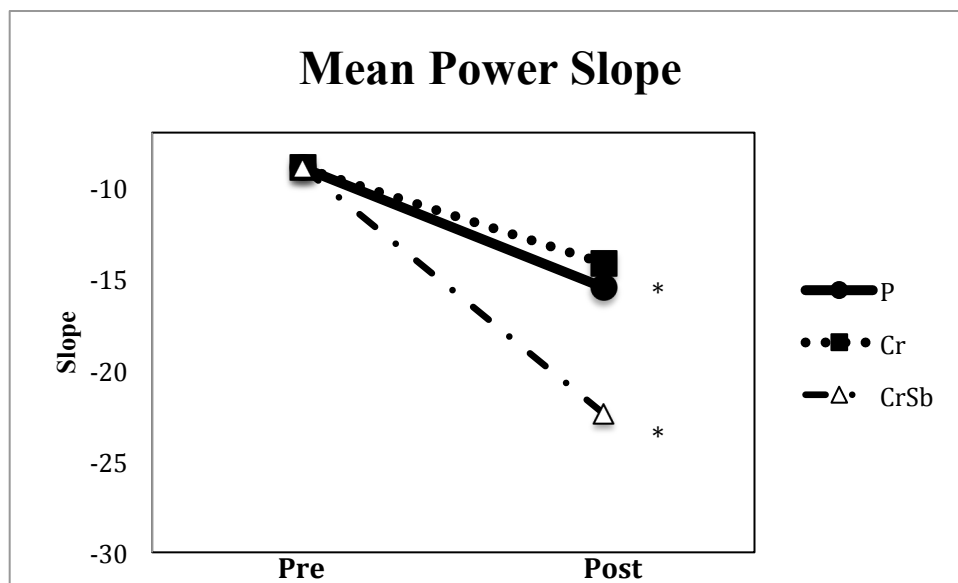


**Figure 4.2.** Relative Peak Power Slope in the Three Groups. P = placebo, Cr = Creatine, CrSb = Creatine and Sodium Bicarbonate; Pre = before 8 week supplementation, Post = after 8 week supplementation. \* Placebo post slope significantly worse ( $p=0.009$ ); Creatine and Sodium Bicarbonate post slope significantly worse ( $p=0.04$ ).

### Mean Power

There was no significant difference ( $p=0.18$ ) in slope (rate of decline) between the three groups in mean power (Figure 4.3). Using a general linear model, to examine differences across sprints within groups, mean power was significantly lower ( $p<0.05$ ) in the creatine and sodium bicarbonate group in sprint 4, 5, and 6 compared to sprint 1 (Table 4-1). Moreover, mean power was significantly lower ( $p<0.05$ ) in sprint 6 compared to sprint 1 in placebo (Table 4-1).

In exploratory analysis, the placebo group ( $p=0.0008$ ) and the creatine and sodium bicarbonate group ( $p=0.001$ ) slope (rate of decline) was significantly worse from pre to post. There was no significant difference ( $p=0.43$ ) in slope (rate of decline) from pre to post in the creatine group.



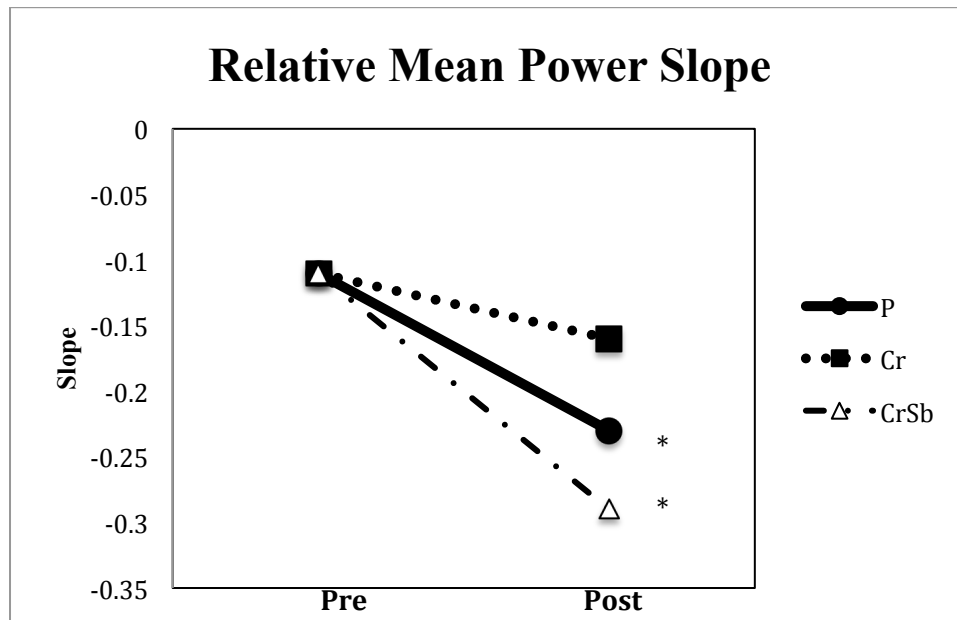
**Figure 4.3.** Mean Power Slope in the Three Groups. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation. \*P post slope significantly worse ( $p=0.0008$ ); CrSb post slope significantly worse ( $p=0.001$ ).



### Relative Mean Power

There was no significant difference ( $p=0.15$ ) in slope (rate of decline) between the three groups in relative mean power (Figure 4.4). Using a general linear model, to examine differences across sprints within group, the creatine and sodium bicarbonate group and placebo group showed significantly lower ( $p<0.05$ ) power output values in sprint 4, 5, and 6 compared to sprint 1 (Table 4-1).

In exploratory analysis, placebo ( $p=0.002$ ) and creatine and sodium bicarbonate groups ( $p = 0.004$ ) slope (rate of decline) was significantly worse from pre to post. There was no significant difference ( $p = 0.44$ ) in the creatine group slope (rate of decline) from pre to post.

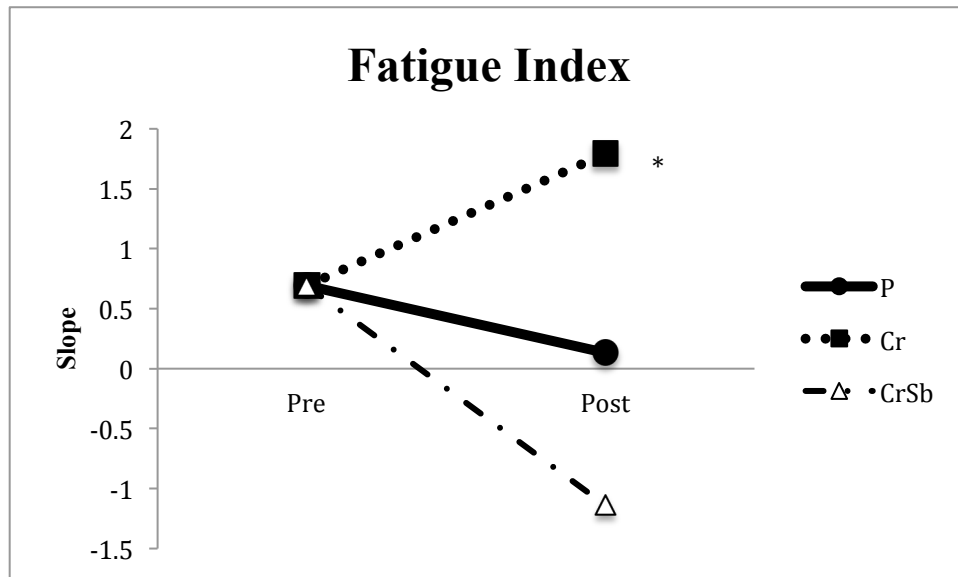


**Figure 4.4.** Relative Mean Power Slope in the Three Groups. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation. \*P post slope significantly worse ( $p = 0.002$ ); CrSb post slope significantly worse ( $p = 0.004$ ).

### Fatigue Index

There was no significant difference ( $p=0.14$ ) in slope (rate of decline) in fatigue index (Figure 4.5). Using a general linear model, there was no significant ( $p>0.05$ ) difference within groups in fatigue index (Table 4-1).

In exploratory analysis, fatigue index was not significantly different in placebo and creatine and sodium bicarbonate pre to post ( $p = 0.2$  and  $p = 0.6$  respectively). However, fatigue index was significantly higher ( $p = 0.03$ ) from pre to post in the creatine group.



**Figure 4.5.** Fatigue Index in the Three Groups. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation.\*Cr post slope significantly higher ( $p = 0.03$ ).

### *Rate of Perceived Exertion*

There was a main effect for treatment ( $p < 0.001$ ), time ( $p < 0.001$ ) and interaction of treatment \* time ( $p < 0.001$ ). Placebo group RPE post supplementation was significantly higher ( $p < 0.001$ ) than RPE in the pre supplementation condition. RPE was significantly higher in the creatine ( $p = 0.03$ ) and creatine and sodium bicarbonate groups ( $p = 0.002$ ) during pre and post conditions. However, there were no significant ( $p > 0.05$ ) differences within those groups from pre to post supplementation.

### *Gastrointestinal Distress Questionnaire*

There was no significant main effect of treatment for any of the questions. The creatine group showed a significant decrease in nausea ( $p = 0.007$ ) and muscle cramps ( $p = 0.02$ ) from pre to post. The creatine and sodium bicarbonate group showed a significant increase in nausea ( $p = 0.002$ ) and muscle cramps ( $p = 0.02$ ) from pre to post. The placebo group showed a significant increase in nausea ( $p = 0.04$ ) from pre to post. Other gastrointestinal distress questions were not significant ( $p > 0.05$ ). Individual values are shown in Table 4-2.

Variable	Sprint	Placebo	Creatine	Creatine + Sb
<b>Peak Power (W)</b>	1	738 $\pm$ 176	836 $\pm$ 289	806 $\pm$ 221
	2	720 $\pm$ 166	796 $\pm$ 260	794 $\pm$ 206
	3	720 $\pm$ 160	790 $\pm$ 281	774 $\pm$ 233
	4	692 $\pm$ 166	781 $\pm$ 265	743 $\pm$ 214*
	5	688 $\pm$ 171	779 $\pm$ 256	735 $\pm$ 213*
	6	687 $\pm$ 152	776 $\pm$ 246	719 $\pm$ 200*
<b>Relative Peak Power (W/kg)</b>	1	10.6 $\pm$ 1.5	11.6 $\pm$ 1.6	11.2 $\pm$ 1.8
	2	10.3 $\pm$ 1.4	11 $\pm$ 1.4	10.9 $\pm$ 1.5
	3	10.3 $\pm$ 1.2	10.9 $\pm$ 1.6	10.8 $\pm$ 1.4
	4	9.9 $\pm$ 1.4	10.8 $\pm$ 1.4	10.3 $\pm$ 1.3
	5	9.8 $\pm$ 1.4	10.8 $\pm$ 1.3	10.2 $\pm$ 1.3
	6	9.8 $\pm$ 1.3	10.8 $\pm$ 1.3	10 1. $\pm$ 2
<b>Mean Power (W)</b>	1	663 $\pm$ 160	740 $\pm$ 239	727 $\pm$ 202
	2	640 $\pm$ 155	710 $\pm$ 215	707 $\pm$ 193
	3	640 $\pm$ 151	684 $\pm$ 210	675 $\pm$ 201
	4	608 $\pm$ 155	668 $\pm$ 190	649 $\pm$ 184 *
	5	606 $\pm$ 160	656 $\pm$ 176	637 $\pm$ 183 *
	6	604 $\pm$ 147*	660 $\pm$ 180	630 $\pm$ 177 *
<b>Relative Mean Power (W/kg)</b>	1	9.5 $\pm$ 1.5	10.3 $\pm$ 1.4	10.1 $\pm$ 1.7
	2	9.2 $\pm$ 1.4	9.9 $\pm$ 1.3	9.8 $\pm$ 1.5
	3	9.2 $\pm$ 1.4	9.5 $\pm$ 1.3	9.4 $\pm$ 1.4
	4	8.7 $\pm$ 1.5*	9.3 $\pm$ 1.1	9.1 $\pm$ 1.2*
	5	8.7 $\pm$ 1.5*	9.1 $\pm$ 1.1	8.9 $\pm$ 1.2*
	6	8.7 $\pm$ 1.5*	9.2 $\pm$ 0.99	8.8 $\pm$ 1.2*
<b>Fatigue Index (W/s)</b>	1	17.4 $\pm$ 14.1	21.6 $\pm$ 15.1	18.3 $\pm$ 6.5
	2	21.4 $\pm$ 8.1	20.1 $\pm$ 14.7	20.9 $\pm$ 7.5
	3	18.5 $\pm$ 14.5	22.8 $\pm$ 19.3	22.4 $\pm$ 10.9
	4	18.4 $\pm$ 15.1	25.5 $\pm$ 9.9	21.6 $\pm$ 12.4
	5	19.1 $\pm$ 13.9	27.4 $\pm$ 20.1	22.2 $\pm$ 11
	6	19.2 $\pm$ 14.1	27.9 $\pm$ 19.8	20.6 $\pm$ 10.4
<b>RPE</b>	1	12.2 $\pm$ 1.8	12 $\pm$ 1.9	12.1 $\pm$ 2.2
	2	13.5 $\pm$ 1.9	13.7 $\pm$ 1.7	13.7 $\pm$ 1.9
	3	14.6 $\pm$ 1.9	14.9 $\pm$ 1.5	15.1 $\pm$ 1.8
	4	15.5 $\pm$ 1.9	16 $\pm$ 1.5	15.8 $\pm$ 1.8
	5	16.2 $\pm$ 1.6	16.8 $\pm$ 1.6	16.7 $\pm$ 1.8
	6	16.6 $\pm$ 1.7	17.6 $\pm$ 1.6	17.2 $\pm$ 1.7

**Table 4-1.** Mean Values of Variables by Sprint. Values are in means  $\pm$  SD. W = watts, W/kg = Watts per kilogram of body mass, W/s = watts per second, RPE = rate of perceived exertion. \*significantly lower than sprint 1

Section/Question	Condition	Placebo	Creatine	CrSb	
<b>Upper Abdominal</b> 1	Pre	0.10+0.30	0.09+0.44	0+0	
	Post	0+0	0+0	0.05+0.21	
	2	Pre	0.05+0.23	0.09+0.44	0+0
	Post	0.10+0.45	0+0	0.27+0.77	
	3	Pre	0.05+0.23	0.14+0.65	0.41+1.33
	Post	0.05+0.22	0+0	0.14+0.47	
4	Pre	0.05+0.23	0.29+1.10	0.41+1.33	
	Post	0.1+0.31	0.19+0.87	0.18+0.66	
5	Pre	0.40+1.57	0.24+0.77	0.27+1.08	
	Post	0.20+0.52	0.09+0.44	0.50+1.47	
6	Pre	0.50+1.57	0.76+1.48	0.41+0.96	
	Post	1.35+1.79**	0.29+0.78*	1.77+2.29**	
<b>Lower Abdominal</b> 1	Pre	0.05+0.22	0.14+0.65	0+0	
	Post	0.05+0.22	0.14+0.65	0.05+0.21	
	2	Pre	0.30+0.92	0.14+0.48	0.36+1.14
	Post	0.10+0.45	0.09+0.44	0.24+0.89	
	3	Pre	0.15+0.49	0.19+0.60	0.05+0.21
		Post	0+0	0.19+0.87	0.14+0.35
	4	Pre	0.05+0.22	0.14+0.65	0+0
		Post	0.10+0.45	0.14+0.48	0.09+0.29
	5	Pre	0.05+0.22	0.14+0.65	0+0
		Post	0+0	0.05+0.22	0.09+0.29
	6	Pre	0.05+0.22	0.05+0.22	0.05+0.21
		Post	0+0	0.09+0.44	0.14+0.64
	7	Pre	0.05+0.22	0.05+0.22	0+0
		Post	0+0	0+0	0.14+0.47
<b>Systemic</b> 1	Pre	0.50+1.10	0.67+1.49	0.82+1.37	
	Post	0.90+1.45	0.29+1.10	1+2.02	
	2	Pre	0.45+0.83	0.71+1.35	0.45+1.06
	Post	0.15+0.49*	0.43+1.21	0.41+0.96	
	3	Pre	0.45+0.95	1.05+2.01	0.41+0.96
		Post	0.25+0.72	0.33+1.15*	0.86+1.55**
	4	Pre	0.10+0.32	0.33+0.97	0.18+0.85
		Post	0+0	0.14+0.65	0.05+0.21

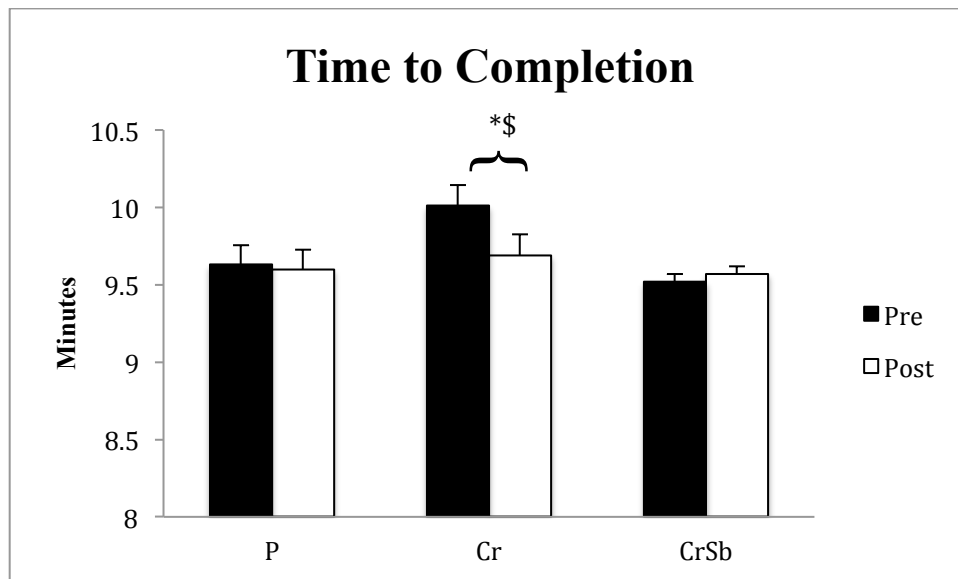
**Table 4-2.** Gastrointestinal Distress Questionnaire Responses (Wingate). CrSb = Creatine and Sodium Bicarbonate. Values are in means  $\pm$  SD. \*Post value significantly lower than Pre value; \*\* Post value significantly higher than Pre value

## Time Trial

### Time to Completion

There was a significant main effect for treatment ( $p = 0.02$ ) (Figure 4.6) but no significant effect for time or interaction of treatment\*time. The creatine group had significantly longer ( $p = 0.01$ ) times than the creatine and sodium bicarbonate group at baseline.

In exploratory analysis the creatine group showed a significant decrease in time to completion ( $p=0.01$ ). There was no significant improvement in the placebo ( $p=0.8$ ) or creatine and sodium bicarbonate groups( $p=0.8$ ).

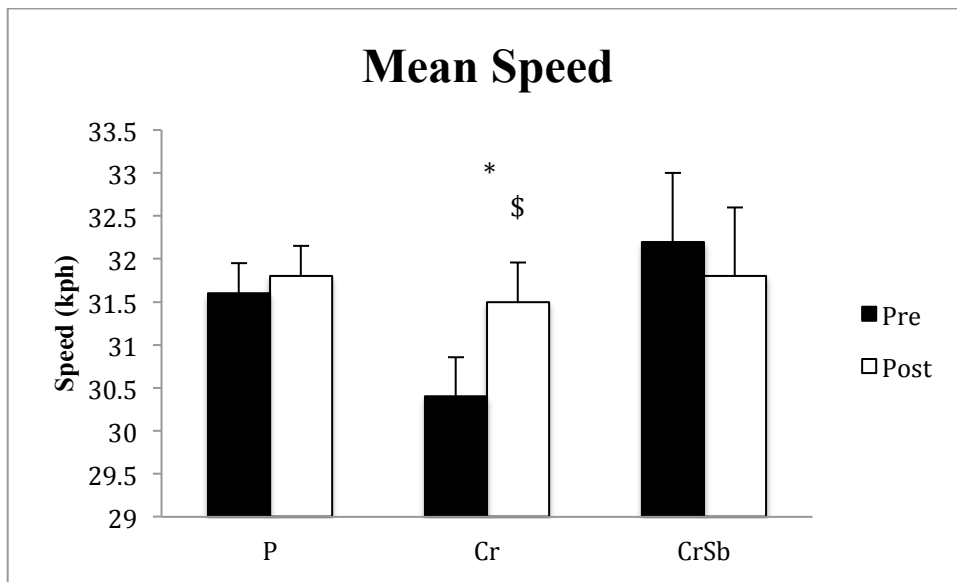


**Figure 4.6.** 5-K Time to Completion in the Three Groups. Values are mean  $\pm$  SEM. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation. \* Cr time to completion was significantly higher than CrSb ( $p=0.01$ ). \$ Cr post time to completion was significantly lower than pre time to completion ( $p=0.01$ ).

### Mean Speed

There was a main effect for treatment ( $p = 0.01$ ), but no effect of time or interaction of treatment\*time (Figure 4.7). The creatine group had significantly lower ( $p = 0.02$ ) mean speed than the creatine and sodium bicarbonate group at baseline.

In exploratory analysis, the creatine group had a significant increase in mean speed ( $p=0.01$ ). Combined creatine and sodium bicarbonate ( $p = 0.6$ ) and placebo ( $p=0.6$ ) had no significant difference within groups.

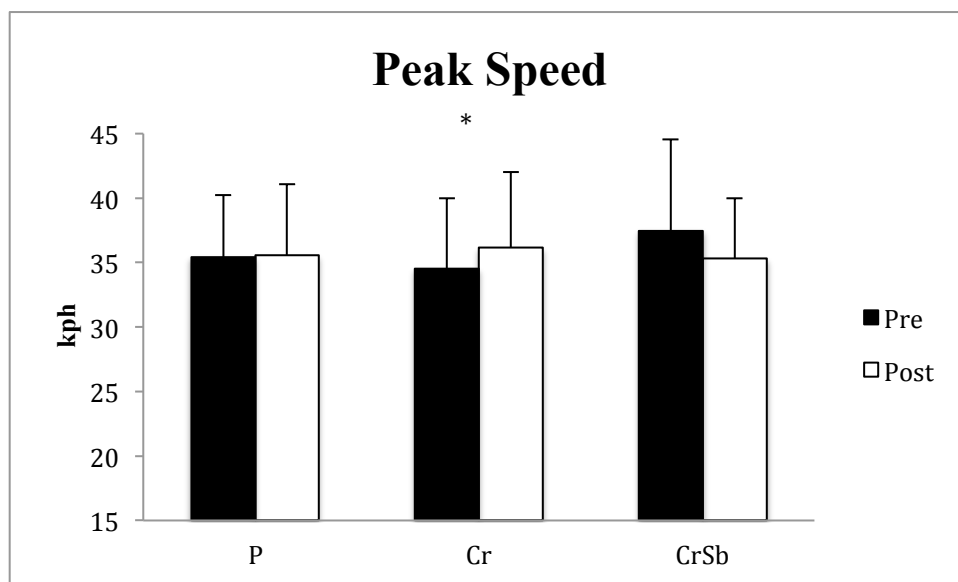


**Figure 4.7.** 5-K Mean Speed in the Three Groups. Values are mean  $\pm$  SEM. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation. \* Cr had a significantly lower mean speed than CrSb ( $p=0.01$ )\$ Cr post supplementation mean speed is significantly higher than pre mean speed ( $p=0.01$ ).

### Peak Speed

There was a significant main effect for treatment ( $p = 0.04$ ), but no effect of time or interaction of treatment\*time (Figure 4.8). The creatine group had significantly lower ( $p = 0.04$ ) peak speed than the creatine and sodium bicarbonate group at baseline.

In exploratory analysis there was no significant difference between pre and post supplementation peak speed within any of the groups.



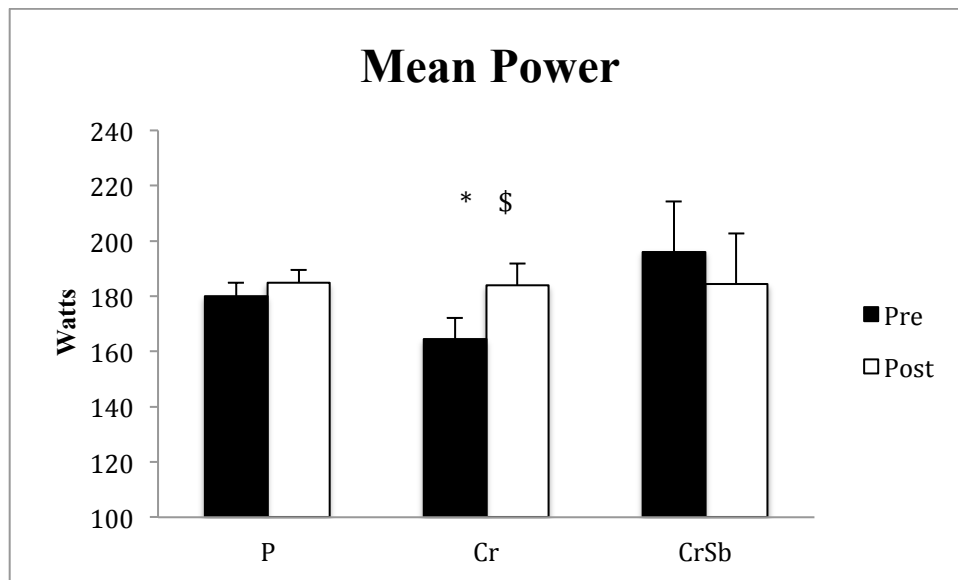
**Figure 4.8.** 5-K Peak Speed in the Three Groups. Values are mean  $\pm$  SEM. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; KPH = kilometers per hour; Pre = before 8 week supplementation, Post = after 8 week supplementation. \* Cr peak speed significantly lower ( $p=0.04$ ) than CrSb.



### Mean Power

There was a main effect for treatment ( $p = 0.03$ ), but no effect of time or interaction of treatment\*time (Figure 4.9). The creatine group had significantly lower ( $p=0.03$ ) average power than the creatine and sodium bicarbonate group at baseline.

In exploratory analysis, the creatine group had a significant increase in mean power ( $p=0.01$ ) pre to post. Combined creatine and sodium bicarbonate and placebo had no significant difference within groups between pre and post supplementation mean power.

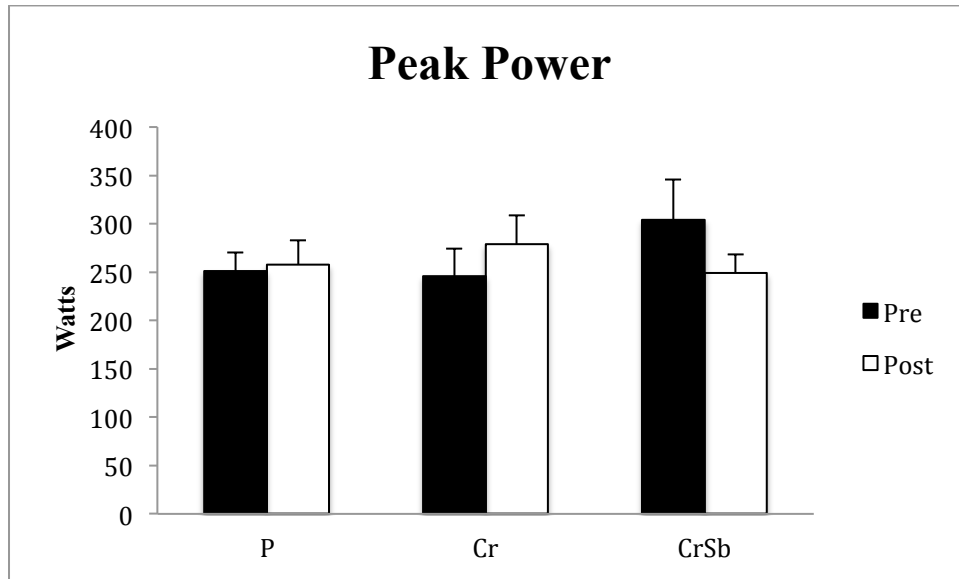


**Figure 4.9.** 5-K Mean Power in the Three Groups. Values are mean  $\pm$  SEM. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation. \*Cr significantly lower mean power than CrSb ( $p=0.03$ ) \$ Cr post supplementation mean power is significantly higher than pre mean power ( $p=0.01$ ).

### Peak Power

There was no significant main effect of treatment, time or interaction of treatment\*time (Figure 4.10).

In exploratory analysis, there was no significant difference between pre and post supplementation peak power within any of the groups.

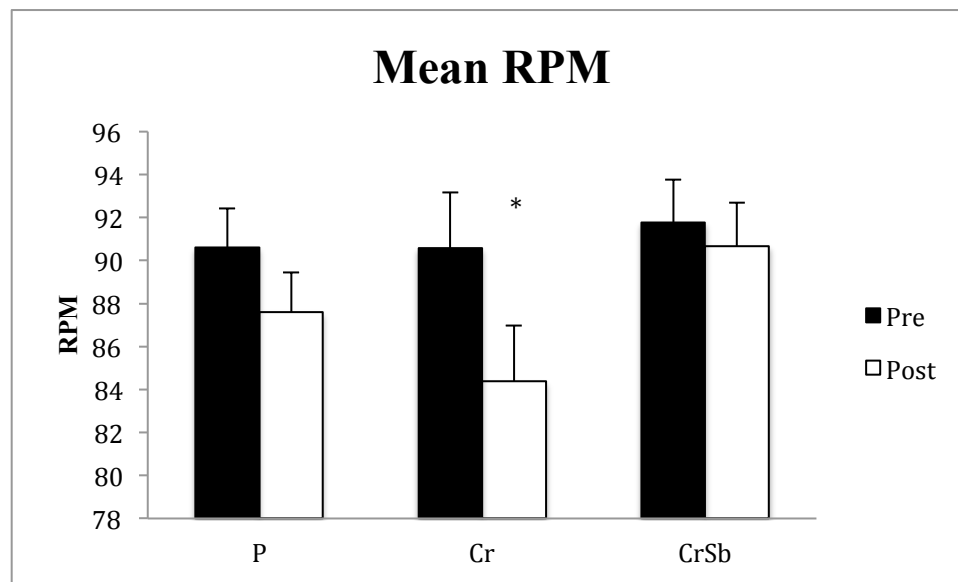


**Figure 4.10.** 5-K Peak Power in the Three Groups. Values are mean  $\pm$  SEM. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation.

### Mean RPM

There was no significant main effect of treatment, time or interaction of treatment\*time (Figure 4.11).

In exploratory analysis, the creatine group had a significant decrease in mean RPM ( $p=0.03$ ). Combined creatine and sodium bicarbonate ( $p = 0.6$ ) and placebo ( $p=0.1$ ) had no significant difference within groups between pre and post mean RPM.

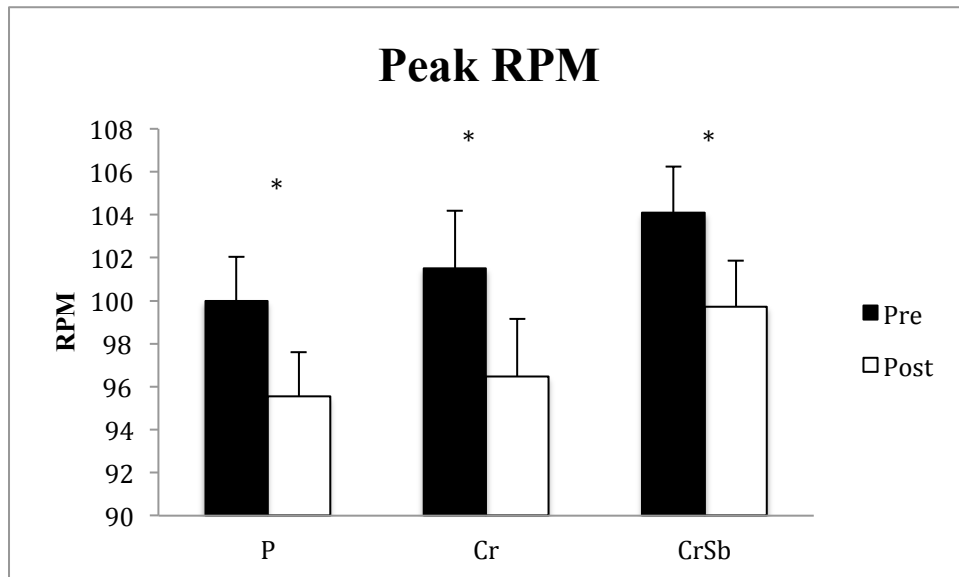


**Figure 4.11.** 5-K Mean RPM in the Three Groups. Values are mean  $\pm$  SEM. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation. \*Cr post supplementation mean RPM is significantly lower than pre mean RPM ( $p=0.03$ ).

### Peak RPM

There was no significant main effect of treatment was observed. There was an effect of time ( $p = 0.02$ ) such that post supplementation peak RPM was significantly lower than pre supplementation RPM. The interaction of treatment\*time was not significant ( $p > 0.05$ ) (Figure 4.12).

In exploratory analysis, the placebo ( $p = 0.03$ ), creatine ( $p = 0.04$ ), and creatine and sodium bicarbonate ( $p = 0.04$ ) groups all showed a significant decrease in peak RPM from pre to post supplementation.



**Figure 4.12.** 5-K Peak RPM in the Three Groups. Values are mean  $\pm$  SEM. P = placebo group, Cr = creatine group, CrSb = creatine and sodium bicarbonate group; Pre = before 8 week supplementation, Post = after 8 week supplementation. \* P ( $p=0.03$ ), Cr ( $p=0.04$ ), and CrSb ( $p=0.04$ ) post supplementation peak RPM is significantly lower than pre peak RPM.

### *Mean Heart Rate*

There was no significant main effect of treatment, time or interaction of treatment\*time (data not shown). In exploratory analysis, there was no significant difference between pre and post supplementation mean heart rate within any of the groups.

### *Peak Heart Rate*

There was no significant main effect of treatment, time or interaction of treatment\*time (data not shown). In exploratory analysis, there was no significant difference between pre and post supplementation peak heart rate within any of the groups.

### *Rate of Perceived Exertion*

There was no significant main effect of treatment, time or interaction of treatment\*time. There was no significant difference in RPE from pre to post in halfway point of 5 km time trial (Placebo  $p = 0.5$ ; Cr  $p = 0.7$ ; CrSb  $p = 0.6$ ) or last minute point of 5 km time trial (Placebo  $p = 1$ ; Cr  $p = 0.6$ ; CrSb  $p = 0.3$ ). All groups had a significantly higher ( $p < 0.001$ ) last minute RPE than half-way RPE in both pre and post supplementation.

*Gastrointestinal Distress Questionnaire*

No main effect of treatment was observed for any of the questions. However, there was a significant interaction of treatment\*time (p=0.012) such that the placebo group had a significant increase in nausea (p=0.02) from pre to post. Moreover, the creatine and sodium bicarbonate group had a significant increase in loose stool (p = 0.04) and diarrhea (p=0.04) from pre to post. There was no significant difference in any gastrointestinal distress markers in the creatine group. Other gastrointestinal distress questions were not significant (p>0.05). Individual values are shown in Table 4-4.

<b>Variable</b>	<b>Condition</b>	<b>Placebo</b>	<b>Creatine</b>	<b>CrSb</b>
<b>Time to Completion (Min)</b>	<b>Pre</b>	9.63 ± 1.28	10.01 ± 1.26	9.52 ± 1.36
	<b>Post</b>	9.59 ± 1.33	9.69 ± 1.33*	9.57 ± 1.22
<b>Mean Speed (kph)</b>	<b>Pre</b>	32 ± 4	30 ± 4	32 ± 5
	<b>Post</b>	32 ± 4	32 ± 4*	32 ± 4
<b>Peak Speed (kph)</b>	<b>Pre</b>	35 ± 5	35 ± 5	37 ± 7
	<b>Post</b>	36 ± 6	36 ± 6	35 ± 5
<b>Mean Power (W)</b>	<b>Pre</b>	180 ± 55	164 ± 55	196 ± 103
	<b>Post</b>	185 ± 66	184 ± 66*	185 ± 62
<b>Peak Power (W)</b>	<b>Pre</b>	251 ± 84	246 ± 131	304 ± 202
	<b>Post</b>	258 ± 110	279 ± 138	249 ± 87
<b>Mean RPM</b>	<b>Pre</b>	90.6 ± 11.8	90.57 ± 12.65	92 ± 11
	<b>Post</b>	87.6 ± 10.63	84.38 ± 13.63*	91 ± 12
<b>Peak RPM</b>	<b>Pre</b>	100 ± 13	102 ± 13	104 ± 12
	<b>Post</b>	96 ± 12*	96 ± 11*	100 ± 12*
<b>RPE</b>	<b>Pre Half Way</b>	14 ± 2	14 ± 2	13 ± 2
	<b>Pre End</b>	16 ± 2**	16 ± 2**	16 ± 2**
	<b>Post Half Way</b>	14 ± 2	14 ± 2	13 ± 2
	<b>Post End</b>	16 ± 2**	16 ± 2**	16 ± 1**

**Table 4-3.** Mean Values of Variables by Sprint. Values are in means ± SD. W = watts, Min = minutes, kph = kilometers per hour, RPE = rate of perceived exertion. \* (p<0.05) Post value significantly different than pre value. \*\*End RPE significantly different (p<0.0001) than Half Way RPE.

Section/Question	Condition	Placebo	Creatine	CrSb	
<b>Upper Abdominal</b>	1	Pre Post	0.05+0.22 0.10+0.31	0.26+0.89 0.05+0.22	0.05+0.21 0+0
	2	Pre Post	0.05+0.22 0+0	0.09+0.44 0.05+0.22	0.05+0.21 0.14+0.64
	3	Pre Post	0.15+0.37 0.05+0.22	0.31+1.05 0.05+0.22	0.27+0.70 0.23+0.69
	4	Pre Post	0.10+0.45 0.10+0.45	0.29+1.31 0.19+0.87	0.14+0.35 0.27+0.77
	5	Pre Post	0.05+0.22 0.10+0.45	0.09+0.44 0+0	0.09+0.29 0.05+0.21
	6	Pre Post	0.05+0.22 0.60+1.14**	0.24+0.77 0.05+0.22	0.41+1.05 1.77+2.29
<b>Lower Abdominal</b>	1	Pre Post	0.05+0.22 0.05+0.22	0.09+0.44 0.14+0.48	0+0 0+0
	2	Pre Post	0.40+1.35 0.15+0.49	0.19+0.68 0.09+0.44	0.23+1.07 0.18+0.85
	3	Pre Post	0.05+0.22 0.05+0.22	0.05+0.22 0.05+0.22	0+0 0.50+2.13
	4	Pre Post	0.05+0.22 0.05+0.22	0.14+0.65 0.05+0.22	0+0 0+0
	5	Pre Post	0.05+0.22 0.05+0.22	0.14+0.65 0.14+0.48	0.05+0.21 0.09+0.43
	6	Pre Post	0+0 0+0	0.09+0.44 0+0	0+0 0.27+0.70**
	7	Pre Post	0+0 0+0	0.05+0.22 0+0	0+0 0.23+0.61**
<b>Systemic</b>	1	Pre Post	0.35+0.75 0.45+0.89	0.33+0.97 0.29+0.90	0.64+1.53 0.45+1.01
	2	Pre Post	0.35+0.75 0.30+0.73	0.33+1.15 0.19+0.68	0.45+1.18 0.14+0.64
	3	Pre Post	0.65+1.09 0.35+0.99	0.24+0.89 0.43+1.12	0.73+1.42 0.68+1.46
	4	Pre Post	0+0 0+0	0.24+0.89 0.09+0.44	0+0 0+0

**Table 4-4.** Gastrointestinal Distress Questionnaire Responses (5-K). Values are in means  $\pm$  SD. \*\* Post value significantly higher than Pre value.

## Chapter 5

### Discussion

The primary purpose of this study was to determine whether 8 weeks of low-dose creatine supplementation increased exercise performance. The secondary purpose was to determine if a combined supplementation of creatine and sodium bicarbonate had an additive effect on exercise performance. The main findings of this study were: 1) creatine supplementation, compared to placebo and creatine and sodium bicarbonate, improved peak power output slope (rate of decline) in repeated sprints, 2) in exploratory analyses, placebo and creatine and sodium bicarbonate supplementation, had worse mean power and relative mean power output slopes (rate of decline) in repeated sprints, 3) in exploratory analyses, creatine supplementation improved time to completion, increased speed, and increased mean power output during the 5-km time trial and 4) creatine supplementation reduced nausea and cramping, whereas placebo and creatine and sodium bicarbonate supplementation did not. However, in contrast to our hypothesis, we noted no additive effect of sodium bicarbonate to creatine supplementation. These data suggest that 8 weeks of low dose creatine supplementation improves exercise performance while minimizing gastrointestinal distress but adding sodium bicarbonate supplementation to creatine offers no beneficial effect.

In general, creatine supplementation is well established to improve exercise performance (22, 24, 25, 28, 35). However, doses are typically very high (>20g/day) which may cause gastrointestinal distress (16, 17, 22, 22, 24, 25). Few studies have evaluated whether low dose creatine supplementation improves exercise performance and none have evaluated 3g/day on repeated sprint cycling performance. Results of the



current study are consistent with and extend previous studies indicating that low doses of creatine are effective in increasing exercise performance (11, 28, 49). Hoffman et al (28) found that 6g/day for 6 days reduced the rate of decline (slope) in total work over 3 sprints versus placebo during repeated Wingate sprints. In a study with a similar dosing regimen, Rawson et al (49) found that 2.3 g/day for 6 weeks enhanced resistance to fatigue in resistance exercise. In the current study, we found that creatine supplementation, compared to placebo and creatine and sodium bicarbonate supplementation, had a significantly higher slope (reduced rate of decline) in peak power over six sprints. Additionally, placebo and creatine and sodium bicarbonate groups experienced a steeper slope (greater rate of decline) in mean power and relative mean power over six sprints from pre to post supplementation. The creatine group experienced no change in slope (rate of decline) over six sprints from pre to post supplementation. Taken together, these data suggest that low-dose, creatine supplementation improves repeated sprint performance.

Many studies indicate that creatine supplementation increases short duration, high-intensity exercise performance (22, 24, 25, 28, 35). Evidence for positive effects on longer duration, aerobic activity is limited. Van Loon et al (58) observed that creatine supplementation did not improve 20 minute cycling time trial performance. To our knowledge, the present study is the only study to examine the effects of creatine supplementation, with and without sodium bicarbonate supplement, on a 5-k cycling time trial. We observed improved performance (decreased time to completion, and increased mean speed and mean power) with creatine supplementation, but no impact of placebo or creatine plus sodium bicarbonate supplementation in a 5-k time trial. Study differences

in time-trial performance with creatine supplementation may hinge on; 1) Previous studies have used time trials that are longer in duration than the current study. Research indicates that creatine is effective in increasing performance for short-term activities (7). In the study by Van Loon et al (58), the duration ( $\geq 20$  minutes) may have been too long for creatine to have a positive effect on time trial performance. Whereas in the current study, mean 5-km time trial was 9.6 minutes and appears to be short enough in duration for creatine supplementation to have a positive impact 2) In the current study, creatine supplementation took place over 8 weeks (3g/day). Van Loon et al (58) used lower doses of creatine per day (2g/day) and took place over a shorter amount of time (6 weeks); it is possible that the creatine supplementation was not high enough or long enough to have a positive effect on time trial performance (58). Nonetheless, our data supports positive benefits of creatine supplementation on 5-km time trial performance, but warrants further investigation to determine longer duration aerobic performance.

The exact mechanism of how creatine supplementation improves exercise performance remains unclear. However, creatine supplementation has been shown to increase total creatine and creatine phosphate levels which may improve performance by aiding in the rephosphorylation of ADP to ATP, enhancing cross bridge cycling and maintenance of tension, and buffering changes in pH (4, 7, 21, 22, 24, 26, 58). Many studies have found that short-term (<10 days) creatine supplementation increases both muscle and plasma total (PCr + free creatine) creatine (55). In the current study, although we did not take blood samples or a muscle biopsy to shed light on a potential mechanism, it is quite possible that both muscle and plasma total creatine levels were increased, leading to enhanced performance. Two studies with similar dosages to the current study

provide evidence for this assumption. Rawson et al (49) found that 2.3 g/day for 6 weeks caused a significant increase (182%) in plasma creatine levels. Hultman et al (30) examined the effects of 3g/day for 28 days versus 20g/day for 6 days. They found that while the rate of creatine uptake is slower in lower dose regimen, there was no difference in muscle total creatine concentration between the two groups, both increased by 20%. These data suggest that longer, lower dose regimens are as effective in increasing both muscle and plasma total creatine levels as short -term high dosing regimens.

Anecdotally, creatine supplementation has been linked to muscle cramps and gastrointestinal distress (42, 55) but little empirical data supports this notion. In the current study we found that the creatine group experienced a decrease in muscle cramps and nausea. This is in agreement with most other studies (14, 23, 42, 55, 60). Greenwood et al (23) found that creatine supplementation (0.3g/kg of body weight for 5 days then 0.03g/kg of body weight for an additional 115 days) resulted in significantly less cramping than placebo. Additionally, creatine supplementation has been used successfully as a treatment to alleviate muscle cramps by 60% in dialysis patients (14). Ostojic and Ahmetovic (42) found no significant difference in gastrointestinal distress between placebo and creatine supplementation (10g/day for 28 days). Taken together, these data suggest that creatine supplementation decreases cramps, reduces nausea and does not increase the incidence of gastrointestinal distress.

In contrast to our secondary hypothesis, adding sodium bicarbonate to creatine did not have an additive effect on performance. This is in disagreement with the previous study by Barber et al (6) showing that supplementation of creatine plus sodium bicarbonate had the slowest rate of decline across six repeated sprints and a 7% increase

in performance whereas creatine supplementation alone only increased by 4% (6). Differences study results may be related to: 1) In the current study the dose of sodium bicarbonate was not high enough to have a positive effect. We and others previous showed that 0.3-0.5 g/kg of body weight of sodium bicarbonate are needed to increase performance (27, 33, 37), 2) Ergogenic effects of sodium bicarbonate increase pH levels and increase buffering capacity (34, 54). However, higher pH may interfere with ATP synthesis by decreasing creatine kinase activity (34, 54). Increasing creatine kinase activity and muscular phosphocreatine stores, and ultimately increasing ATP synthesis, are thought to be main ways creatine supplementation increases performance (7). Thus, by adding sodium bicarbonate to creatine supplementation we may have inadvertently inhibited the beneficial effect of creatine on ATP synthesis, 3) As with any intervention study, it is possible that subjects in the creatine and sodium bicarbonate group did not ingest as many of their pills as they reported. However, we took great care in administering our treatments (weekly pill pickup and return of pill cases, and 3-4 weekly phone calls/ text messages to remind subjects to take pills). Based on weekly, self-reported logs subjects consumed 96% in placebo, 97% in creatine, and 97% in creatine and sodium bicarbonate with no significant difference ( $p=0.58$ ) between groups. Thus, we are confident that the negative finding of adding sodium bicarbonate to creatine supplementation is a “true” finding and not related to our administration of treatment.

Results of the current study have real-world significance, and can be used by coaches and athletes seeking to improve high-intensity, repeated sprints or cycling time trial performance. Using an 8-week, low-dose creatine supplement, we found an improvement in peak power slope (rate of decline) (36%) over six repeated sprints and an

improvement in time to completion (3%), mean speed (4%), and mean power output (12%) during a 5-k time trial. While changes of 3-4% in the time trial may seem small, any improvement over 1% is considered a meaningful improvement in a cycling time trial (29). Additionally, we observed decreased muscle cramps and nausea with creatine supplementation. The implication of these results is that an 8-week, low-dose creatine supplementation can effectively improve exercise performance without increasing gastrointestinal side effects.

## Bibliography

1. Velotron Wingate Software Manual. (2010)
2. Aaserud, R., et al. "Creatine supplementation delays onset of fatigue during repeated bouts of sprint running." *Scandinavian Journal of Medicine & Science in Sports* 8.5 (1998): 247-251.
3. Ahrendt, Dale M. "Ergogenic aids: counseling the athlete." *American Family Physician* 63.5 (2001): 913-922.
4. Balsom, P. D., et al. "Skeletal muscle metabolism during short duration high-intensity exercise: influence of creatine supplementation." *Acta Physiologica Scandinavica* 154.3 (1995): 303-310.
5. Banerjee, Rupa, et al. "Oral buffered esomeprazole is superior to iv pantoprazole for rapid rise of intragastric pH: a wireless pH metry analysis." *Journal of Gastroenterology and Hepatology* 25.1 (2010): 43-47.
6. Barber, James J., et al. "Effects of Combined Creatine and Sodium Bicarbonate Supplementation on Repeated Sprint Performance in Trained Men." *The Journal of Strength & Conditioning Research* 27.1 (2013): 252-258.
7. Bemben, Michael G., and Hugh S. Lamont. "Creatine supplementation and exercise performance." *Sports Medicine* 35.2 (2005): 107-125.
8. Birch, R., D. Noble, and P. L. Greenhaff. "The influence of dietary creatine supplementation on performance during repeated bouts of maximal isokinetic cycling in man." *European Journal of Applied Physiology and Occupational Physiology* 69.3 (1994): 268-270.

9. Borg, Gunnar, Gunilla Ljunggren, and Ruggero Ceci. "The increase of perceived exertion, aches and pain in the legs, heart rate and blood lactate during exercise on a bicycle ergometer." *European Journal of Applied Physiology and Occupational Physiology* 54.4 (1985): 343-349.
10. Bouissou, P., et al. "Metabolic and blood catecholamine responses to exercise during alkalosis." *Medicine and Science in Sports and Exercise* 20.3 (1988): 228-232.
11. Burke, Darren G., et al. "The effect of continuous low dose creatine supplementation on force, power, and total work." *International Journal of Sport Nutrition and Exercise Metabolism* 10.3 (2000): 235-244.
12. Casey, Anna, and Paul L. Greenhaff. "Does dietary creatine supplementation play a role in skeletal muscle metabolism and performance?." *The American Journal of Clinical Nutrition* 72.2 (2000): 607s-617s.
13. Chambers, E. S., M. W. Bridge, and D. A. Jones. "Carbohydrate sensing in the human mouth: effects on exercise performance and brain activity." *The Journal of Physiology* 587.8 (2009): 1779-1794.
14. Chang, Chiz-Tzung, et al. "Creatine monohydrate treatment alleviates muscle cramps associated with haemodialysis." *Nephrology Dialysis Transplantation* 17.11 (2002): 1978-1981.
15. Costill, D. L., et al. "Acid-base balance during repeated bouts of exercise: influence of HCO<sub>3</sub>." *International Journal of Sports Medicine* 5.05 (1984): 228-231.

16. Cox, Greg, et al. "Acute creatine supplementation and performance during a field test simulating match play in elite female soccer players." *International Journal of Sport Nutrition and Exercise Metabolism* 12.1 (2002): 33-46.
17. Eckerson, Joan., et al. "Effect of creatine phosphate supplementation on anaerobic working capacity and body weight after two and six days of loading in men and women." *The Journal of Strength & Conditioning Research* 19.4 (2005): 756-763.
18. Edge, Johann, David Bishop, and Carmel Goodman. "Effects of chronic NaHCO<sub>3</sub> ingestion during interval training on changes to muscle buffer capacity, metabolism, and short-term endurance performance." *Journal of Applied Physiology* 101.3 (2006): 918-925.
19. Feldman, Elaine B. "Creatine: a dietary supplement and ergogenic aid." *Nutrition Reviews* 57.2 (1999): 45-50.
20. Gao, Jiaping, et al. "Sodium bicarbonate ingestion improves performance in interval swimming." *European journal of applied physiology and occupational physiology* 58.1-2 (1988): 171-174.
21. Greenhaff, Paul L. "The nutritional biochemistry of creatine." *The Journal of Nutritional Biochemistry* 8.11 (1997): 610-618.
22. Greenhaff, P. L., et al. "Effect of oral creatine supplementation on skeletal muscle phosphocreatine resynthesis." *American Journal of Physiology-Endocrinology and Metabolism* 266.5 (1994): E725-E730.



23. Greenwood, Michael, et al. "Creatine supplementation during college football training does not increase the incidence of cramping or injury." *Molecular and Cellular Biochemistry* 244.1-2 (2003): 83-88.
24. Harris, Roger C., Karin Soderlund, and Eric Hultman. "Elevation of creatine in resting and exercised muscle of normal subjects by creatine supplementation." *Clinical Science* 83.Pt 3 (1992): 367-374.
25. Havenetidis, Konstantinos, et al. "The use of varying creatine regimes on sprint cycling." *Journal of Sports Science Medicine* 2 (2003): 88-97.
26. Hickner, Robert C., et al. "Research article Effect of 28 days of creatine ingestion on muscle metabolism and performance of a simulated cycling road race." (2010).
27. Higgins, Matthew F., Rob S. James, and Mike J. Price. "The effects of sodium bicarbonate (NaHCO<sub>3</sub>) ingestion on high intensity cycling capacity." *Journal of Sports Sciences* 31.9 (2013): 972-981.
28. Hoffman, Jay R., et al. "Effect of low-dose, short-duration creatine supplementation on anaerobic exercise performance." *The Journal of Strength & Conditioning Research* 19.2 (2005): 260-264.
29. Hultman, E., et al. "Muscle creatine loading in men." *Journal of Applied Physiology* 81.1 (1996): 232-237.
30. Hopkins, William G., John A. Hawley, and Louise M. Burke. "Design and analysis of research on sport performance enhancement." *Medicine and Science in Sports and Exercise* 31.3 (1999): 472-485.

31. Inbar, Omri, Oded Bar-Or, and James S. Skinner. *The Wingate anaerobic test*. Champaign, IL: Human Kinetics, 1996.
32. Jacobs, Kevin A., et al. "Sildenafil has little influence on cardiovascular hemodynamics or 6-km time trial performance in trained men and women at simulated high altitude." *High Altitude Medicine & Biology* 12.3 (2011): 215-222.
33. Lavender, G., and S. R. Bird. "Effect of sodium bicarbonate ingestion upon repeated sprints." *British Journal of Sports Medicine* 23.1 (1989): 41-45.
34. Matson, Larry G., and Z. Vu Tran. "Effects of sodium bicarbonate ingestion on anaerobic performance: a meta-analytic review." *International Journal of Sport Nutrition* 3.1 (1993): 2.
35. McArdle, William D., Frank I. Katch, and Victor L. Katch. *Exercise physiology: nutrition, energy, and human performance*. Lippincott Williams & Wilkins, 2010.
36. McKenzie, D. C., et al. "Maximal work production following two levels of artificially induced metabolic alkalosis." *Journal of Sports Sciences* 4.1 (1986): 35-38.
37. McNaughton, Lars R., Jason Siegler, and Adrian Midgley. "Ergogenic effects of sodium bicarbonate." *Current Sports Medicine Reports* 7.4 (2008): 230-236.
38. McNaughton, Lars, et al. "Effects of chronic bicarbonate ingestion on the performance of high-intensity work." *European Journal of Applied Physiology and Occupational Physiology* 80.4 (1999): 333-336.

39. Mero, Antti A., et al. "Combined creatine and sodium bicarbonate supplementation enhances interval swimming." *The Journal of Strength & Conditioning Research* 18.2 (2004): 306-310.
40. Noble, B.J., et al. "A category-ratio perceived exertion scale: relationship to blood and muscle lactates and heart rate." *Medicine & Science in Sports & Exercise* 15.6 (1983): 523-528.
41. Nuernberg, Bernd, and Kay Brune. "Buffering the stomach content enhances the absorption of diflunisal in man." *Biopharmaceutics & Drug Disposition* 10.4 (1989): 377-387.
42. Ostojic, Sergej M., and Zlatko Ahmetovic. "Gastrointestinal distress after creatine supplementation in athletes: are side effects dose dependent?." *Research in Sports Medicine* 16.1 (2008): 15-22.
43. Peyrebrune, M. C., et al. "The effects of oral creatine supplementation on performance in single and repeated sprint swimming." *Journal of Sports Sciences* 16.3 (1998): 271-279.
44. Pfeiffer, Beate, et al. "The effect of carbohydrate gels on gastrointestinal tolerance during a 16-km run." *International Journal of Sport Nutrition* 19.5 (2009): 485.
45. Pottier, Andries, et al. "Mouth rinse but not ingestion of a carbohydrate solution improves 1-h cycle time trial performance." *Scandinavian Journal of Medicine & Science in Sports* 20.1 (2010): 105-111.
46. Powers, Scott K., and Edward T. Howley. *Exercise physiology: Theory and application to fitness and performance*. McGraw-Hill, 2012.

47. Price, Michael J., and Christopher Simons. "The effect of sodium bicarbonate ingestion on high-intensity intermittent running and subsequent performance." *The Journal of Strength & Conditioning Research* 24.7 (2010): 1834-1842.
48. Price, Mike, Paul Moss, and Stuart Rance. "Effects of sodium bicarbonate ingestion on prolonged intermittent exercise." *Medicine and science in sports and exercise* 35.8 (2003): 1303-1308.
49. Rawson, Eric S., and Jeff Volek. "Effects of creatine supplementation and resistance training on muscle strength and weightlifting performance." *The Journal of Strength & Conditioning Research* 17.4 (2003): 822-831.
50. Requena, Bernardo, et al. "Sodium bicarbonate and sodium citrate: ergogenic aids?." *The Journal of Strength & Conditioning Research* 19.1 (2005): 213-224.
51. Shelton, Jose, and Gideon V. Praveen Kumar. "Sodium Bicarbonate—A Potent Ergogenic Aid?." *Food and Nutrition* 1 (2010): 1-4.
52. Skare, O-C., Ø. Skadberg, and A. R. Wisnes. "Creatine supplementation improves sprint performance in male sprinters." *Scandinavian Journal of Medicine & Science in Sports* 11.2 (2001): 96-102.
53. Soderlund, K., P. L. Greenhaff, and E. Hultman. "Energy metabolism in type I and type II human muscle fibres during short term electrical stimulation at different frequencies." *Acta Physiologica Scandinavica* 144.1 (1992): 15-22.

54. Szasz, Gabor, Wolfgang Gruber, and Erich Bernt. "Creatine kinase in serum: 1. Determination of optimum reaction conditions." *Clinical Chemistry* 22.5 (1976): 650-656.
55. Terjung, Ronald L., et al. "American College of Sports Medicine roundtable. The physiological and health effects of oral creatine supplementation." *Medicine and Science in Sports and Exercise* 32.3 (2000): 706-717.
56. Tesch, P. A., A. Thorsson, and N. Fujitsuka. "Creatine phosphate in fiber types of skeletal muscle before and after exhaustive exercise." *Journal of Applied Physiology* 66.4 (1989): 1756-1759.
57. Van Leemputte, Marc, K. Vandenberghe, and Peter Hespel. "Shortening of muscle relaxation time after creatine loading." *Journal of Applied Physiology* 86.3 (1999): 840-844.
58. Van Loon, Luc. "Effects of creatine loading and prolonged creatine supplementation on body composition, fuel selection, sprint and endurance performance in humans." *Clinical Science* 104 (2003): 153-162.
59. Heywood, V. "Advanced fitness assessment and exercise prescription." *Champaign, IL: Human Kineticspub Europe Ltd* (2002).
60. Wilder, Nathan, et al. "The effects of low-dose creatine supplementation versus creatine loading in collegiate football players." *Journal of Athletic Training* 36.2 (2001): 124.

61. Williams, Melvin H., and J. David Branch. "Creatine supplementation and exercise performance: an update." *Journal of the American College of Nutrition* 17.3 (1998): 216-234.
62. Ziegenfuss, Tim N., et al. "Effect of creatine loading on anaerobic performance and skeletal muscle volume in NCAA Division I athletes." *Nutrition* 18.5 (2002): 397-402.

## APPENDIX A: Informed Consent

1

### California Polytechnic State University

#### INFORMED CONSENT TO PARTICIPATE IN A RESEARCH PROJECT ON THE EFFECTS OF A DIETARY SUPPLEMENT ON EXERCISE PERFORMANCE

**INVESTIGATORS:** A research project focused on whether a dietary supplement increases exercise performance is being conducted by Todd Hagobian, Ph.D. ([thagobia@calpoly.edu](mailto:thagobia@calpoly.edu)), Jennifer Olmstead, M.S. ([jdolmste@calpoly.edu](mailto:jdolmste@calpoly.edu)), and student Amanda Morris ([amorris@calpoly.edu](mailto:amorris@calpoly.edu)) in the Kinesiology Department at Cal Poly, San Luis Obispo.

**NOTE:** You are being asked to participate in a research study. Your participation is voluntary. If you are a student, your decision whether or not to participate will not have any effect on your academic status. Please feel free to ask questions at any time if there is anything you do not understand. Please be aware that you are not required to participate in this research, you may omit any items you prefer not to answer, and you may discontinue your participation at any time without penalty or loss of benefits.

**PURPOSE:** Athletes are continuously seeking ways to increase exercise performance. Dietary supplements are the most common method to increase exercise performance. Creatine and sodium bicarbonate are two widely studied supplements that may impact exercise performance, but it is unclear whether combining these supplements is more beneficial. Also, other supplements such as beta alanine, ginkgo biloba, and rhodiola rosea may increase exercise performance. The purpose of the study is to determine the impact of creatine, creatine plus sodium bicarbonate, and creatine plus sodium bicarbonate plus beta alanine, ginkgo biloba, and rhodiola rosea on exercise performance. You will be randomly assigned to one of four groups; 1) placebo, 2) creatine alone, 3) creatine plus sodium bicarbonate, 4) creatine plus sodium bicarbonate plus beta alanine, ginkgo biloba, and rhodiola rosea. You and the data collector will not know which group you are in. Each supplement period will last 8 weeks. Before and after the eight weeks, you will complete two exercise performance tests on separate days. Your participation will include nine visits (see below) and will take approximately six hours total. On seven of these visits you will be asked to exercise. All visits will occur in the Human Performance Laboratory in the Kinesiology Department. You are being asked to participate because you are a normal, healthy man or woman and are 18 to 40 years old. Up to 80 subjects will participate in this study.

#### OVERVIEW OF STUDY:

Visit 1: Informed consent, measurement of physical characteristics, and questionnaires (~1 hour)

Visit 2: Maximal oxygen consumption exercise test (~ 1 hour)

Visits 3 and 4: Familiarization with exercise performance tests (~ 1 hour total)

Visits 5 and 6: Exercise performance tests (~1 hour total)

Visit 7: Dietary supplement or Placebo randomization (~1 hour)

Visits 8-9: Exercise performance tests (~ 1 hour total)

#### STUDY PROCEDURES:

**Visit 1 – Informed Consent:** You will be provided with a full description of the study and have the opportunity to ask any questions. At this time you should inform the investigators of any other studies that you are participating in. If you are interested in participating in the study, you will be familiarized

Initials \_\_\_\_\_

with the procedures and equipment, and your body height and body weight will be measured. You will be asked to complete a questionnaire about your health and physical activity levels.

**Visit 2 – Maximal oxygen consumption:** Maximal oxygen consumption will be determined by exercising on a stationary bicycle. You will be wearing a heart rate monitor and breathe into a mouthpiece and tube. A clip will be placed on your nose so that you can only breathe through your mouth. You will begin pedaling at a very easy workload as a warm-up. You will continue to pedal at the same rate while the workload is increased slightly every 2 minutes. It will become more and more difficult to maintain your pedaling rate as the test progresses. The test will be stopped when you no longer wish to continue (test usually lasts a total of 8-15 minutes). This test is demanding and you may feel fatigued after the test. The results of this standard test will be used to set the appropriate level of physical work during the exercise test.

**Visit 3 and 4 - Familiarization with exercise tests and questionnaire:** This will occur in the morning after you have not eaten for the last 8-12 hours. You will then complete a high-intensity exercise test on a stationary bike. After a 5 minutes warm-up, the researcher will place the appropriate workload on the bike and you will be asked to ride as fast and hard as you can for 10 seconds. After a 30 second rest, you will complete another 10-second test. This will continue until you have completed 6 sprints total. During each rest period, you will ride the bike with no workload on it and complete a questionnaire to assess whether your stomach is upset.

On a separate day, you will complete a 5-kilometer (3.1 mile) time trial on a stationary bike. The goal of this exercise test is for you to ride as hard and fast as you can to complete the 5-kilometer time trial. You will have control of the workload and be able to adjust it at any time during the test.

Both exercise tests should feel difficult and you will probably feel fatigued near the end. During the test, if you experience any problems (light-headed, nauseous, excessive redness in the face, or irregular heart rate) the exercise test will be immediately stopped. There will be at least 2 CPR certified persons in the room during testing at all times. In the rare event that you experience a serious medical emergency you will immediately stop exercising. One CPR certified individual will call 911, and the other CPR certified individual will attend to your needs.

**Visits 5 and 6 - Exercise performance tests and questionnaire:** You will complete the two exercise tests described above again and this will be your baseline assessment.

**Visit 7 - Dietary supplement randomization:** After all the preliminary tests, you will then be randomized to one of four groups; 1) placebo, 2) creatine alone, 3) creatine plus sodium bicarbonate, or 4) creatine plus sodium bicarbonate plus beta alanine, ginkgo biloba, and rhodiola rosea. You will take your supplement for eight weeks. The placebo will be a calcium pill, and the supplements will be 3 grams of creatine, 1 gram of sodium bicarbonate, 1 gram of  $\beta$  - alanine, 60 mg of ginkgo biloba, and 350 mg of rhodiola rosea. All pills will be similar in color and taste, and neither you nor the researcher will know which pill you are getting.

**Visits 8 and 9 Exercise performance tests and questionnaire:** After eight weeks of taking the placebo or supplement, you will complete the two exercise tests and questionnaire mentioned above.

Initials \_\_\_\_\_



**RISKS AND DISCOMFORTS:**

Even though the risks are minimal in this study, all possible attempts will be made to minimize the risks involved. Trained individuals will conduct all laboratory procedures with your well being as their first priority. All procedures will be explained and demonstrated until you are comfortable with the proposed study. **NOTE:** Since exercising is important in this study, if you are at all uncomfortable with exercising at high-intensity you should not participate.

**Exercise:** During any type of exercise, especially strenuous exercise, there are slight health risks, along with the possibility of fatigue and muscle soreness. These health risks are small in people with no prior history of cardiovascular, respiratory or musculoskeletal disease or injury. Any ordinary fatigue or muscle soreness is temporary and usually lasts 24-96 hours.

**Supplement:** High doses of creatine or sodium bicarbonate supplementation may cause diarrhea or your stomach to be upset. The dose in this study is very small, and there are no short- or long-term harmful side effects. However, if you experience any diarrhea, vomiting, or if your stomach is upset, contact Dr. Hagobian, Jennifer Olmstead, M.S., or Amanda Morris immediately and stop taking your pills.

**BENEFITS:** There are no direct benefits to you in participating in this study. These data are collected purely for the purposes of research and do not have a clinical or diagnostic value. However, these data may further our understanding of how dietary supplements impact exercise performance. Also, you will gain knowledge about your fitness level. After completion of the study, you will be offered to see the findings from the study.

**CONFIDENTIALITY:** We are required by federal regulations to protect your confidentiality. All records and assessment data from this study will be treated as confidential. Your name and the fact that you are in the study will be kept confidential. Information stored on our computer will be password protected. A participant ID will identify information on worksheets and questionnaires, and be decoded using a list kept in a locked cabinet. Only research staff and the principal investigator will have access to the locked cabinet. All questionnaires and data collection material completed in this study will be shredded within seven years after the study's completion.

**COSTS/PAYMENTS:** There are no costs to you for your participation in this study. You will not be paid for participation, and your participation is strictly voluntary.

**YOUR RIGHT TO WITHDRAW FROM THE STUDY:** You may refuse to participate at any time. You may change your mind about being in the study and quit after the study has started. If you are a student your decision whether or not to participate will not have any effect on your academic status. You may withdraw from the study at any time and for any reason. Your decision whether or not to participate in this study, or a decision to withdraw will not involve any penalty or loss of benefits to which you are entitled.

**QUESTIONS:** If you have questions regarding this study or would like to be informed of the results when the study is completed, please feel free to contact Dr. Todd Hagobian ([thagobia@calpoly.edu](mailto:thagobia@calpoly.edu); 805-756-7511), Jennifer Olmstead, M.S. ([jdolmste@calpoly.edu](mailto:jdolmste@calpoly.edu)), or Amanda Morris ([amorris@calpoly.edu](mailto:amorris@calpoly.edu)). If you have concerns regarding the manner in which the study is conducted, you may contact Dr. Steve Davis, Chair of the Cal Poly Human Subjects Committee, at (805) 756-2754, [sdavis@calpoly.edu](mailto:sdavis@calpoly.edu), or Dr. Susan Opava, Dean of Research and Graduate Programs, at (805) 756-1508, [sopava@calpoly.edu](mailto:sopava@calpoly.edu).

Initials \_\_\_\_\_

4

If you agree to voluntarily participate in this research project as described, please indicate your agreement by signing below. Please keep one copy of this form for your reference, and thank you for your participation in this research.

\_\_\_\_\_  
Signature of Volunteer                      Date

\_\_\_\_\_  
Signature of Researcher                      Date

Initials \_\_\_\_\_

**APPENDIX B:  
Health History Questionnaire**

**HEALTH & FITNESS HISTORY**

**Subject #:** \_\_\_\_\_ **Date:** \_\_\_\_\_ **Age:**  
\_\_\_\_\_

**Height (cm):** \_\_\_\_\_ **Weight (kg):** \_\_\_\_\_ **BMI (kg/m<sup>2</sup>):** \_\_\_\_\_

1. Have you ever been diagnosed as having any of the following and if yes, how are you currently treating the condition?

Y N High Blood Pressure

Y N High Cholesterol or High Triglycerides

Y N Diabetes

Y N Hypoglycemia (low blood sugar)

Y N Asthma

2. Does anyone in your family (immediate family including your grandparents) have a history of cardiovascular disease? (heart attacks, strokes, etc.) Please explain:

3. Does anyone in your family (immediate family including your grandparents) have a history of type II diabetes? Please explain:

4. Have you ever had a glucose tolerance test? Y N  
If yes, what were the results?

5. Have you ever had a fasting blood sugar test? Y N  
If yes, what were the results?

6. *For women:*

- Are you pregnant or plan on becoming pregnant within the next year? Y N

- Are you on hormonal birth control (pill, patch, etc) or estrogen replacement?  
Describe in detail (e.g. the type):

- What was the date of your last menstruation? Is your cycle regular?

- Do you know the phase of your current menstrual cycle? Y N If yes,  
please explain:

7. Do you have any orthopedic or other health problems that may affect your ability to  
perform exercise? If yes, please explain:

8. Are you currently taking any medications, including over-the-counter drugs such as  
aspirin, Tylenol or Ibuprofen? Please list:

9. Do you smoke or use smokeless tobacco? Y N

10. Do you drink coffee or other caffeinated beverages? Y N What kind, how much  
and how often?

11. Please list all vitamins, minerals and herbs and other nutritional supplements you're  
taking:

12. Do you have any food allergies or intolerances? Y N Please describe:

13. How would you describe the type of diet you currently eat? Have you recently been  
on any special diets? What kinds of diets have you used to lose weight or lower  
cholesterol? Please list and describe:

14. What changes have you made in your diet in the last 6 months? Have you gained  
or lost more than 10lbs within the last year?

15. Do you exercise regularly? Y N What kinds of exercise?

How often?

Please describe how much walking you do on a daily basis:

16. How does your current exercise and physical activity compare to 6 months ago? 1 year ago?

17. Have you had a physical exam in the past two years? Y N Please describe your assessment of your overall health:

**Participant's Signature:** \_\_\_\_\_

**Date:** \_\_\_\_\_

**APPENDIX C:  
GI Distress Questionnaire**

**Subject:**\_\_\_\_\_ **Date:**\_\_\_\_\_ **Visit/Ex test:** Wingate TT Pre Post

**Section 1: Upper Abdominal Problems**

1) Do you have reflux?

0    1    2    3    4    5    6    7    8    9    10  
*No problem at all* *Worst it has ever been*

2) Do you have heartburn?

0    1    2    3    4    5    6    7    8    9    10  
*No problem at all* *Worst it has ever been*

3) Do you have bloating problems?

0    1    2    3    4    5    6    7    8    9    10  
*No problem at all* *Worst it has ever been*

4) Do you have cramps?

0    1    2    3    4    5    6    7    8    9    10  
*No problem at all* *Worst it has ever been*

5) Do you have vomiting problems?

0    1    2    3    4    5    6    7    8    9    10  
*No problem at all* *Worst it has ever been*

6) Do you have nausea problems?

0    1    2    3    4    5    6    7    8    9    10  
*No problem at all* *Worst it has ever been*

**Section 2: Lower Abdominal Problems**

1) Do you have intestinal cramps?

0    1    2    3    4    5    6    7    8    9    10  
*No problem at all* *Worst it has ever been*

2) Do you have flatulence?

0    1    2    3    4    5    6    7    8    9    10  
*No problem at all* *Worst it has ever been*

3) Do you have an urge to defecate?

0    1    2    3    4    5    6    7    8    9    10

No problem  
at all

Worst it has  
ever been

4) Do you have left abdominal pain?

0 1 2 3 4 5 6 7 8 9 10

No problem  
at all

Worst it has  
ever been

5) Do you have right abdominal pain?

0 1 2 3 4 5 6 7 8 9 10

No problem  
at all

Worst it has  
ever been

6) Do you have loose stool?

0 1 2 3 4 5 6 7 8 9 10

No problem  
at all

Worst it has  
ever been

7) Do you have diarrhea?

0 1 2 3 4 5 6 7 8 9 10

No problem  
at all

Worst it has  
ever been

### Section 3: Systemic Problems

1) Do you have dizziness problems?

0 1 2 3 4 5 6 7 8 9 10

No problem  
at all

Worst it has  
ever been

2) Do you have a headache?

0 1 2 3 4 5 6 7 8 9 10

No problem  
at all

Worst it has  
ever been

3) Do you have a muscle cramp?

0 1 2 3 4 5 6 7 8 9 10

No problem  
at all

Worst it has  
ever been

4) Do you have an urge to urinate?

0 1 2 3 4 5 6 7 8 9 10

No problem  
at all

Worst it has  
ever been

**APPENDIX D:  
Physical Activity Log**

Date: \_\_\_\_\_

Subject #: \_\_\_\_\_

<b>Day</b>	<b>Time</b>	<b>Type: Aerobic or Lifting</b>	<b>Intensity: Low, Med, or High</b>	<b>Duration</b>
<b>Saturday</b>				
<b>Sunday</b>				
<b>Monday</b>				
<b>Tuesday</b>				
<b>Wednesday</b>				
<b>Thursday</b>				
<b>Friday</b>				